Contents

WJEC AS GCE in Physics
WJEC A Level GCE in Physics

2009 & 2010

First AS Award - Summer 2009
First A level Award - Summer 2010

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GCE Physics

Subject/Option Entry Codes	
Advanced Subsidiary (AS) "Cash in" entry *Advanced Level (AL) "Cash in" entry*	*2321* *3321*
PH1 : Motion, Energy & Charge	1321
PH2 : Waves & Particles	1322
PH3 : Practical Physics	1323
PH4 : Oscillations & Fields	1324
PH5 : Electromagnetism, Nuclei & Options	1325
PH6 : Experimental Physics	1326

When making entries, the following option codes should be entered after the four digit unit or cash-in code to indicate English medium or Welsh medium entries:

English medium 01
Welsh medium W1

Availability of Assessment Units

Unit	**January 2009**	**June 2009**	**January 2010 & each subsequent year**	**June 2010 & each subsequent year**
PH1	✓	✓	✓	✓
PH2		✓	✓	✓
PH3		✓		✓
PH4			✓	✓
PH5				✓
PH6				✓

SUMMARY OF ASSESSMENT

This specification is divided into a total of 6 units: 3 AS units and 3 A2 units. Weightings noted below are expressed in terms of the full A level qualification.

AS (3 units)

PH1	20% 1¼ hour Written Paper 80 marks[120 UM]
Motion, Energy & Charge Approx 7 structured questions. No question choice. No sections.	
PH2	20% 1¼ hours Written Paper 80 marks [120 UM]
Waves & Particles Approx 7 structured questions. No question choice. No sections.	
PH3	10% Internal Assessment 48 marks [60 UM]
Practical Physics Experimental tasks, performed under controlled conditions, based upon experimental techniques developed in the AS course.	

A LEVEL (the above plus a further 3 units)

PH4	18% 1¼ hour Written Paper 80 marks [108 UM]
Oscillations & Fields Approx 7 questions. Includes synoptic assessment. No question choice. No sections.	
PH5	22% 1¾ hour written paper 100 marks[132 UM]
Electromagnetism, Nuclei and Options Section A: Approximately 5 questions on the compulsory content of the unit. 60 marks Section B: Case Study, synoptic in nature, based upon open-source material distributed by the board. 20 marks Section C: Options: Alternating Currents, Revolutions, Materials, Medical Physics, Energy. 20 marks	
PH6	10% Internal Assessment [UMS = 60]
Experimental Physics An experimental task (25 marks), and a data-analysis task (25 marks) performed under controlled conditions, both synoptic in nature.	

- Assessment units PH1, PH2 and PH4 are available in the winter examination series. All units are available in the summer examination series.
- Synoptic assessment is included in PH4 and PH5. It is inherent in the internal assessment PH6

PHYSICS

1 INTRODUCTION

1. 1 Criteria for AS and A Level GCE

This specification has been designed to meet the general criteria for GCE Advanced Subsidiary (AS) and A level (A) and the subject criteria for AS/A *Physics* as issued by the regulators [July 2006]. The qualifications will comply with the grading, awarding and certification requirements of the Code of Practice for 'general' qualifications (including GCE).

The AS qualification will be reported on a five-grade scale of A, B, C, D, E. The A level qualification will be reported on a six-grade scale of A*, A, B, C, D, E. The award of A* at A level will provide recognition of the additional demands presented by the A2 units in term of 'stretch and challenge' and 'synoptic' requirements. Candidates who fail to reach the minimum standard for grade E are recorded as U (unclassified), and do not receive a certificate. The level of demand of the AS examination is that expected of candidates half way through a full A level course.

The AS assessment units will have equal weighting with the second half of the qualification (A2) when these are aggregated to produce the A level award. AS consists of three assessment units, referred to in this specification as PH1, PH2 and PH3. A2 also consists of three units, referred to as PH4, PH5 and PH6.

Assessment units may be retaken prior to certification for the AS or A level qualifications, in which case the better result will be used for the qualification award. Individual assessment unit results, prior to certification for a qualification, have a shelf-life limited only by the shelf-life of the specification.

The specification and assessment materials are available in English and Welsh.

1.2 Prior learning

The specification assumes that candidates will have previously completed courses in GCSE Science **and** Additional Science **or** GCSE Physics. However, prior learning from courses other than GCSE or from work-based experience may, at the discretion of individual centres, be deemed a suitable foundation for this course of study.

In particular, at the outset of the course, it is assumed that candidates will be familiar with

- SI units and their multiples/submultiples
- quantities expressed in standard form
- simple algebraic equations

and the specification provides contexts for the reinforcement and development of these skills.

The specification is not age-specific and provides opportunities for candidates to extend their life-long learning.

1.3 Progression

The six-part structure of this specification (3 units for AS, and an additional 3 for the full A level) allows for both staged and end-of-course assessment and thus allows candidates to defer decisions about progression from AS to the full A level qualification.

This specification provides a suitable foundation for the study of *Physics, Engineering, Medicine* or a related area through a range of higher education courses or direct entry into employment. In addition, the specification provides a coherent, satisfying and worthwhile course of study for candidates who do not progress to further study in this subject.

1.4 Rationale

The specification for AS and A-level Physics complies with the GCE AS and A Subject Criteria for Science Subjects, published by CCEA, DELLS and QCA. It provides

(a) a complete course in Physics to GCE A level;

(b) a firm foundation in Physics knowledge and understanding, together with mathematical competence for those wishing proceed to further studies in Physics, Engineering, Mathematics, Medicine or the Natural Sciences.

Students who follow the specification will be introduced to a wide range of Physics principles and be led to an understanding of how nature operates at both microscopic and macroscopic scales. They will understand how these principles are applied in tackling problems of human society.

1.5 The Wider Curriculum

Physics is a subject that by its nature requires candidates to consider individual, ethical, social, cultural and contemporary issues. The specification provides a framework for exploration of such issues and includes specific content through which educators may address these issues; for example, the use of radioactive isotopes in medicine, the discussion on nuclear power and the environmental consequences of the use of fossil fuels.

The specification contains topics which allow teachers within Wales to draw upon Welsh examples and priorities in line with the Curriculum Cymreig, for example in the development of energy resources.

1.6 Prohibited combinations and overlap

Every specification is assigned a national classification code indicating the subject area to which it belongs. Centres should be aware that candidates who enter for more than one GCE qualification with the same classification code will only have one grade (the highest) counted for the purpose of the School and College Performance Tables. The classification code for this specification is 1210.

This specification does not overlap significantly with any other, although there will be elements of overlap, for example, with Electronics. There are no prohibited combinations.

1.7 Equality and Fair Assessment

AS/A levels often require assessment of a broad 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 was 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.

In *GCE Physics* practical assistants may be used for manipulating equipment and making observations. Technology may help visually impaired students to take readings and make observations.

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. Information on reasonable adjustments is found in the Joint Council for Qualifications document *Regulations and Guidance Relating to Candidates who are eligible for Adjustments in Examinations.* This document is available on the JCQ website (www.jcq.org.uk).

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 of the competences have been addressed. This will be kept under review and may be amended in future.

2 AIMS

The AS and A specifications in Physics aim to encourage students to:

(a) develop an enthusiasm for Physics and, where appropriate to pursue this enthusiasm in its further study;

(b) understand the processes of Physics, as a Natural Science, the way the subject develops through experiment, theory, insight and creative thought;

(c) appreciate the role of Physics in society, in particular how its discoveries are applied in industry and medicine and how decisions about its use are made;

(d) appreciate the interconnectedness of the subject and the ways in which different strands of Physics can be used to solve problems and gain new insights into the natural world;

(e) acquire a more general understanding of the way in which scientific disciplines make progress, acquire and interpret evidence, propose and evaluate solutions, communicate ideas and interact with society, as outlined in section 3.6, *How Science Works*, of the GCE AS and A level criteria for Science Subjects.

How science Works

In the context of AS/A Physics, candidates should:

- use theories, models and ideas to develop and modify scientific explanations;
- use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas;
- use appropriate methodology, including ICT, to answer scientific questions and solve scientific problems;
- carry out experimental and investigative activities, including appropriate risk management, in a range of contexts;
- analyse and interpret data to provide evidence, recognising correlations and causal relationships;
- evaluate methodology, evidence and data, and resolve conflicting evidence;
- appreciate the tentative nature of scientific knowledge;
- communicate information and ideas in appropriate ways using appropriate terminology;
- consider applications and implications of science and appreciate their associated benefits and risks;
- appreciate the role of the scientific community in validating new knowledge and ensuring integrity;
- appreciate the ways in which society uses physics knowledge and practice to inform decision-making.

3 ASSESSMENT OBJECTIVES

Candidates must meet the following assessment objectives in the context of the content detailed in Section 4 of the specification:

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*

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.

Weightings

Assessment objective weightings are shown below as % of the full A level, with AS weightings in brackets.

Unit	raw marks				unit % weighting
	Unit total	AO1	AO2	AO3	
PH1	80	35	35	10	20 (40)
PH2	80	35	35	10	20 (40)
PH3	48	4	4	40	10 (20)
PH4	80	30	40	10	18
PH5	100	34	60	6	22
PH6	50	5	5	40	10

	AO1	AO2	AO3
Total AS%	37	37	27
Total A2%	30	46	23
Total A%	34	42	25

4 SPECIFICATION CONTENT

4.1 Units

SI units will be used throughout this specification. Knowledge of SI multipliers will be required. A table of the SI multipliers will be included in each examination paper.

4.2 Practical Work

Practical work will play an important role throughout the course. Attention is drawn to the specified content in each unit and the instructions relating to the practical internal assessments.

4.3 Mathematical requirements

The following list of requirements is taken from the *GCE AS and A level Criteria for Science Subjects* [July 2006]. The sections in **bold type** [i.e. use of radians, the exponential and log functions] will not be required at AS level, because the subject content which requires these concepts is not met in this part of the course.

Candidates will be required to:

4.3.1 Computation

- recognise and use expressions in decimal and standard form
- use ratios, fractions and percentages
- use calculators to find and use power, **exponential and logarithmic** functions
- use calculators to handle sin *x,* cos *x,* tan *x* when *x* is expressed in degrees **or radians**

4.3.2 Handling data

- use an appropriate number of significant figures
- find arithmetic means
- make order of magnitude calculations.

4.3.3 Algebra

- understand and use the symbols: $=, <, \ll, \gg, >, \propto, \sim$
- change the subject of an equation
- substitute numerical values into algebraic equations using appropriate units for physical quantities
- solve simple algebraic equations

4.3.4 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 $y = k/x$, $y = kx^2$, $y = k/x^2$, **$y = \sin x$, $y = \cos x$, $y = e^{-x}$**

4.3.5 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 sin, cos and tan in physical problems
- **understand the relationship between degrees and radians and translate from one to the other**.

Advanced Subsidiary

PH1 Assessment Unit – MOTION, ENERGY & CHARGE

The Unit is built around a core relating to the following Subject Criteria content:

S3.3 (a) – (d) Mechanics
S4.4(a) – (d) Electrical Circuits

SPECIFICATION

PH1.1 **BASIC PHYSICS**

Content

- Units and dimensions
- Scalar and vector quantities
- Force
- Free body diagrams
- Movements and stability
- Equilibrium

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall and use SI units,

(b) check equations for homogeneity using units,

(c) contrast scalar and vector quantities and give examples of each – displacement, velocity, acceleration, force, speed, time, density, pressure etc.,

(d) appreciate the concept of force and understand Newton's 3rd law of motion,

(e) use free body diagrams to represent forces on a particle or body,

(f) recall and use the relationship $\Sigma F = ma$ in situations where mass is constant,

(g) add and subtract coplanar vectors, and perform mathematical calculations limited to **two** perpendicular vectors,

(h) resolve a vector into two perpendicular components,

(i) understand the concept of density, use the equation $\rho = \frac{m}{V}$ to calculate mass, density and volume;

(j) understand and define the turning effect of a force;

(k) recall and use the principle of moments;

(l) understand and use centre of gravity, for example in simple problems including toppling and stability. Identify its position in a cylinder, sphere and cuboid (beam) of uniform density;

(m) understand that a body is in equilibrium when the resultant force is zero and the net moment is zero, and be able to perform simple calculations.

PH1.2 KINEMATICS

Content

- Rectilinear motion.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) define displacement, mean and instantaneous values of speed, velocity and acceleration,

(b) use graphical methods to represent displacement, speed, velocity and acceleration,

(c) understand and use the properties of displacement-time graphs, velocity-time graphs, acceleration-time graphs, and interpret speed and displacement-time graphs for non-uniform acceleration,

(d) derive and use equations which represent uniformly accelerated motion in a straight line,

(e) describe the motion of bodies falling in a gravitational field with and without air resistance – terminal velocity,

(f) recognise and understand the independence of vertical and horizontal motion of a body moving freely under gravity,

(g) describe and explain motion due to a uniform velocity in one direction and uniform acceleration in a perpendicular direction, and perform simple calculations.

PH1.3 **ENERGY CONCEPTS**

Content

- Work, Power and Energy.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall the definition of work as the product of a force and distance moved in the direction of the force when the force is constant; calculation of work done, for constant forces, when force is not along the line of motion ($\text{W.D.} = Fx\cos\theta$)

(b) understand that the work done by a varying force is the area under the Force-distance graph,

(c) recall and use Hooke's law $F = kx$, and apply this to (b) above to show that elastic potential energy is $\frac{1}{2}Fx$ or $\frac{1}{2}kx^2$,

(d) understand and apply the work – energy relationship $Fs = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ and recall that $E_k = \frac{1}{2}mv^2$,

(e) recall and apply the principle of conservation of energy including use of gravitational potential energy $mg\Delta h$, elastic potential energy $\frac{1}{2}kx^2$, and kinetic energy $\frac{1}{2}mv^2$,

(f) define power as the rate of energy transfer,

(g) appreciate that dissipative forces e.g. friction, viscosity, cause energy to be transferred from a system and reduce the overall efficiency of the system,

(h) recall and use Efficiency = $\dfrac{\text{Useful energy obtained}}{\text{Energy input}} \times 100\%$,

PH1.4 CONDUCTION OF ELECTRICITY

Content

- Electric charge.
- Electric current.
- Nature of charge carriers in conductors.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) understand how attraction and repulsion between rubbed insulators can be explained in terms of charges on the surfaces of these insulators, and that just two sorts of charge are involved;

(b) understand that the name negative charge was arbitrarily given to the sort of charge on an amber rod rubbed with fur, and positive to that on a glass rod rubbed with silk;

(c) recall that electrons can be shown to have a negative charge, and protons, a positive;

(d) explain frictional charging in terms of electrons removed from, or added to, surface atoms;

(e) recall that the unit of charge is the coulomb (C), and that an electron's charge, *e*, is a very small fraction of a coulomb;

(f) recall that charge can flow through certain materials, called conductors;

(g) understand that electric current is rate of flow of charge;

(h) recall and use the equation $I = \frac{\Delta Q}{\Delta t}$;

(i) recall that current is measured in ampère (A), where A = Cs^{-1};

(j) understand and describe the mechanism of conduction in metals as the drift of free electrons;

(k) derive and use the equation $I = nAve$ for free electrons.

PH1.5 RESISTANCE

CONTENT

- Relationship between current and potential difference.
- Resistance
- Resistivity.
- Variation of resistance with temperature for metals.
- Superconductivity
- Heating effect of an electric current.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) define potential difference and recall that its unit is the volt (V) where $V = JC^{-1}$.

(b) sketch $I - V$ graphs for a semiconductor diode, the filament of a lamp, and a metal wire at constant temperature;

(c) state Ohm's Law;

(d) define resistance;

(e) recall that the unit of resistance is the ohm (Ω), where $\Omega = VA^{-1}$;

(f) recall and use $P = IV = I^2R = \frac{V^2}{R}$.

(g) understand that collisions between free electrons and ions give rise to electrical resistance, and to a steady drift velocity under a given p.d.,

(h) recall and use $R = \frac{\rho l}{A}$ and understand that this is the defining equation for resistivity;

(i) describe how to determine the resistivity of a metal experimentally;

(j) describe how to investigate experimentally the variation of resistance with temperature of a metal wire;

(k) recall that the resistance of metals varies almost linearly with temperature over a wide range;

(l) understand what is meant by superconductivity, and superconducting transition temperature;

(m) recall that not all metals show superconductivity, and that, for those that do, the transition temperatures are a few degrees above absolute zero (–273°C);

(n) recall that certain special materials (high temperature superconductors) have transition temperatures above the boiling point of nitrogen (–196°C), and can therefore be kept below their transition temperatures using liquid nitrogen;

(o) recall that superconducting magnets are used in particle accelerators, tokamaks and magnetic resonance imaging machines, and are expected soon to be used in some large motors and generators;

(p) understand that ordinarily (that is, above the transition temperature), collisions between free electrons and ions in metals increase the random vibration energy of the ions, so the temperature of the metal increases;

PH1.6 D.C. CIRCUITS

CONTENT

- Series and parallel circuits.
- Combination of resistors.
- The internal resistance of sources.
- The potential divider.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) understand and recall that the current from a source is equal to the sum of the currents in the separate branches of a parallel circuit, and that this is a consequence of conservation of charge;

(b) understand and recall that the sum of the p.d.s across components in a series circuit is equal to the p.d. across the supply, and that this is a consequence of conservation of energy;

(c) understand and recall that the p.d.s across components in parallel are equal;

(d) recall and use formulae for the combined resistance of resistors in series and parallel;

(e) derive and use the potential divider formula $\frac{V}{V_{\text{total}}}\left(\text{or } \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right) = \frac{R}{R_{\text{total}}}$;

(f) define the e.m.f. of a source and appreciate that its unit, the volt (V), is the same as that of potential difference.

(g) appreciate that sources have internal resistance and use the formula $V = E - Ir$

(h) calculate current and p.d.s in a simple circuit containing one cell or cells in series.

PH2 Assessment Unit – WAVES & PARTICLES

The Unit is contains the following Subject Criteria content:

3.5	Waves
3.7 (a) – (b)	Quantum physics: photons, particles

SPECIFICATION

PH2.1 **WAVES**

Content

- Progressive waves.
- Transverse and longitudinal waves.
- Polarisation.
- Frequency, wavelength and velocity of waves.
- Diffraction.
- Interference.
- Two-source interference patterns.
- Stationary waves.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) understand that a progressive wave transfers energy or information from a source to a detector without any transfer of matter;

(b) distinguish between transverse and longitudinal waves,

(c) describe experiments which demonstrate the polarisation of light and microwaves;

(d) explain the terms displacement, amplitude, wavelength, frequency, period and velocity of a wave,

(e) draw and interpret graphs of displacement against time, and displacement against position for transverse waves only,

(f) recall and use the equation $c = f\lambda$,

(g) be familiar with experiments which demonstrate the diffraction of water waves, sound waves and microwaves, and understand that significant diffraction only occurs when λ is of the order of the dimensions of the obstacle or slit,

(h) state, explain and use the principle of superposition,

(i) describe an experimental demonstration of two-source interference for light, appreciating the historical importance of Young's experiment, and be familiar with experiments which demonstrate two source interference for water waves, sound waves and microwaves;

(j) use the equation $\lambda = \frac{ay}{D}$ for double-slit interference,

(k) show an understanding of path difference, phase difference, and coherence,

(l) state the conditions necessary for two-source interference to be observed, i.e. constant phase difference, vibrations in the same line,

(m) recall the shape of the intensity pattern from a single slit and its effect on double-slit and diffraction grating patterns,

(n) use the equation $d \sin \theta = n\lambda$ for a diffraction grating,

(o) give examples of coherent and incoherent sources,

(p) be familiar with experiments which demonstrate stationary waves, e.g. vibrations of a stretched string and for sound in air,

(q) state the differences between stationary and progressive waves,

(r) understand that a stationary wave can be regarded as a superposition of two progressive waves of equal amplitude and frequency, travelling in opposite directions and that the internodal distance is $\frac{\lambda}{2}$

PH2.2 **REFRACTION OF LIGHT**

Content

- Refraction.
- Wave Model of Refraction
- Optical Fibre Communications

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall and use Snell's Law of refraction;

(b) recall and use the equations

$$n_1 v_1 = n_2 v_2 \quad \text{and} \quad n_1 \sin\theta_1 = n_2 \sin\theta_2\,;$$

(c) understand how Snell's Law relates to the wave model of light propagation;

(d) understand the conditions for total internal reflection and derive and use the equation for the critical angle

$$n_1 \sin c = n_2 ;$$

(e) apply the concept of total internal reflection to multimode optical fibres;

(f) appreciate the problem of multi-mode dispersion with optical fibres in terms of limiting the rate of data transfer and transmission distance;

(g) explain how the introduction of monomode optical fibres has allowed for much greater transmission rates and distances;

(h) compare optical fibre communications to terrestrial microwave links, satellite links and copper cables for long distance communication.

PH2.3 PHOTONS

Content

- The photoelectric effect.
- Photons
- The electromagnetic spectrum
- Line emission and line absorption spectra
- X-rays
- Spontaneous and stimulated emission
- Lasers – energy levels and structure
- The semiconductor laser and its uses

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) describe how the photo-electric effect can be demonstrated

(b) describe how the maximum kinetic energy, KE_{max}, of emitted electrons can be measured, using a vacuum photocell;

(c) sketch a graph of KE_{max} against frequency of illuminating radiation;

(d) understand and recall how a photon picture of light leads to Einstein's equation, KE_{max} and how this equation correlates with the graph of KE_{max} against frequency;

(e) describe in outline how X-rays are produced in an X-ray tube, and sketch a graph of intensity against wavelength;

(f) recall the characteristic properties and orders of magnitude of the wavelengths of the radiations in the electromagnetic spectrum;

(g) calculate typical photon energies for these radiations;

(h) understand in outline how to produce line emission and line absorption spectra from atoms;

(i) describe the appearance of such spectra as seen in a diffraction grating;

(j) understand and use atomic energy level diagrams, together with the photon hypothesis, to explain line emission and line absorption spectra;

(k) calculate ionisation energies from an energy level diagram;

(l) understand and explain the process of stimulated emission and how this process leads to light emission that is coherent;

(m) understand the concept of population inversion (Note: for A level students the condition $N_2 > N_1$ will suffice) and explain that population inversion is necessary for a laser to operate;

(n) understand that population inversion is not (usually) possible with a 2-level energy system;

(o) understand how population inversion is attained in 3 and 4-level energy systems;

(p) understand the process of pumping and its purpose;

(q) recall the structure of a typical laser i.e. an amplifying medium between two mirrors, one of which partially transmits light;

(r) know the basic structure of a semiconductor diode laser;

(s) know that laser systems are far less than 1% efficient in general (usually around 0.01% efficient) due to pumping losses but that semiconductor lasers can obtain 70% efficiency and that pumping requires the application of a p.d. of around 3V;

(t) know the advantages and uses of a semiconductor laser i.e. small, cheap, efficient and used for CDs, DVDs, telecommunication etc.

PH2.4 MATTER, FORCES AND THE UNIVERSE.

Content

- The nuclear atom
- Leptons and Quarks
- Particle interactions
- Conservation Laws

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) describe a simple model for the nuclear atom in terms of nucleus and electrons orbiting in discrete orbits, explaining the composition of the nucleus in terms of protons and neutrons and expressing the nuclear and atomic structures using the ${}^{A}_{Z}X$ notation

(b) recall that matter is composed of quarks and leptons – the following information will be available to candidates in examinations:

	Leptons			Quarks	
particle (symbol)	electron (e^-)	electron neutrino (ν_e)		up (u)	down (d)
charge (e)	– 1	0		$+\frac{2}{3}$	$-\frac{1}{3}$

[N.B. No questions will be set involving generations higher than generation 1.]

(c) recall that antiparticles exist to the particles given in the table above, that the properties of an antiparticle are identical to those of its corresponding particle apart from having opposite charge, and that particles and antiparticles annihilate; use the above table to give the symbols of the antiparticles;

(d) recall the following information about the four forces or interactions, which are experienced by particles:

Interaction	Experienced by	Range	Comments
Gravitational	all particles	infinite	very weak – negligible except in the context of large objects such as planets and stars
Weak	all particles	very short range	only significant in cases where the electromagnetic and strong interactions do not operate
Electromagnetic	all charged particles	infinite	also experienced by neutral hadrons because they are composed of quarks
Strong	quarks	short range	experienced by quarks and particles composed of quarks

(e) recall that quarks are never observed in isolation, but bound into composite particles called hadrons, which are classified as **either** baryons (e.g. the proton or neutron) which consist of 3 quarks **or** mesons (e.g. pions) which consist of a quark-antiquark pair;

(f) use tables of data to suggest the quark structure of given baryons or mesons;

(g) understand that, in particle interactions, charge and lepton number are conserved.

PH2.5 USING RADIATION TO INVESTIGATE STARS

Content

- Black-body radiation
- Wien's displacement law – stellar temperatures
- Stefan's law and stellar luminosity
- Intensity and the inverse square law
- Fraunhofer lines and stellar composition

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall that a stellar spectrum consist of a continuous emission spectrum, from the dense gas of the surface of the star, and a line absorption spectrum arising from the passage of the emitted electromagnetic radiation through the tenuous atmosphere of the star,

(b) recall that bodies which absorb all incident radiation are known as black bodies and that stars are very good approximations to black bodies,

(c) recall the shape of the black body spectrum and that the peak wavelength is inversely proportional to the absolute temperature (defined by $T/\text{K} = \theta/°\text{C} + 273{\cdot}15$) – Wien's displacement law;

(d) use Wien's displacement law, Stefan's Law and the inverse square law to investigate the properties of stars – luminosity, size, temperature and distance [N.B. stellar brightness in magnitudes will not be required];

(e) interpret data on stellar line spectra to identify elements present in stellar atmospheres;

(f) recall that the analysis of stellar spectra reveals that roughly 75% of the universe, by mass, is Hydrogen and 24% Helium, with very small quantities of the other elements;

(g) recall the main branch of the proton-proton chain, which is the main energy production mechanism in stars like the Sun:

$$p + p \rightarrow d + e^{+} + \nu_e \qquad \text{(where d = deuteron } {}^2_1\text{H)}$$

$$p + d \rightarrow {}^3_2\text{He} + \gamma \qquad \text{(where } \gamma \text{ = photon)}$$

$${}^3_2\text{He} + {}^3_2\text{He} \rightarrow {}^4_2\text{He} + p + p$$

and that neutrinos from the first step of this chain can be detected on Earth;

PH3 Internal Assessment Unit – PRACTICAL PHYSICS

This Unit gives candidates opportunities to demonstrate development of their experimental, manipulative, interpretative and communication skills.

SPECIFICATION

Candidates are required to undertake, under controlled conditions, a set of experimental tasks. The tasks are devised by the WJEC and assessed by the supervisor using a marking scheme provided by the WJEC.

AMPLIFICATION OF CONTENT

Candidates should be able to:

- follow instructions and plan experimental activities,
- make observations and draw conclusions,
- take measurements and record data showing awareness of the limits of accuracy and correct use of significant figures,
- assess the uncertainty in measurements and derived quantities,
- present data in different forms, including graphically,
- analyse and interpret data, demonstrating appropriate knowledge and understanding of physics, and investigate the relationships between physical quantities,
- evaluate experimental techniques and outcomes,
- communicate experimental findings clearly using SI units.

Task details

- Measuring instrument requirements will include items expected to be found in a school laboratory [see section 8 – Guidance on Internal Assessment].
- Other equipment requirements will include standard laboratory items such as clamp stands and slotted masses, but may also include items which need to be obtained specially for the assessment from equipment suppliers or D.I.Y. stores.
- Detailed requirements for the assessment will be issued to centres two months prior to the assessment. The information provided will give the context of the task and detailed instructions on measuring instruments required, and assemblage of apparatus.

- The assessment is in two sections: **Section A** and **Section B**.

  Section A consists of 3 short items, each of duration 15 minutes. These items concentrate on making measurements, determining the magnitude of quantities and the associated uncertainty. The contexts are from across the AS specification. The 3 items each carry 8 marks.

  Section B consists of a single item of duration 45 minutes. Candidates are expected to undertake an investigation into the relationship between quantities. Section B carries 24 marks.

  There is no requirement for candidates to undertake the items in any specific order.

- Centres are free to organise the progression of candidates between the items as they wish, but the timings lend themselves to assessing candidates in multiples of 6, with 3 candidates being engaged in Section A [tackling the items in a cycle] and 3 in Section B at any one time.

- Centres are issued with a marking scheme for the assessment of candidates' responses. The results should be forwarded to the WJEC and the candidates' work presented for moderation in line with the procedures of the WJEC.

Advanced Level

PH4 Assessment Unit – OSCILLATIONS & FIELDS

Advanced Level A2

The Unit is built around a core relating to the following Subject Criteria content:

3.3 (e) – (g)	Mechanics: momentum, circular motion, oscillations
3.6	Matter: molecular kinetic theory, internal energy
3.8 (a)	Fields: force fields

SPECIFICATION

PH4.1 **VIBRATIONS**

Content

- Circular motion
- Physical and mathematical treatment of undamped simple harmonic motion.
- Energy interchanges during simple harmonic motion.
- Damping of oscillations.
- Free oscillations, forced oscillations and resonance.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) understand and use period of rotation, frequency, the radian measure of angle,

(b) define and use angular velocity ω,

(c) recall and use $v = \omega r$, and hence $a = \omega^2 r$,

(d) define simple harmonic motion as a statement in words,

(e) recall, recognise and use $a = -\omega^2 x$ as a mathematical defining equation of simple harmonic motion,

(f) illustrate, and interpret graphically, the variation of acceleration with displacement during simple harmonic motion,

(g) recall and use $x = A\sin(\omega t + \varepsilon)$ as a solution to $a = -\omega^2 x$,

(h) explain the terms frequency, period, amplitude and phase $(\omega t + \varepsilon)$,

(i) recall and use the period as $\frac{1}{f}$ or $\frac{2\pi}{\omega}$,

(j) recall and use $v = A\omega \cos(\omega t + \varepsilon)$ for the velocity during simple harmonic motion,

(k) illustrate, and interpret graphically, the changes in displacement and velocity with time during simple harmonic motion,

(l) recall and use the equation $T = 2\pi\sqrt{\frac{m}{k}}$ for the period of a system having stiffness (force per unit extension) k and mass m,

(m) illustrate, and interpret graphically, the interchange between kinetic energy and potential energy during undamped simple harmonic motion, and perform simple calculations on energy changes,

(n) explain what is meant by free oscillations and understand the effect of damping in real systems,

(o) describe practical examples of damped oscillations, and the importance of critical damping in appropriate cases such as vehicle suspensions,

(p) explain what is meant by forced oscillations and resonance, and describe practical examples,

(q) sketch the variation of the amplitude of a forced oscillation with driving frequency and know that increased damping broadens the resonance curve,

(r) appreciate that there are circumstances when resonance is useful e.g. circuit tuning, microwave cooking and other circumstances in which it should be avoided e.g. bridge design.

PH4.2 MOMENTUM CONCEPTS

Content

- Linear momentum.
- Newton's laws of motion.
- Conservation of linear momentum; particle collision.
- The momentum of a photon

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) define linear momentum as the product of mass and velocity,

(b) recall Newton's laws of motion and know that force is rate of change of momentum, applying this in situations where mass is constant,

(c) state the principle of conservation of momentum and use it to solve problems in one dimension involving elastic collisions (where there is no loss of kinetic energy) and inelastic collisions (where there is loss of kinetic energy).

(d) use the formula for the momentum of a photon: $p = \dfrac{h}{\lambda} = \dfrac{hf}{c}$;

(e) appreciate that the absorption or reflection of photons gives rise to radiation pressure.

PH4.3 THERMAL PHYSICS

Content

- Ideal gas laws and the equation of state.
- Kinetic theory of gases.
- The kinetic theory of pressure of a perfect gas
- Internal energy.
- The internal energy of an ideal gas
- Energy transfer.
- First law of thermodynamics.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall and use Boyles law for an ideal gas,

(b) recall and use the equation of state for an ideal gas expressed as $pV = nRT$ where R is the molar gas constant, and understand that this equation can be used to define the Kelvin scale of temperature and the absolute zero of temperature,

(c) recall the assumptions of the kinetic theory of gases which includes the random distribution of energy among the molecules,

(d) explain how molecular movement causes the pressure exerted by a gas, and understand and use $p = \frac{1}{3}\rho\overline{c^2} = \frac{1}{3}\dfrac{N}{V}m\overline{c^2}$ where N is the number of molecules,

(e) define the Avogadro constant N_A and hence the mole;

(f) understand that the molar mass M is related to the relative molecular mass M_r by M/kg = M_r/1000, and that the number of moles n is given by $\dfrac{\text{Total mass}}{\text{Molar mass}}$;

(g) compare $pV = \frac{1}{3}Nm\overline{c^2}$ with $pV = nRT$ and deduce that the total translational kinetic energy of a mole of a monatomic gas is given by $\frac{3}{2}RT$ and hence the average kinetic energy of a molecule is $\frac{3}{2}kT$ where $k\left(=\frac{R}{N_A}\right)$ is the Boltzmann constant, and deduce that T is proportional to the mean kinetic energy

(h) understand that the internal energy of a system is the sum of the potential and kinetic energies of its molecules;

(i) understand that the internal energy of an ideal monatomic gas is wholly kinetic so is given by $U = \frac{3}{2}nRT$

(j) understand that heat enters or leaves a system through its boundary or container wall, according to whether the system's temperature is lower or higher than that of its surroundings, so heat is energy in transit and not contained within the system;

(k) understand that if no heat flows between systems in contact, then they are said to be in thermal equilibrium, and are at the same temperature;

(l) understand that energy can also enter or leave a system by means of work, so work is also energy in transit;

(m) use $W = p\Delta V$ to calculate the work done by a gas under constant pressure;

(n) understand and explain that, even if p changes, W is given by the area under the $p - V$ graph;

(o) recall and use the first law of thermodynamics, in the form $\Delta U = Q - W$, knowing how to interpret negative values of ΔU, Q, and W.

(p) understand that for a solid (or liquid), W is usually negligible, so $Q = \Delta U$;

(q) use the formula $Q = mc\Delta\theta$, for a solid or liquid, understanding that this is the defining equation for specific heat capacity, c.

PH4.4 ELECTROSTATIC AND GRAVITATIONAL FIELDS OF FORCE

Content

- Electrostatic and gravitational fields.
- Field strength (intensity).
- Electrical and gravitational inverse square laws.
- Potential in force fields.
- Relation between force and potential energy gradient.
- Relation between intensity and potential gradient
- Field lines and equipotential surfaces.
- Vector addition of electric fields.
- Potential energy of a system of charges.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall the main features of electric and gravitational fields as specified in the **table opposite**

(b) recall that the gravitational field outside spherical bodies such as the earth is essentially the same as if the whole mass were concentrated at the centre

(c) understand that field lines (or lines of force) give the direction of the field at a point, thus, for a positive point charge, the field lines are radially outward; and that equipotential surfaces join points of equal potential and are therefore spherical for a point charge

(d) calculate the net potential and resultant field strength for a number of point charges and point masses

(e) appreciate that $\Delta U_P = mg\Delta h$ for distances over which the variation of g is negligible.

REQUIREMENT	ELECTRIC FIELDS	GRAVITATIONAL FIELDS
Define …	electric field strength, E, as the force per unit charge on a small positive test charge placed at the point,	gravitational field strength, g, as the force per unit mass on a small test mass placed at the point,
Recall and use the inverse square law for the force between	two electric charges in the form $F = k\frac{Q_1 Q_2}{r^2}$ where $k = \frac{1}{4\pi\varepsilon_0}$ (Coulomb's Law)	two masses in the form $F = k\frac{m_1 m_2}{r^2}$ where k = G (Newton's Law of Gravitation)
Recall that	F can be attractive or repulsive	F is attractive only
Recall and use …	$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ for the field strength due to a point charge in free space or air	$g = \frac{Gm}{r^2}$ for the field strength due to a point mass
Define potential at a point due to …	a point charge in terms of the work done in bringing unit positive charge from infinity to that point,	a point mass in terms of the work done in bringing a unit mass from infinity to that point,
Recall and use the equations….	$V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$	$V_g = \frac{-GM}{r}$
• Know that the change in potential energy of … • Use these relationships.	a point charge moving in any electric field $= q\Delta V_E$,	a point mass moving in any gravitational field $= m\Delta V_g$
• Recall that the field strength at a point is given by … • Use these relationships.	E = - slope of the $V_E - r$ graph at that point	g = - slope of the $V_g - r$ graph at that point, and for uniform fields.
• Know that the potential difference is given by …	the area under the $E - r$ graph.	the area under the $g - r$ graph.

PH4.5 APPLICATION TO ORBITS IN THE SOLAR SYSTEM AND THE WIDER UNIVERSE

Content

- Kepler's Laws of Planetary Motion
- Circular orbits of satellites, planets and stars
- Centre of Mass
- Missing mass in galaxies – Dark Matter
- Objects in mutual orbit
- Doppler shift of spectral lines
- Extra-solar planets

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) state Kepler's three Laws of Planetary Motion,

(b) recall and use Newton's law of Gravitation $F = G\frac{m_1 m_2}{r^2}$ in simple examples, including the motion of planets and satellites;

(c) derive Kepler's 3rd Law, for the case of a circular orbit from Newton's Law of Gravity and the formula for centripetal acceleration,

(d) use data on orbital motion, such as period or orbital speed, to calculate the mass of the central object;

(e) appreciate that the orbital speeds of objects in spiral galaxies implies the existence of dark matter;

(f) calculate the position of the centre of mass of two spherically-symmetric objects, given their masses and separation, and calculate their mutual orbital period in the case of circular orbits,

(g) use the Doppler relationship in the form $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$;

(h) calculate a star's radial velocity (i.e. the component of its velocity along the line joining it and an observer on the Earth) from data about the Doppler shift of spectral lines,

(i) use data on the variation of the radial velocities of the bodies in a double system (e.g. a star and orbiting planet) and their orbital period to determine the masses of the bodies for the case of a circular orbit edge on as viewed from the Earth

PH5 Assessment Unit – ELECTROMAGNETISM, NUCLEI & OPTIONS

Advanced Level A2

The Unit is built around a core relating to the following Subject Criteria content:

3.4 (e)	Electrical circuits: capacitance
3.7 (c) – (d)	Nuclear Physics: nuclear decay, nuclear energy
3.8 (b) – (c)	Fields: B-fields, flux and electromagnetic induction

SPECIFICATION

PH5.1 **CAPACITANCE**

Content

- The parallel plate capacitor.
- Concept of capacitance.
- Factors affecting capacitance.
- Energy stored in a capacitor.
- Capacitors in series and parallel.
- Capacitor discharge.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) understand that a simple parallel plate capacitor consists of a pair of equal parallel metal plates separated by vacuum or air,

(b) understand that the capacitor stores energy by transferring charge from one plate to the other, so that the plates carry equal but opposite charges (the net charge being zero),

(c) define capacitance as $C = \frac{Q}{V}$,

(d) use $C = \frac{\varepsilon_o A}{d}$ for a parallel plate capacitor, with no dielectric,

(e) know that a dielectric increases the capacitance of a vacuum-spaced capacitor;

(f) recall that the *E* field within a parallel plate capacitor is uniform and of value *V/d,*

(g) use the equation $U = \frac{1}{2}QV$ for the energy stored in a capacitor,

(h) use formulae for capacitors in series and in parallel,

(i) understand the process by which a capacitor discharges through a resistor,

(j) use the equation

$Q = Q_0 e^{-t/RC}$ where *RC* is the time constant.

PH5.2 B-FIELDS

Content

- Concept of magnetic fields (B-fields).
- Force on a current-carrying conductor.
- Force on a moving charge.
- Magnetic fields due to currents.
- Effect of a ferrous core.
- Force between current – carrying conductors.
- Definition of the ampere.
- Measurement of magnetic field strength *B*.
- Deflection of beams of charged particles in electric and magnetic fields.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) predict the direction of the force on a current-carrying conductor in a magnetic field,

(b) define magnetic field *B* by considering the force on a current-carrying conductor in a magnetic field; recall and use $F = BIl \sin\theta$,

(c) use $F = Bqv \sin\theta$ for a moving charge in a magnetic field;

(e) understand the processes involved in the production of a Hall voltage and understand that $V_H \propto B$ for constant *I*.

(f) describe how to investigate steady magnetic fields with a Hall probe,

(g) sketch the magnetic fields due to a current in

(i) a long straight wire,
(ii) a long solenoid,

(h) use the equations $B = \frac{\mu_0 I}{2\pi a}$ and $B = \mu_0 nI$ for the field strengths due to a long straight wire and in a long solenoid,

(i) know that adding an iron core increases the field strength in a solenoid,

(j) explain why current-carrying conductors exert a force on each other and predict the directions of the forces,

(k) understand how the equation for the force between two currents in straight wires leads to the definition of the ampere,

(m) describe quantitatively how ion beams, i.e. charged particles, are deflected in uniform electric and magnetic fields,

(o) apply knowledge of the motion of charged particles in magnetic and electric fields to linear accelerators, cyclotrons and synchrotrons.

PH5.3 **ELECTROMAGNETIC INDUCTION**

Content

- Magnetic flux.
- Laws of electromagnetic induction.
- Calculation of induced emf.
- Self induction.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall and define magnetic flux as $\Phi = AB\cos\theta$ and flux linkage = $N\Phi$

(b) recall the laws of Faraday and Lenz,

(c) recall and use e.m.f. = – rate of change of flux linkage and use this relationship to derive an equation for the e.m.f. induced in a linear conductor moving at right angles to a uniform magnetic field,

(e) relate qualitatively the instantaneous e.m.f. induced in a coil rotating at right angles to a magnetic field to the position of the coil, flux density, coil area and angular velocity;

(f) understand and use the terms frequency, period, peak value and root-mean-square value when applied to alternating voltages and currents,

(g) understand that the r.m.s. value is related to the energy dissipated per cycle, and use the relationships $V_{\text{r.m.s.}} = \frac{V_0}{\sqrt{2}}$ and $I_{\text{r.m.s}} = \frac{I_0}{\sqrt{2}}$

(h) recall that the mean power dissipated in a resistor is given by $\overline{P} = VI = \frac{V^2}{R} = I^2R$, where V and I are the r.m.s. values;

(i) describe the use of a cathode ray oscilloscope to measure:

  (i) a.c. and d.c. voltages and currents,

  (ii) frequencies.

PH5.4 RADIOACTIVITY AND RADIOISOTOPES

Content

- Radioactive decay.
- Half-life.
- Applications of radioactivity.
- Hazards and safety precautions.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) recall the spontaneous nature of nuclear decay; describe the nature of α, β and γ radiation, and use equations to represent the nuclear transformations using the $^{A}_{Z}X$ notation,

(b) describe methods used to distinguish between α, β and γ radiation and explain the connections between the nature, penetration and range for ionising particles,

(c) account for the existence of background radiation and make allowance for this in experimental measurements,

(d) explain what is meant by half-life $T_{½}$,

(e) define activity A and the becquerel,

(f) define decay constant (λ) and recall and use the equation $A = -\lambda N$.

(g) recall and use the exponential law of decay in graphical and algebraic form,

[$N = N_{\mathrm{o}} \mathrm{e}^{-\lambda t}$ (or $N = \frac{N_{\mathrm{o}}}{2^{x}}$) and $A = A_{\mathrm{o}} \mathrm{e}^{-\lambda t}$ (or $A = \frac{A_{\mathrm{o}}}{2^{\mathrm{x}}}$)

where x is the number of half-lives elapsed – not necessarily an integer,]

(h) derive and recall that $\lambda = \frac{\log_{e} 2}{T_{½}}$,

(i) describe briefly the use of radioisotopes (any two applications),

(j) show an awareness of the biological hazards of ionising radiation e.g. whether exposed to external radiation or when radioactive materials are absorbed (ingestion and/or inhalation).

PH5.5 NUCLEAR ENERGY

Content

- Binding Energy.
- Fission and Fusion.
- Nuclear Reactors.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) appreciate the association between mass and energy and recall that $E = mc^2$,

(b) calculate the binding energy for a nucleus and hence the binding energy per nucleon, making use, where necessary, of the unified atomic mass unit (u) and the electron-volt (eV),

(c) apply the conservation of mass/energy to particle interactions – e.g. fission, fusion and neutrino detection interactions

(d) describe the relevance of binding energy per nucleon to nuclear fission and fusion,

(e) explain how neutron emission gives the possibility of a chain reaction,

(f) understand and describe induced fission by thermal neutrons and the roles of moderator, control rods and coolants in thermal reactors,

(g) understand and recall the factors influencing choice of materials for moderator, control rods and coolant,

(h) discuss the environmental problems posed by the disposal of the waste products of nuclear reactors.

OPTIONAL CONTENT IN UNIT A2

The following section contains the 5 optional sections to A2. It is anticipated that candidates will study only **one** of these optional topics. The approximate teaching time required for each option is 15 hours. The questions on the optional topics will occupy a separate section in the PH5 paper and account for 20 marks.

Option A2/A Further Electromagnetism and Alternating Currents

Content

- Mutual induction.
- Simple treatment of the transformer.
- Self induction and self inductance
- A.C. behaviour of a capacitor and an inductor; reactance, mean power.
- Vector treatment of RC, RL and RCL series circuits; impedance.
- Uses: simple RC filters, tuned circuits.

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) describe, in terms of electromagnetic induction, how a changing current in one coil induces an e.m.f. in another coil;

(b) understand that a closed-loop iron core enables a real transformer to approximate to the ideal case where there is no flux leakage;

(c) understand and recall that that if there is no flux leakage, or voltage drops in the primary or secondary, then $\frac{V_1}{V_2} = \frac{N_1}{N_2}$;

(d) understand and recall that if there were no energy dissipation in the transformer itself, then $V_1 I_1 = V_2 I_2$, in which the p.d.s and currents are r.m.s. values;

(e) recall that in practice there is some energy dissipation due to

(i) the resistance of the primary and secondary coils,
(ii) eddy currents in the iron core,
(iii) energy used cyclically to change the magnetisation of the core;

(f) recall that these losses can be reduced by

(i) using thick enough wires for the coils,
(ii) laminating the core,
(iii) choosing a suitable alloy for the core;

(g) describe, in terms of electromagnetic induction, how a changing current in a coil induces in that coil an e.m.f., whose direction is such as to oppose the change in current;

(h) define the self-inductance of a coil by the equation $E = -L\dfrac{\Delta I}{\Delta t}$;

(i) understand the 90° phase lag of current behind p.d. for an inductor in a sinusoidal a..c. circuit;

(j) recall that $\dfrac{V_{\mathrm{rms}}}{I_{\mathrm{rms}}}$ is called the reactance, X_{L}, of the inductor, and use the equation $X_{\mathrm{L}} = \omega L$;

(k) understand the 90° phase lead of current ahead of p.d. for a capacitor in a sinusoidal a..c. circuit, and use the equation $X_{\mathrm{C}} = \dfrac{1}{\omega C}$;

(l) recall that the mean power dissipation in an inductor or a capacitor is zero;

(m) add p.d.s across series *RC*, *RL* and *RCL* combinations using phasors;

(n) calculate phase angle and impedance, *Z*, (defined as $\dfrac{V_{\mathrm{rms}}}{I_{\mathrm{rms}}}$) for such circuits;

(o) derive an expression for the resonance frequency of an *RCL* series circuit;

(p) understand that the sharpness of the resonance curve is determined by the ratio $\dfrac{\omega L}{R}$, known as the Q factor of the circuit;

(q) understand how a series *LCR* circuit can be used to select frequencies;

(r) understand how a *CR* circuit can be used as a simple high-pass or low-pass filter;

Option A2/B **Revolutions in Physics**

This option module consists of two topics, **which will be examined in alternate years**.

Topics

- The Newtonian Revolution
- Electromagnetism and Space-Time

AMPLIFICATION OF CONTENT

1. The Newtonian Revolution

General Approach

- Why do things *move* in the way they do? How our concepts of force and motion developed during the seventeenth century, culminating with Newton's *Principia*.
- The course is structured around the study of some 10 short extracts from the (translated) works of the giants of the revolution, including Kepler, Descartes and Galileo, as well as Newton himself.
- Questions about the nature of science will arise and invite discussion e.g. can an abstract mathematical law really be said to *explain* what makes the planets move in ellipses?
- WJEC will provide teachers' notes, including guidance on what to look for in the extracts.
- In examinations, candidates would be expected to recognise, say, a diagram from Newton or Descartes, or a paragraph from Galileo and to comment on its significance. This wouldn't, of course, be the only sort of question.

Ground to be Covered

- The official (post-Aristotle) view of the 'perfect', eternal, circular motion of heavenly bodies and the short-lived motion of bodies (like carts and arrows) on the Earth.
- Ptolemy's earth-centred universe and Copernicus's Sun-centred system
- Kepler's elliptical orbits.
- Galileo: the Law of Inertia and the heliocentric system made plausible.
- Descartes: A mechanistic universe of particles and contact forces, including the vortex theory of the solar system. No place for occult forces and influences in Descartes' world?
- Newton's 'shoulders of giants' synthesis: the link between force and motion, how a central force can account for planetary motion, the inverse square law, celestial and terrestrial dynamics unified…
- Questions raised: Did Newton really explain anything? Was Newton satisfied with his own work? What were the effects of the Newtonian revolution on the way people thought? Has Newton's work been superseded? …

2. Electromagnetism and Space-Time

General Approach

- This course sketches how the evidence was uncovered for light being an electromagnetic wave, and how this preceded revolutionary changes in our views of time and space.

- The study of some eight shortish extracts from the works of Young, Faraday, Maxwell, Hertz and others will help to give the course structure. In examinations, candidates would be expected to recognise a diagram or a paragraph from these extracts and to comment on its significance.

- Questions about the nature of science will arise and invite discussion e.g. Can science and common sense be at odds?

- WJEC will provide teachers' notes, including guidance on what to look for in the extracts.

Ground to be Covered

- The background: exciting work in Physics around 1800: Young's resurrection of the wave theory of light, Galvani's twitching frog's leg and Volta's pile.

- Oersted's discovery that an electric current gives rise to a magnetic field and Ampère's quantitative work.

- Faraday's lines of force, tending to contract along their length and to expand sideways, explaining the forces of coils or magnets (or charges) on one another – contrasted with the 'action at a distance' theories of Ampère and others.

- Faraday's discovery of electromagnetic induction.

- Maxwell's espousal of Faraday's lines of force as physical things and a glimpse of his early 'vortex' model, which led to his prediction of electromagnetic waves with the same speed as light – surely not a co-incidence.

- Maxwell's realisation that the testable Physics in his model could all be summed up in four [sets of] equations, so the model itself could be ditched.

- Hertz: Maxwell vindicated.

- The aether: a medium needed for the propagation of light and other e-m waves? The purpose and principle and result of the Michelson-Morley experiment.

- Einstein's Special Relativity accounts naturally for this result. A simple thought experiment on time dilation to give a flavour of the theory.

Option A2/C Materials

Content

- Hooke's Law
- Stress-strain and the Young Modulus
- Strain energy – elastic hysteresis
- Elastic and plastic behaviour
- Composite materials

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) Classify solids as crystalline, amorphous and polymeric in terms of their microscopic structure.

(b) Describe an experiment to investigate the behaviour of a spring in terms of load and extension, recall and use Hooke's law and define the spring constant as force per unit extension. $F = k\Delta x$

(c) Define tensile stress $\left(\sigma = \frac{F}{A}\right)$ and tensile strain $\left(\varepsilon = \frac{\Delta l}{l}\right)$ and the Young modulus and perform simple calculations; compare the Young modulus of various solids

(d) Describe an experiment to determine the Young modulus of a metal in the form of a wire.

(e) Deduce the strain energy in a deformed solid material from the area under a force/extension graph $\left(\frac{1}{2}F\Delta x\right)$ and recall and derive the equation: strain energy per unit volume $= \frac{1}{2}\sigma\varepsilon$ and apply to cases in which K.E is absorbed by a wire or rope.

(f) Describe the main features of force/extension, stress/strain graphs for ductile materials such as copper and compare these with less ductile metals such as steel.

(g) Describe the deformation of ductile materials at the molecular level and distinguish between elastic and plastic strain.

(h) Describe, at the molecular level, the effect of dislocations and the strengthening and stiffening of materials by the introduction of dislocation barriers such as foreign atoms, other dislocations and grain boundaries;

(i) understand, on a simple molecular level, how superalloys have been developed to withstand extreme conditions, and describe some of their uses;

(j) Describe in molecular terms failure mechanisms in ductile materials: ductile fracture (necking), creep and fatigue.

(k) Understand that heat treatment processes may control the mechanical properties of metals: cold working (work hardening), annealing (e.g. copper) and quench hardening (e.g. steel)

(l) Demonstrate an understanding of the force/extension, stress/strain graph for a brittle substance such as glass and be able to compare it with the graph for a ductile material.

(m) Describe brittle fracture in molecular terms and the effect of surface imperfections on breaking stress (UTS) and the increased breaking stress of thin glass fibres.

(n) Describe thermoplastic (e.g. polythene) and thermosetting (e.g. melamine) polymers at the molecular level. Compare and contrast their properties and describe some of their uses.

(o) Demonstrate an understanding of the force/extension, stress/strain graph for polymeric substances (rubber and polyethylene).

(p) Compare the behaviour of rubber and polyethylene in terms of molecular structure and behaviour under stress with reference also to the effect of temperature. Understand the importance of hysteresis in rubber.

(q) Recall that materials do not always behave in a similar way in tension and compression and that crack propagation is more difficult under compression- with particular reference to concrete and prestressed glass as examples.

(r) Understand that composite materials are developed to take advantage of the mechanical properties of the individual materials from which they are made, with reference to vehicle tyres, reinforced concrete, fibre reinforced polymers (e.g. glass and carbon) and wood based composites used as examples.

Option A2/D Biological Measurement and Medical Imaging

Content

- X-rays
- Ultrasound
- Magnetic resonance imaging
- Nuclear imaging

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) describe the nature and properties of X-rays.

(b) describe the production of X-ray spectra including methods of controlling the beam intensity, photon energy, image sharpness, contrast and patient dosage.

(c) describe the use of high energy X-rays in the treatment of patients (therapy) and low energy X-rays in diagnosis.

(d) use the equation $I = I_0 \exp(-\mu x)$ for the attenuation of X-rays;

(e) understand the use of X-rays to give images of internal structures, image intensifiers and contrast media.

(f) describe the use of a rotating beam CT scanner (computerised axial tomography).

(g) describe the generation and detection of Ultrasound using piezoelectric transducers;

(h) describe scanning with Ultrasound for diagnosis including A-scans and B-scans (use of real time B-scans is not required) incorporating examples and applications;

(i) understand the significance of acoustic impedance, defined by $Z = c\rho$ for the reflection and transmission of sound waves at tissue boundaries, including appreciating the need for a coupling medium;

(j) understand the use of the Doppler equation $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ to study blood flow using an ultrasound probe.

(k) understand the principles of magnetic resonance with reference to precession of nuclei, resonance and relaxation time.

(l) describe the use of the MRI in obtaining diagnostic information about internal structures.

(m) discuss the advantages and disadvantages of ultra sound imaging, X-ray imaging and MRI in examining internal structures;

(n) understand the structure of the heart as a double pump

(o) describe methods of detecting electrical signals at the skin surface.

(p) describe the basic method of operation of an ECG machine, and explain the characteristic waveform by considering the heart's response to a potential originating at the sino-atrial node;

(q) describe the effects of α, β, and γ radiation on living matter.

(r) define and use the Gray (Gy) as the unit of absorbed dose and the sievert (Sv) as the unit of dose equivalent

(s) describe uses of radionuclides as tracers to image body parts with particular reference to I-123 and I-131.

(t) describe the use of the gamma camera including the principles of the collimator, scintillation counter and photomultiplier.

(u) understand the principles of positron emission tomography (PET) scanning and its use in detecting tumours.

Option A2/E ENERGY MATTERS

This Option addresses energy in the real world. While the main emphasis is on the physics of energy producing and conserving processes, candidates should have an awareness of current energy issues (economic, environmental, humanitarian and political) together with an overview of key statistics and trends. A typical examination question might consist of a topical passage from which students will draw conclusions, extract data for calculations etc. Much of the underlying physics is straightforward and will have been treated earlier in the specification as indicated below:

PH1.3 Energy concepts
PH1.5 Resistance
PH2.1 Waves
PH2.3 Photons
PH2.5 Matter forces and the universe (a) to (d)
PH4.3 Thermal physics
PH5.5 Nuclear energy.

Content

- Renewable energy sources
- Energy storage
- Nuclear, fossil and other non-renewable energy sources
- Hazards and harmful consequences
- Mass transfer processes
- Energy transfer processes
- Work from heat

AMPLIFICATION OF CONTENT

Candidates should be able to:

(a) estimate hydroelectric, tidal and wind power from simple mechanical models;

(b) be aware of existing and intended projects: hydroelectric (e.g. Yangtze); tidal (e.g. La Rance, Severn); wind (e.g. London Array);

(c) understand the principle of energy storage in projects such as Ffestiniog and Dinorwig;

(d) interpret equations representing fission and fusion reactions, and calculate resulting energies from given mass data;

(e) understand the principles underlying breeding and enrichment in nuclear fission applications;

(f) show an understanding of the difficulties in producing sustained fusion power and be aware of current progress (JET) and prospects (ITER);

(g) recognise convection as mass movement of fluids and understand that energy losses by convection can be minimised by, for example, trapping gas in bubbles;

(h) understand and apply the thermal conduction equation in the form $\frac{\Delta Q}{\Delta t} = -AK\frac{\Delta \theta}{\Delta x}$ (derivation and recall not required);

(i) be aware of the origin and means of transmission of solar energy, and the form of the sun's power spectrum;

(j) recall and use the Stefan-Boltzman T^4 law and the Wien displacement law;

(k) understand what is meant by, and calculate, the Solar Constant from the sun's temperature and geometrical formulae in the maths datasheet;

(l) be aware of the problems in harnessing solar energy and the limitations of solar cells;

(m) recognise the environmental effects of carbon fuels and understand the basis of the greenhouse effect;

(n) understand the principles of fuel cell operation and appreciate the benefits of fuel cells particularly regarding greenhouse gas emission;

(o) understand the principles underlying the ideal heat engine, the Carnot cycle, refrigerators and heat pumps (including recent applications e.g. the Cardiff Senedd);

(p) state and explain the second law of thermodynamics (Kelvin form); understand how the second law places an upper limit on the efficiencies of heat engines, for example of the turbines in conventional and nuclear power stations.

PH6 Internal Assessment Unit – Experimental Physics

This unit gives candidates the opportunity of demonstrating their ability to carry out their own investigations and to analyse and evaluate secondary experimental data. The unit is entirely synoptic in character.

AMPLIFICATION OF CONTENT

Candidates should be able to:

- plan and carry out an investigation at a level appropriate to the A2 course;
- analyse and evaluate data from their own investigation and from secondary sources using graphical and mathematical techniques including those specific to the A2 course;
- combine uncertainties arising from various measurements and judge which uncertainties are the most significant in a procedure;

Task Details

Candidates are required to undertake individually, under controlled conditions, two tasks: Task A and Task B. The tasks are devised by the WJEC, undertaken under controlled conditions and the outcomes assessed by the centre using marking schemes provided by the WJEC.

Task A: Data Analysis

This is a 45 minute task, carrying 25 marks. Candidates are provided with a set of experimental data on a topic drawn from the A level specification. They are given details of how the data were obtained. They will be expected to:

- analyse the data graphically and algebraically in order to establish a relationship between the variables and/or to derive a significant quantity – the graphical and analytic techniques may involve log-log or semi-log plots and the use of powers (positive or negative);
- derive an uncertainty from the graphical and/or algebraic analysis and express the solution in SI units to a precision commensurate with the uncertainty;
- make appropriate comments upon the analysis.

Task B: Investigation

This is a 75 minute task, carrying 25 marks. Candidates are provided with a set of apparatus and an experimental problem. They will be expected to:

- plan the safe use of some or all of the apparatus to investigate the problem (15 minutes);
- carry out their planned investigation, including analysing their data, drawing conclusions and evaluating both the data and the experimental techniques (1 hour).

In order to make the task discriminating and also to allow all candidates to make progress, provision is made for the supervisor to provide extra information where necessary. The provision of such information will result in marking penalties.

Both tasks will be carried out in the second half of the spring term. The details for the timing of the tasks and the receipt of the appropriate information will be given in the WJEC booklet *Manual of Internal Assessment* which is produced annually.

The candidates' work is marked by the supervisor. The results are be forwarded to the WJEC and the candidates' work presented for moderation in line with the procedures of the WJEC.

5 SCHEME OF ASSESSMENT

AS and A level qualifications are available to candidates following this specification.

Advanced Subsidiary

The AS is the first half of an A level course. It will contribute 50% of the total A level marks. Candidates must complete the following **three units** in order to gain an AS qualification.

		Weighting Within AS	Weighting Within A level
PH1	Motion, Energy & Charge	40%	20%
PH2	Waves & Particles	40%	20%
PH3	Practical Physics	20%	10%

PH1: Written Paper (1¼ hours)

The paper consists of approximately 7 questions with 80 raw marks. There are no optional questions and no sections.

PH2: Written Paper (1¼ hours)

The paper consists of approximately 7 questions with 80 raw marks. There are no optional questions and no sections.

PH3: Internal Assessment

The internal assessment consists of a 1 hour 30 minute set of practical physics tasks, set by the WJEC and taken under controlled conditions. It contains 3 short tasks lasting 45 minutes, which tests measurement techniques and uncertainties and one investigation lasting 45 minutes.

Advanced

The A level specification consists of two parts: Part 1 (AS) and Part 2 (A2).

Part 1 (AS) may be taken separately and added to A2 at a further examination sitting to achieve an A level qualification, or alternatively, both the AS and A2 may be taken at the same sitting.

Candidates must complete the AS units outlined above plus a further three units to complete A level Physics. The A2 units will contribute 50% of the total A level marks.

		Weighting within A2	Weighting within A level
PH4*	Oscillations & Fields	36%	18%
PH5*	Electromagnetism, Nuclei & Options	44%	22%
PH6*	Experimental Physics	20%	10%

*Includes synoptic assessment

PH4: Written Paper (1¼ hours)

The paper consists of approximately 7 questions with 80 raw marks. There are no optional questions and no sections. Some of the questions draw upon material initially encountered in the AS course and contribute towards the synoptic assessment.

PH5: Written Paper (1¾ hours)

The paper consists of 3 sections: A, B and C.

Section A (60 raw marks) consists of approximately 5 questions which cover the compulsory content of the unit, some of which draw upon material encountered earlier in the A-level course, contributing towards the synoptic assessment. There are no optional questions in this section.

Section B (20 raw marks) consists of a structured question relating to open source material on a topical issue, or piece of contemporary research, either of which is related to the content of the specification. The open-source material is distributed in January of the year in which the unit is to be taken. This section is synoptic in nature.

Section C (20 raw marks) consists of 5 questions, of which the candidate must answer 1. Each of which is set on the content of one of the Optional sections in this unit.

PH6: Internal Assessment

The internal assessment consists of two tasks: a Practical Test and a Data Analysis Task.

- **Practical Test**: This is a 1¼ -hour practical task, with 25 raw marks, which is set by the WJEC and taken under controlled conditions. It consists of a single experimental task with time for planning and analysis.

- **Data Analysis Task**: This is a 45-minute task, with 25 raw marks, set by the WJEC and taken under controlled conditions, consisting of one or more question testing the candidate's ability to analyse experimental data using A level graphical and mathematical techniques.
  Both parts of the internal assessment are marked by the supervisor, using marking schemes provided by the WJEC.

Synoptic Assessment

Synoptic assessment, testing candidates' understanding of the connections between the different elements of the subject and their holistic understanding of the subject, is a requirement of all A level specifications. In the context of Physics this means:

PH4: The work on vibrations, thermodynamics, electric and gravitation fields and potentials and the Doppler shift of spectral lines, builds upon concepts built up in the AS course. Questions examine these synoptic aspects.

PH5: All compulsory areas of this unit draw upon work in previous units: e.g. capacitors on electrical circuits (PH1) and electric fields (PH4); motion of charges in magnetic fields on circular motion (PH4); nuclear properties on particles (PH2). Questions are set which link these themes. The Case Study (section B) is synoptic in nature.

PH6: All aspects of the two parts of this internally-assessed unit are synoptic in nature.

Quality of Written Communication

Candidates will be required to demonstrate their competence in written communication in all assessment units where they are required to produce extended written material: PH2, PH5 and PH6. Mark schemes for these units include the following specific criteria for the assessment of written communication.

- legibility of text; accuracy of spelling, punctuation and grammar; clarity of meaning;
- selection of a form and style of writing appropriate to purpose and to complexity of subject matter;
- organisation of information clearly and coherently; use of specialist vocabulary where appropriate.

The front pages of all the external assessment papers include an emboldened statement informing candidates of the necessity for expressing themselves clearly using correct technical terms. The marking schemes covers include a statement of the requirement to take level of language into account and the detailed marking key indicates, using *(QWC),* places where the quality of the written communication will contribute to the assessment of performance.

Availability of Units

Unit	January	June
PH1	✓	✓
PH2	✓	✓
PH3		✓
PH4	✓	✓
PH5		✓
PH6		✓

Awarding, Reporting and Re-sitting

The overall grades for the GCE AS qualification will be recorded as a grade on a scale from A to E. The overall grades for the GCE A level qualification will be recorded on a grade scale from A* to E. Results not attaining the minimum standard for the award of a grade will be reported as U (Unclassified). Individual unit results and the overall subject award will be expressed as a uniform mark on a scale common to all GCE qualifications (see table below). The grade equivalence will be reported as a lower case letter ((a) to (e)) on results slips, but not on certificates:

	Max. UMS	A	B	C	D	E
PH1 & PH2 (weighting 20%)	120	96	84	72	60	48
PH3 & PH6 (weighting 10%)	60	48	42	36	30	24
PH4 (weighting 18%)	108	86	76	65	54	43
PH5 (weighting 22%)	132	106	92	79	66	53
AS Qualification	300	240	210	180	150	120
A Qualification	600	480	420	360	300	240

At A level, Grade A* will be awarded to candidates who have achieved a Grade A in the overall A level qualification and an A* on the aggregate of their A2 units.

Candidates may re-sit units prior to certification for the qualification, with the best of the results achieved contributing to the qualification. Individual unit results, prior to certification of the qualification have a shelf-life limited only by the shelf-life of the specification.

6 KEY SKILLS

Key Skills are integral to the study of AS/A level Physics and may be assessed through the course content and the related scheme of assessment as defined in the specification. The following key skills can be developed through this specification at level 3:

- Communication
- Application of Number
- Problem Solving
- Information and Communication Technology
- Improving Own Learning and Performance

Mapping of opportunities for the development of these skills against Key Skills evidence requirement is provided in 'Exemplification of Key Skills for Physics, available on the WJEC website.

7 PERFORMANCE DESCRIPTIONS

Introduction

Performance descriptions have been created for all GCE subjects. They describe the learning outcomes and levels of attainment likely to be demonstrated by a representative candidate performing at the A/B and E/U boundaries for AS and A2.

In practice most candidates will show uneven profiles across the attainments listed, with strengths in some areas compensating in the award process for weaknesses or omissions elsewhere. Performance descriptions illustrate expectations at the A/B and E/U boundaries of the AS and A2 as a whole; they have not been written at unit level.

Grade A/B and E/U boundaries should be set using professional judgement. The judgement should reflect the quality of candidates' work, informed by the available technical and statistical evidence. Performance descriptions are designed to assist examiners in exercising their professional judgement. They should be interpreted and applied in the context of individual specifications and their associated units. However, performance descriptions are not designed to define the content of specifications and units.

The requirement for all AS and A level specifications to assess candidates' quality of written communication will be met through one or more of the assessment objectives.

The performance descriptions have been produced by the regulatory authorities in collaboration with the awarding bodies.

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.
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.

8 INTERNAL ASSESSMENT GUIDELINES

The schemes of internal assessment are designed to encourage candidates to develop a wide range of experimental techniques and analytical methods. They should be engaged in practical work in all aspects of the specification, which lend themselves to this in a school/college laboratory. Secondary sources, such as simulations and published data should also be used to give candidates experience of the analysis of data which they could not obtain for themselves. By experience in carrying out practical work, they should develop an understanding of the uncertainties inherent both in direct measurements and in the quantities which they derive from measurement. The aim of both internally-assessed units is to test whether candidates can think as physicists in the practical situation.

PH3 Practical Physics

The theory unit PH1 contains many possibilities for undertaking practical work. Experiments in the following will be expected:

Density in the context of regular solids, moments, accelerated motion, elastic potential energy, e.m.f. /potential difference / internal resistance, resistivity, current-voltage characteristics, oscillations.

Unit PH2 contains fewer possibilities for practical work, though the following will be expected:

Interference and diffraction of water waves, microwaves and light, refraction and total internal reflection of light.

Experiments are possible, which combine the content of PH1 and PH2 such as LED spectra and current-voltage characteristics.

Both the short-duration tasks [section A] and the investigation [section B] may include work on the determination of uncertainties. Guidance notes are issued on the depth of treatment required but as a brief guide, candidates will be expected to:

- estimate the uncertainty in a mean value arising from a set of readings;
- estimate the uncertainty in the determination of a quantity arising from limitations in the measuring instrument or technique;
- express uncertainty either in absolute terms or fractional/percentage terms [the precision];
- combine uncertainties in quantities to produce an estimate of the uncertainty in a derived quantity;
- express the value of a quantity together with its uncertainty and unit, e.g. $35{\cdot}6 \pm 0{\cdot}3$ cm

PH6 Experimental Physics

The theory units PH4 and PH5 contain many aspects which candidates can investigate directly – oscillations and damping, thermodynamics, electric fields and capacitors, magnetic fields and inductors, basic a.c. theory, nuclear decay. Many of these investigational areas require a greater analytical ability than the AS content. There are also parts of the A2 specification which draw on investigations inaccessible to the school laboratory and require a mainly theoretical approach or which rely on data from secondary sources – electric and gravitations fields, orbits, dark matter and extrasolar planets and nuclear binding energy. All these areas should be used as sources of material for investigational work, either through direct experimentation or through the analysis of data derived from the experimental work of others. These topics provide a wealth of data to stimulate the interest of candidate and develop their analytical abilities.

There are two tasks in the PH6 unit:

PH6A Data Analysis task
PH6B Experimental Task

The PH6A data analysis requires candidates to interact with experimentally derived data, which may or may not be in a context familiar to candidates from their own laboratory experience. The data are from a context related to the specification and the candidates are informed about the salient features of how the data have been acquired. The analysis is generally graphical and algebraic and the task is designed to provide stretch and challenge – the candidates may be expected to use log-log or semi-log graphs, power or trigonometrical functions as appropriate.

The PH6B Experimental Task provides the candidates with a practical problem, which they are expected to solve by planning and performing an investigation.

In performing these tasks, candidates are expected to think like physicists. The experimental and data analysis tasks may be from simple contexts but candidates need to display a mature awareness of uncertainties and their combination, which is more developed than at AS level – this includes using uncertainties derived from graphical work and involving higher mathematical functions in line with the mathematical requirements in section 4 of this specification.