

CCEA GCE Specification in Physics

For first teaching from September 2008

For first award of AS Level in Summer 2009

For first award of A Level in Summer 2010

Subject Code: 1210

physics

Foreword

This booklet contains CCEA's Advanced Subsidiary (AS) and Advanced GCE Physics specification for first teaching from September 2008.

The AS is the first part of the full advanced GCE course and will be assessed at a standard appropriate for candidates who have completed the first half of the full Advanced GCE course.

The full Advanced GCE comprises the AS and the second half of the Advanced GCE course referred to as A2. However, the AS can be taken as a "stand-alone" qualification without progression to A2.

The A2 will be assessed at a standard appropriate for candidates who have completed a full advanced GCE course and will include synoptic assessment and an element of stretch and challenge.

The Advanced GCE award will be based on aggregation of the marks from the AS (50%) and the A2 (50%).

An A* will be awarded to the candidates who attain an overall grade A in the qualification and an aggregate of at least 90% of the uniform marks across the A2 units.

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1 Introduction

This specification sets out the content and assessment details for our Advanced Subsidiary (AS) and Advanced Level (A Level) courses in Physics. This specification is for first teaching from September 2008. You can view and download the latest version of this specification from our website: www.ccea.org.uk.

Students can take the AS course as a final qualification or as the first half of the A Level qualification. Students who wish to obtain a full A Level qualification must also complete the second half of the course, referred to as A2. We will make the first AS awards for this specification in 2009 and the first A Level awards in 2010.

The specification builds on the broad objectives of the revised Northern Ireland Curriculum. It is also relevant to key curriculum concerns in England and Wales.

The specification promotes continuity, coherence and progression within the study of physics. The A Level award provides a basis for the further study, at tertiary level, of physics, electronics and engineering. For those progressing directly into employment, an AS or A Level award is relevant not only in the fields of science, engineering and medicine, but also to areas of commerce and public service that value problem-solving and practical skills. The specification helps to provide an understanding of the impact of technological developments on the environment. It also contributes towards an understanding of ethical and cultural issues, thus adding to a full and rounded education.

1.1 Aims

The specification aims to encourage students to:

- develop their interest in and enthusiasm for Physics, including developing an interest in further study and careers in the subject;
- appreciate how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society;
- develop and demonstrate a deeper appreciation of the skills, knowledge and understanding of how science works; and
- develop essential knowledge and understanding of different areas of the subject and how they relate to each other.

1.2 Key features

The specification's key features are as follows:

- The total time spent in written examinations (6 hours) is 11 percent less than the 2000 specification.
- More testing and less structured questions stretch and challenge students at A2.
- The specification provides a firm grounding for those wishing to enter higher education courses in physics, related subjects, and in engineering and electronics. In most of these courses an A Level award is a prerequisite for entry.
- The *Notes for Guidance*, downloadable from our website at www.ccea.org.uk, support teachers and students.

1.3 Prior attainment

The AS specification builds on the knowledge, understanding and skills developed within GCSE Science: Double Award, GCSE Science: Physics or other equivalent courses. Knowledge, understanding and skills developed within GCSE Mathematics are also relevant. The A2 specification builds on the knowledge, understanding and skills developed within the AS course.

1.4 Prohibited combinations

There is a small amount of overlap between this specification and GCE specifications in Chemistry, Mathematics, and GNVQ Advanced Science. However, the overlap is not enough to restrict the combination of any of these subjects with GCE Physics.

In any one series of examinations, a student may not take examinations on this specification with examinations in any other GCE Physics specification.

The classification code for this specification is 1210.

2 Specification at a Glance

The table below summarises the structures of the AS and A Level courses:

Unit	Assessment Format	Duration	Weightings	Availability
AS 1 Forces, Energy and Electricity	A written examination, consisting of a number of compulsory short answer questions, some of which will afford the opportunity for extended writing. Externally assessed Maximum raw marks = 75	1 hour 30 minutes	37% of AS 18.5% of A Level	January and Summer
AS 2 Waves, Photons and Medical Physics	A written examination, consisting of a number of compulsory short answer questions, some of which will afford the opportunity for extended writing. Externally assessed Maximum raw marks = 75	1 hour 30 minutes	37% of AS 18.5% of A Level	January and Summer
AS 3 Practical Techniques	A test of practical skills, consisting of 4 short experimental tests (20 marks) and 1 question requiring the analysis of experimental results (20 marks). Internally assessed Maximum raw marks = 40	1 hour 30 minutes	26% of AS 13% of A Level	Summer only
A2 1 Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics	A written examination, consisting of a number of compulsory short answer questions, some of which will afford the opportunity for extended writing. Elements of synoptic assessment will be embedded within the questions, and in a data analysis question. Externally assessed Maximum raw marks = 90	1 hour 30 minutes	37% of A2 18.5% of A Level	January and Summer
A2 2 Fields and their Applications	A written examination, consisting of a number of compulsory short answer questions, some of which will afford the opportunity for extended writing. Elements of synoptic assessment will be embedded within the questions, and in a longer question drawing together different strands of the specification. Externally assessed Maximum raw marks = 90	1 hour 30 minutes	37% of A2 18.5% of A Level	Summer only
A2 3 Practical Techniques	A test of practical skills, consisting of 2 experimental tests (40 marks) and 1 question on planning and design (20 marks). Synoptic assessment will be assessed through the planning and design question. Internally assessed Maximum raw marks = 60	1 hour 30 minutes	26% of A2 13% of A Level	Summer only

3 Subject Content

The AS course is divided into three units: AS 1, AS 2 and AS 3. Students following the A Level course must study three further units: A2 1, A2 2 and A2 3. The content of each of these units is set out below.

3.1 Unit AS 1: Forces, Energy and Electricity

This unit teaches students to deal with physical quantities and scalars and vectors, which are required in all branches of the subject. Students will build on their knowledge and understanding of Newtonian mechanics and electricity to explain many economic and social applications of physics.

Content	Learning Outcomes
1.1 Physical quantities	<p>Students should be able to:</p> <p>1.1.1 describe all physical quantities as consisting of a numerical magnitude and unit;</p> <p>1.1.2 state the base units of mass, length, time, current, temperature, amount of substance and be able to express other quantities in terms of these units;</p>
1.2 Scalars and vectors	<p>1.2.1 distinguish between and give examples of scalar and vector quantities;</p> <p>1.2.2 calculate the resultant of two coplanar vectors by calculation or scale drawing, with calculations limited to two perpendicular vectors;</p> <p>1.2.3 resolve a vector into two perpendicular components;</p>
1.3 Linear motion	<p>1.3.1 define displacement, speed, velocity and acceleration;</p> <p>1.3.2 recall and use the equations of motion for uniform acceleration;</p> <p>1.3.3 describe an experiment to measure acceleration of free fall, g; and</p> <p>1.3.4 interpret velocity-time and displacement-time graphs for motion with uniform and non-uniform acceleration.</p>

Content	Learning Outcomes
1.4 Dynamics	<p>Students should be able to:</p> <p>1.4.1 describe projectile motion;</p> <p>1.4.2 explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction;</p> <p>1.4.3 apply the equations of motion to projectile motion, excluding air resistance;</p>
1.5 Newton's laws of motion	<p>1.5.1 state Newton's laws of motion;</p> <p>1.5.2 apply the laws to simple situations;</p> <p>1.5.3 recall and use $F = ma$ where mass is constant;</p> <p>1.5.4 understand that friction is a force that opposes motion;</p>
1.6 Principle of moments	<p>1.6.1 define the moment of a force about a point;</p> <p>1.6.2 state the principle of moments;</p> <p>1.6.3 use the principle of moments to solve simple problems;</p>
1.7 Work done, potential and kinetic energy	<p>1.7.1 define work done, potential energy, kinetic energy, efficiency and power;</p> <p>1.7.2 recognise that when work is done energy is transferred from one form to another;</p> <p>1.7.3 calculate the work done for constant forces, including force not along the line of motion;</p> <p>1.7.4 recall and use the equations $\Delta p.e. = mg\Delta h$ and $k.e. = \frac{1}{2}mv^2$;</p> <p>1.7.5 state the principle of conservation of energy and use it to calculate exchanges between gravitational potential energy and kinetic energy;</p> <p>1.7.6 recall and use: $P = \frac{\text{work done}}{\text{time taken}}$, $P = Fv$, $\text{efficiency} = \frac{\text{useful energy (power) output}}{\text{energy (power) input}};$</p>

Content	Learning Outcomes
1.8 Deformation of solids	Students should be able to: <ul style="list-style-type: none"> 1.8.1 state Hooke's law and use $f = kx$ to solve simple problems; 1.8.2 understand the terms elastic and plastic deformation and elastic limit; 1.8.3 distinguish between limit of proportionality and elastic limit; 1.8.4 define the terms stress, strain, ultimate tensile stress; 1.8.5 define the Young modulus; 1.8.6 perform and describe an experiment to determine the Young modulus;
1.9 Electric current and charge	<ul style="list-style-type: none"> 1.9.1 describe current as the rate of flow of charge; 1.9.2 recall and use the equation $I = \frac{\Delta Q}{\Delta t}$;
1.10 Potential difference and electromotive force	<ul style="list-style-type: none"> 1.10.1 recall and use the equations $V = \frac{W}{q}$, $V = \frac{P}{I}$; 1.10.2 define the volt; 1.10.3 define electromotive force; 1.10.4 distinguish between electromotive force and potential difference;
1.11 Resistance, resistivity	<ul style="list-style-type: none"> 1.11.1 describe the relationship between current, voltage and resistance in series and parallel circuits; 1.11.2 state Ohm's law; 1.11.3 recall and use the equations $R = \frac{V}{I}$ and $P = I^2R$; 1.11.4 define resistivity; 1.11.5 recall and use the equation $R = \frac{\rho l}{A}$; 1.11.6 perform and describe an experiment to measure resistivity;

Content	Learning Outcomes
1.11 Resistance, resistivity (cont.)	<p>Students should be able to:</p> <p>1.11.7 demonstrate knowledge and simple understanding of superconductivity;</p> <p>1.11.8 distinguish between ohmic and non-ohmic behaviour;</p> <p>1.11.9 perform experiments to determine the current – voltage characteristics for a metallic conductor and a negative temperature coefficient (ntc) thermistor;</p> <p>1.11.10 sketch and explain the variation with temperature of the resistance of a pure metallic conductor and a negative temperature coefficient (ntc) thermistor;</p> <p>1.11.11 appreciate the existence of internal resistance of sources and understand the simple consequences of internal resistance for external circuits;</p> <p>1.11.12 use the equation $V = E - Ir$;</p> <p>1.11.13 perform and describe an experiment to measure internal resistance;</p>
1.12 Direct current circuits	<p>1.12.1 use conservation of charge and energy in simple d.c. circuits;</p> <p>1.12.2 recall and use the equations for resistors in series and in parallel;</p> <p>1.12.3 understand the use of a potential divider as a source of variable p.d.; and</p> <p>1.12.4 use $V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$.</p>

3.2 Unit AS 2: Waves, Photons and Medical Physics

The ideas about waves in this topic provide vital links to the study of light and sound. The section on photons introduces the quantum theory and the concept of wave-particle duality, two of the most revolutionary advances in physics. Work on medical physics introduces an application with opportunities for discussion on ethical, moral and environmental issues.

Content	Learning Outcomes
2.1 Waves	Students should be able to: <ul style="list-style-type: none"> 2.1.1 demonstrate a knowledge and understanding of the terms ‘transverse wave’ and ‘longitudinal wave’; 2.1.2 be able to categorise waves as transverse or longitudinal; 2.1.3 understand polarisation as a phenomenon associated with transverse waves; 2.1.4 recall and use $v = f\lambda$; 2.1.5 recall radio waves, microwaves, infrared, visible, ultraviolet, x-rays and gamma-rays as regions of the electromagnetic spectrum; 2.1.6 state typical wavelengths for each of these regions; 2.1.7 analyse graphs to obtain data on amplitude, period, frequency, wavelength and phase;
2.2 Refraction	<ul style="list-style-type: none"> 2.2.1 describe an experiment to verify Snell’s law; 2.2.2 recall and use the formula $\frac{\sin i}{\sin r} = n$; 2.2.3 perform and describe an experiment to measure refractive index; 2.2.4 demonstrate knowledge and understanding of total internal reflection; and 2.2.5 recall and use the formula $\sin C = \frac{1}{n}$.

Content	Learning Outcomes
2.3 Lenses	<p>Students should be able to:</p> <p>2.3.1 draw ray diagrams for converging and diverging lenses;</p> <p>2.3.2 use the equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ for converging lenses;</p> <p>2.3.3 perform and describe an experiment to measure the focal length of a converging lens;</p> <p>2.3.4 recall and use the equation $m = \frac{v}{u}$;</p> <p>2.3.5 describe the use of lenses to correct myopia and hypermetropia;</p> <p>2.3.6 perform calculations on the correction of long sight;</p> <p>2.3.7 perform calculations involving the lens power of converging lenses;</p>
2.4 Superposition and interference	<p>2.4.1 illustrate the concept of superposition by the graphical addition of two sinusoidal waves;</p> <p>2.4.2 demonstrate knowledge and understanding of the graphical representation of standing waves in stretched strings and air in pipes closed at one end;</p> <p>2.4.3 identify node and anti-node positions;</p> <p>2.4.4 understand the significance of coherence as applied to wave sources;</p> <p>2.4.5 state the conditions for observable interference;</p> <p>2.4.6 understand the significance of path difference and phase difference in explaining interference effects;</p> <p>2.4.7 describe Young's slits interference experiment with monochromatic light; and</p> <p>2.4.8 use the formula $\lambda = \frac{ay}{d}$ applied to Young's slits experiment.</p>

Content	Learning Outcomes
2.5 Diffraction	<p>Students should be able to:</p> <p>2.5.1 describe and explain simple diffraction phenomena; and</p> <p>2.5.2 state qualitatively, and draw diagrams to illustrate, the effect of aperture size on diffraction;</p>
2.6 Sound	<p>2.6.1 determine the frequency of a pure note using a cathode ray oscilloscope;</p> <p>2.6.2 perform and describe an experiment to measure the speed of sound in air using a resonance tube (end correction is not required);</p> <p>2.6.3 use the formula Intensity level/dB = $10 \lg_{10} \frac{I}{I_0}$;</p> <p>2.6.4 interpret, qualitatively, graphs of frequency and intensity response for the ear;</p>
2.7 Imaging techniques	<p>2.7.1 describe the flexible endoscope in terms of structure, technique and applications;</p> <p>2.7.2 describe ultrasonic A-scans and B-scans in terms of physical principles, basic equipment, technique and applications;</p> <p>2.7.3 describe CT scans in terms of physical principles, basic equipment, technique and applications;</p> <p>2.7.4 describe MRI scans in terms of physical principles, basic equipment, technique and applications;</p>
2.8 Photon model	<p>2.8.1 recall and use the formula $E = hf$;</p> <p>2.8.2 use the photon model to explain the photoelectric effect qualitatively using the terms 'photon energy' and 'work function';</p>
2.9 Quantum physics	<p>2.9.1 understand that electrons exist in energy levels in atoms;</p> <p>2.9.2 recall and use the formula $hf = E_1 - E_2$; and</p> <p>2.9.3 provide a simple explanation of laser action.</p>

Content	Learning Outcomes
2.10 Wave-particle duality	Students should be able to: 2.10.1 categorise electromagnetic wave phenomena as being explained by the wave model, the photon model or both; 2.10.2 describe electron diffraction; and 2.10.3 use the de Broglie formula $\lambda = \frac{h}{p}$.

3.3 Unit AS 3: Practical Techniques

In this unit students will acquire essential practical techniques, including planning, implementing, analysis, evaluation and communication. Note that the list below relates to practical techniques and skills rather than to details of content topics, as in the rest of this specification.

Skill	Learning Outcomes
3.1 Planning	Students should be able to: <ul style="list-style-type: none"> <li data-bbox="592 600 1385 674">3.1.1 identify and define a practical problem using available information and their knowledge of physics; <li data-bbox="592 712 1257 815">3.1.2 choose effective and safe procedures after consideration of appropriate qualitative and quantitative methods; <li data-bbox="592 853 1385 1106">3.1.3 select suitable apparatus for the measurement of mass (spring and top-pan balances), length (rule, vernier scale, micrometer, calipers), liquid volume (graduated cylinder), angle (protractor), time (clock, stopwatch), temperature (thermometer), electric current (ammeter), potential difference (voltmeter), and consider the use of ICT in data capture;
3.2 Implementing	<ul style="list-style-type: none"> <li data-bbox="592 1126 1337 1200">3.2.1 assemble and use apparatus correctly, skilfully and effectively with full regard for safety; <li data-bbox="592 1238 1385 1375">3.2.2 make and record sufficient relevant, reliable and valid observations and measurements to the appropriate degree of precision and accuracy, using data loggers where suitable; <li data-bbox="592 1413 1299 1487">3.2.3 show familiarity with both analogue and digital displays; and <li data-bbox="592 1525 1394 1662">3.2.4 modify procedures in response to serious sources of systematic and random error in order to generate results which are as accurate and reliable as allowed by the apparatus.

Skill	Learning Outcomes
3.3 Analysis	Students should be able to: <ul style="list-style-type: none"> <li data-bbox="587 376 1294 450">3.3.1 present work appropriately in written, tabular, graphical or other forms; <li data-bbox="587 488 1358 591">3.3.2 analyse, interpret and explain their own and others' experimental and investigative activities, using ICT and other methods; <li data-bbox="587 629 1342 732">3.3.3 show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data; <li data-bbox="587 770 1273 844">3.3.4 draw valid conclusions by the application of knowledge and understanding of Physics;
3.4 Evaluation	<ul style="list-style-type: none"> <li data-bbox="587 864 1362 938">3.4.1 assess the reliability of data, results and conclusions drawn from the data; <li data-bbox="587 976 1369 1079">3.4.2 evaluate the methodology used in and the impact of the experimental activity, and recognise their limitations; and
3.5 Communication	<ul style="list-style-type: none"> <li data-bbox="587 1099 1342 1202">3.5.1 communicate observations, measurements, results and conclusions in an appropriate and effective manner.

3.4 Unit A2 1: Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

The work on momentum, circular motion and oscillations extends the mechanics foundation included in Assessment Unit AS 1. Thermal physics introduces an example of a simple model that can be extended to explain the properties of gases. The section on atomic and nuclear physics has important social and economic applications and leads to an introduction to particle physics.

Content	Learning Outcomes
4.1 Linear momentum	<p>Students should be able to:</p> <p>4.1.1 define momentum;</p> <p>4.1.2 calculate momentum;</p> <p>4.1.3 demonstrate an appreciation of the conservation of linear momentum;</p> <p>4.1.4 perform calculations involving collisions in one dimension;</p> <p>4.1.5 use the terms ‘elastic’ and ‘inelastic’ to describe collisions;</p>
4.2 Thermal physics	<p>4.2.1 describe simple experiments on the behaviour of gases to show that $pV = \text{constant}$ for a fixed mass of gas at constant temperature, and $\frac{p}{T} = \text{constant}$ for a fixed mass of gas at constant volume, leading to the equation $\frac{pV}{T} = \text{constant}$;</p> <p>4.2.2 recall and use the ideal gas equation $pV = nRT$;</p> <p>4.2.3 recall and use the ideal gas equation in the form $pV = NkT$;</p> <p>4.2.4 use the equation $pV = \frac{1}{3}Nm\langle v^2 \rangle$;</p> <p>4.2.5 demonstrate an understanding of the concept of absolute zero of temperature;</p> <p>4.2.6 demonstrate an understanding of the concept of internal energy as the random distribution of potential and kinetic energy among molecules;</p>

Content	Learning Outcomes
4.2 Thermal physics (cont.)	<p>Students should be able to:</p> <p>4.2.7 use the equations for average molecular kinetic energy $= \frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$;</p> <p>4.2.8 perform and describe an electrical method for determination of specific heat capacity;</p> <p>4.2.9 use the equation $Q = mc\Delta\theta$;</p>
4.3 Uniform circular motion	<p>4.3.1 demonstrate an understanding of the concept of angular velocity;</p> <p>4.3.2 recall and use the equation $v = r\omega$;</p> <p>4.3.3 apply the relationship $F = ma = \frac{mv^2}{r}$ to motion in a circle at constant speed;</p>
4.4 Simple harmonic motion	<p>4.4.1 define simple harmonic motion using the equation $a = -\omega^2 x$ where $\omega = 2\pi f$;</p> <p>4.4.2 perform calculations using $x = A \cos \omega t$;</p> <p>4.4.3 demonstrate an understanding of s.h.m. graphs to include measuring velocity from the gradient of a displacement time graph;</p> <p>4.4.4 know and be able to use the terms free vibrations, forced vibrations, resonance and damping in this context;</p> <p>4.4.5 understand the concepts of light damping, over-damping and critical damping;</p> <p>4.4.6 describe mechanical examples of resonance and damping;</p>
4.5 The nucleus	<p>4.5.1 be able to describe evidence for the existence of atomic nuclei, to include alpha-particle scattering;</p> <p>4.5.2 know and interpret the variation of nuclear radius with nucleon number; and</p> <p>4.5.3 use the equation $r = r_0 A^{\frac{1}{3}}$ to estimate the density of nuclear matter.</p>

Content	Learning Outcomes
4.6 Nuclear decay	<p>Students should be able to:</p> <p>4.6.1 understand how the nature of alpha-particles, beta-particles and gamma-radiation determines their penetration and range;</p> <p>4.6.2 calculate changes to nucleon number and proton number as a result of emissions;</p> <p>4.6.3 appreciate the random nature of radioactive decay;</p> <p>4.6.4 model with constant probability of decay, leading to exponential decay;</p> <p>4.6.5 use the equations $A = \lambda N$ and $A = A_0 e^{-\lambda t}$, where A is the activity;</p> <p>4.6.6 define half-life;</p> <p>4.6.7 use $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$;</p> <p>4.6.8 describe an experiment to measure half-life;</p>
4.7 Nuclear energy	<p>4.7.1 appreciate the equivalence of mass and energy;</p> <p>4.7.2 recall the equation $E = mc^2$ and understand that it applies to all energy changes;</p> <p>4.7.3 use $E = \Delta mc^2$ in nuclear calculations;</p> <p>4.7.4 know how the binding energy per nucleon varies with mass number;</p> <p>4.7.5 describe the principles of fission and fusion with reference to the binding energy per nucleon curve; and</p>
4.8 Nuclear fission	<p>4.8.1 describe a fission reactor in terms of chain reaction, critical size, moderators, control rods, cooling system and reactor shielding.</p>

Content	Learning Outcomes
4.9 Nuclear fusion	Students should be able to: 4.9.1 understand the conditions required for nuclear fusion; 4.9.2 estimate the temperature required for fusion; 4.9.3 describe the following methods of plasma confinement: gravitational, inertial and magnetic; 4.9.4 appreciate the difficulties of achieving fusion on a practical terrestrial scale; 4.9.5 describe the JET fusion reactor; and 4.9.6 state the D-T reaction and appreciate why this is most suitable for terrestrial fusion.

3.5 Unit A2 2: Fields and their Applications

This is a fundamental area of physics which has numerous applications in everyday life. Students will study action-at-a-distance forces that arise between bodies that are separated from one another.

Content	Learning Outcomes
5.1 Force fields	Students should be able to: 5.1.1 explain the concept of a field of force;
5.2 Gravitational fields	5.2.1 define gravitational field strength; 5.2.2 recall and use the equation $g = \frac{F}{m}$; 5.2.3 state Newton's law of universal gravitation; 5.2.4 recall and use the equation for the gravitational force between point masses, $F = G \frac{m_1 m_2}{r^2}$; 5.2.5 recall and apply the equation for gravitational field strength, $g = \frac{Gm}{r^2}$, and use this equation to calculate the Earth's mass; 5.2.6 apply knowledge of circular motion to planetary and satellite motion; 5.2.7 show that the mathematical form of Kepler's third law (T^2 proportional to r^3) is consistent with the law of universal gravitation; 5.2.8 state the period of a geostationary satellite;
5.3 Electric fields	5.3.1 define electric field strength; 5.3.2 recall and use the equation $E = \frac{F}{q}$; 5.3.3 state Coulomb's law for the force between point charges; 5.3.4 recall and use the equation for the force between two point charges, $F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2} = \frac{kq_1 q_2}{r^2}$, where $k = \frac{1}{4\pi\epsilon_0}$;

Content	Learning Outcomes
5.3 Electric fields (cont.)	Students should be able to: <ul style="list-style-type: none"> <li data-bbox="568 376 1283 443">5.3.5 state that ϵ_0 is the permittivity of a vacuum and determine its SI base units; <li data-bbox="568 483 1394 600">5.3.6 recall and use the equation for the electric field strength due to a point charge, $E = \frac{q}{4\pi\epsilon_0 r^2} = \frac{kq}{r^2}$; <li data-bbox="568 645 1347 792">5.3.7 understand that for a uniform electric field, the field strength is constant, and recall and use the equation $E = \frac{V}{d}$; <li data-bbox="568 837 1347 904">5.3.8 recognise similarities and differences in gravitational and electric fields;
5.4 Capacitors	<ul style="list-style-type: none"> <li data-bbox="568 949 932 981">5.4.1 define capacitance; <li data-bbox="568 1025 1139 1093">5.4.2 recall and use the equation $C = \frac{Q}{V}$; <li data-bbox="568 1137 1203 1169">5.4.3 define the unit of capacitance, the farad; <li data-bbox="568 1214 1347 1281">5.4.4 recall and use $\frac{1}{2} QV$ for calculating the energy of a charged capacitor; <li data-bbox="568 1326 1347 1393">5.4.5 use the equations for the equivalent capacitance for capacitors in series and in parallel; <li data-bbox="568 1438 1378 1505">5.4.6 perform and describe experiments to demonstrate the charge and discharge of a capacitor; <li data-bbox="568 1550 1315 1581">5.4.7 explain exponential decay using discharge curves; <li data-bbox="568 1626 1331 1657">5.4.8 define time constant and use the equation $\tau = CR$; <li data-bbox="568 1702 1362 1769">5.4.9 perform and describe an experiment to determine the time constant for R–C circuits; and <li data-bbox="568 1814 1378 1881">5.4.10 apply knowledge and understanding of time constants and stored energy to electronic flash guns.

Content	Learning Outcomes
5.5 Magnetic fields	<p>Students should be able to:</p> <p>5.5.1 explain the concept of a magnetic field;</p> <p>5.5.2 understand that there is a force on a current-carrying conductor in a perpendicular magnetic field and be able to predict the direction of the force;</p> <p>5.5.3 define magnetic flux density using the equation $F = BIl$;</p> <p>5.5.4 define the unit of magnetic flux density, the tesla;</p> <p>5.5.5 understand the concepts of magnetic flux and magnetic flux linkage;</p> <p>5.5.6 recall and use the equations for magnetic flux, $\phi = BA$, and flux linkage, $N\phi$;</p> <p>5.5.7 define the unit of magnetic flux, the weber;</p> <p>5.5.8 state, use and demonstrate experimentally Faraday's and Lenz's laws of electromagnetic induction;</p> <p>5.5.9 recall and calculate induced e.m.f. as rate of change of flux linkage with time;</p> <p>5.5.10 describe how a transformer works;</p> <p>5.5.11 recall and use the equation $\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$ for transformers;</p> <p>5.5.12 explain power losses in transformers and the advantages of high voltage transmission of electricity;</p>
5.6 Deflection of charged particles in electric and magnetic fields	<p>5.6.1 understand that a moving charge in a uniform electric field experiences a force;</p> <p>5.6.2 recall and use the equation $F = Eq$ to calculate the magnitude of the force on a charged particle in an electric field, and determine the direction of the force;</p> <p>5.6.3 understand that a moving charge in a uniform, perpendicular magnetic field experiences a force;</p>

Content	Learning Outcomes
5.6 Deflection of charged particles in electric and magnetic fields (cont.)	<p>Students should be able to:</p> <p>5.6.4 recall and use the equation $F = Bqv$ to calculate the magnitude of the force, and determine the direction of the force;</p> <p>5.6.5 outline the structure of the cathode ray oscilloscope;</p> <p>5.6.6 use, and explain how, the cathode ray oscilloscope can be used as a measuring instrument for voltage;</p>
5.7 Particle accelerators	<p>5.7.1 describe the basic principles of operation of a linear accelerator, cyclotron and synchrotron;</p> <p>5.7.2 compare and contrast the three types of accelerator;</p> <p>5.7.3 understand the concept of antimatter and that it can be produced and observed using high energy particle accelerators;</p> <p>5.7.4 describe the process of annihilation in terms of photon emission and conservation of energy and momentum;</p>
5.8 Fundamental particles	<p>5.8.1 explain the concept of a fundamental particle;</p> <p>5.8.2 identify the four fundamental forces and their associated exchange particles;</p> <p>5.8.3 classify particles as gauge bosons, leptons and hadrons (mesons and baryons);</p> <p>5.8.4 state examples of each class of particle;</p> <p>5.8.5 describe the structure of hadrons in terms of quarks;</p> <p>5.8.6 understand the concept of conservation of charge, lepton number and baryon number; and</p> <p>5.8.7 describe β-decay in terms of the basic quark model.</p>

3.6 Unit A2 3: Practical Techniques

In this unit, students will build on the essential practical techniques that they acquired in Unit AS 3. These include planning, implementing, analysis, evaluation and communication. Note that the list below relates to practical techniques and skills rather than to details of content topics, as in the rest of this specification. Except for details of apparatus with which familiarity should be developed, the learning outcomes are identical with those in Unit AS 3. The experiments carried out in A2 3 should be designed to extend the skills, techniques and knowledge already developed in AS work.

Skill	Learning Outcomes
6.1 Planning	Students should be able to: <ul style="list-style-type: none"> 6.1.1 identify and define a practical problem using available information and their knowledge of Physics; 6.1.2 choose effective and safe procedures after consideration of appropriate qualitative and quantitative methods; 6.1.3 select suitable apparatus for the measurement of mass (spring and top-pan balances), length (rule, vernier scale, micrometer, calipers), liquid volume (graduated cylinder), angle (protractor), time (clock, stopwatch, calibrated timebase of cathode ray oscilloscope), temperature (thermometer), electric current (ammeter), potential difference (voltmeter, cathode ray oscilloscope), and consider the use of ICT in data capture;
6.2 Implementing	<ul style="list-style-type: none"> 6.2.1 assemble and use apparatus correctly, skilfully and effectively with full regard for safety; 6.2.2 make and record sufficient relevant, reliable and valid observations and measurements to the appropriate degree of precision and accuracy, using data loggers where suitable; 6.2.3 show familiarity with both analogue and digital displays; and 6.2.4 modify procedures in response to serious sources of systematic and random error in order to generate results which are as accurate and reliable as allowed by the apparatus.

Skill	Learning Outcomes
6.3 Analysis	<p>Students should be able to:</p> <ul style="list-style-type: none"> 6.3.1 present work appropriately in written, tabular, graphical or other forms; 6.3.2 analyse, interpret and explain their own and others' experimental and investigative activities, using ICT and other methods; 6.3.3 show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data; 6.3.4 draw valid conclusions by the application of knowledge and understanding of Physics;
6.4 Evaluation	<ul style="list-style-type: none"> 6.4.1 assess the reliability of data, results and conclusions drawn from the data; 6.4.2 evaluate the methodology used in and the impact of the experimental activity, and recognise limitations; and
6.5 Communication	<ul style="list-style-type: none"> 6.5.1 communicate observations, measurements, results and conclusions in an appropriate and effective manner.

4 Scheme of Assessment

4.1 Assessment opportunities

Students can choose to be assessed in stages during their AS and A Level courses or to leave all assessment to the end of these courses. Section 2 shows the availability of assessment units for the specification.

Students can choose to resit AS and A2 assessment units. The best result for each assessment unit will count towards the AS and A Level qualifications.

Results for each assessment unit can continue to contribute to an AS or A Level qualification while the specification is on offer.

4.2 Assessment objectives

The specification's assessment objectives are as follows:

A01: Knowledge and understanding of physics and of how physics works

Students should be able to:

- recognise, recall and show understanding of physics knowledge; and
- select, organise and communicate relevant information in a variety of forms.

A02: Application of knowledge and understanding of physics and of how physics works

Students should be able to:

- analyse and evaluate physics knowledge and processes;
- apply physics knowledge and processes to unfamiliar situations, including those related to issues; and
- assess the validity, reliability and credibility of physics information.

A03: How physics works

Students should be able to:

- demonstrate and describe 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; and
- analyse, interpret, explain and evaluate the methodology, results and impact of their own and others' experimental and investigative activities in a variety of ways.

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

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

The skills, knowledge and understanding of how physics works includes the requirements set out below. The content listed in Section 3 incorporates these requirements.

- Use theories, models and ideas to develop and modify physical explanations.
- Use knowledge and understanding to pose physical questions, define physical problems, present physical arguments and physical ideas.
- Use appropriate methodology, including ICT, to answer physical questions and solve physical 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 physical knowledge.
- Communicate information and ideas in appropriate ways using appropriate terminology.
- Consider applications and implications of physics and appreciate their associated benefits and risks.
- Consider ethical issues in the treatment of humans, other organisms and the environment.
- Appreciate the role of the physics community in validating new knowledge and ensuring integrity.
- Appreciate the ways in which society uses physics to inform decision making.

The development of the skills, knowledge and understanding of physics in this specification includes the mathematical requirements set out in Appendix 1.

4.3 Assessment objective weightings

The assessment objective weightings for each assessment unit and the overall AS and A Level qualifications are set out in the tables below:

Assessment Objective	Assessment Units					
	AS 1	AS 2	AS 3	A2 1	A2 2	A2 3
AO1	42.5%	42.5%	20.0%	33.0%	33.0%	20.0%
AO2	42.5%	42.5%	20.0%	50.0%	50.0%	20.0%
AO3	15.0%	15.0%	60.0%	17.0%	17.0%	60.0%

Note that AO3 (How physics works) is assessed in all Assessment Units. The greater part of the weighting for AO3 is in the Experimental Skills units (AS 3 and A2 3). The balance of AO3 appears in relevant questions in the theory units (AS 1, AS 2, A2 1 and A2 2). These questions may include items based on experimental situations.

Assessment Objective	Overall Weightings	
	AS	A2
AO1	36.7%	29.6%
AO2	36.7%	42.2%
AO3	26.7%	28.2%

Assessment Objective	A Level Award
AO1	33.2%
AO2	39.5%
AO3	27.5%

4.4 Quality of written communication

Assessment in AS and A Level qualifications in physics requires students to demonstrate their quality of written communication. In particular, students must:

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

Examiners assess the quality of students' written communication in their responses to questions or tasks that require extended writing. In GCE Physics, this assessment will be made in any one or more assessment units. The total marks allocated to this assessment will be not more than two percent of the award.

4.5 Synoptic assessment

The A2 assessment units include an element of synoptic assessment. This allows students to demonstrate expertise in the essential knowledge, understanding and skills of physics.

In GCE Physics, synoptic assessment requires that students demonstrate that they can:

- build on material first encountered in the AS units;
- make and use connections between different areas of physics;
- apply knowledge and understanding of more than one area to a particular situation or context;
- use knowledge and understanding of principles and concepts of physics in planning experimental work and in analysing and evaluating data; and
- use ideas and skills which permeate physics.

4.6 Symbols, signs and abbreviations

Questions will be set in SI units. Students must be familiar with the symbols for quantities relevant to the specification and with the units for these quantities. Questions will assume knowledge of the symbols for the decimal multiples and sub-multiples. Questions may also use the non-SI units electron-volt (eV) and (unified) atomic mass unit (u). Wherever letter symbols, signs, abbreviations, tabular headings and graphic axis symbols are used, they will follow the recommendations for study beyond 16+ in the ASE Report *Signs, Symbols and Systematics* (2000 revision). Students must be familiar with, and be able to use, these conventions.

4.7 Data and formulae sheet

The examination papers on assessment units AS 1, AS 2, A2 1 and A2 2 will provide separate data and formulae sheets. Students may wish to refer to the relevant sheet when answering questions. Appendix 2 reproduces these sheets.

4.8 Stretch and challenge

The A2 assessment units will include opportunities for stretch and challenge. This will be achieved by:

- including questions constructed with a deliberate incline of difficulty and a decrease in structuring;
- use of a variety of stems in questions to elicit a full range of response types;
- ensuring connectivity between sections of questions;
- providing opportunities for extended writing;
- using a wide range of question types to address different skills; and
- using synoptic assessment.

4.9 Reporting and grading

We report the results of individual assessment units on a uniform mark scale that reflects the assessment weighting of each unit.

AS qualifications are awarded on a five grade scale from A to E with A being the highest. A Level qualifications are awarded on a six grade scale from A* to E with A* being the highest. We determine the AS and A Level grades awarded by aggregating the uniform marks obtained on individual assessment units. To be awarded an A*, candidates will need to achieve a grade A on their full A Level qualification and an A* on the aggregate of their A2 units. For students who fail to attain a grade E, we report their results as unclassified (U).

The grades we award match the performance descriptions published by the regulatory authorities (see Section 6.4).

5 Guidance on Internal Assessment

5.1 Setting of tasks

The assessment tasks will be prescribed by CCEA. Assessment Units AS 3 and A2 3 will each consist of a practical test that will be set by our examiners and will be provided to centres, under confidential cover until the time of the test, in advance of the test date. For both AS 3 and A2 3, centres will have the flexibility of entering their students for a test to be taken on one of two prescribed dates.

The AS 3 assessment unit will consist of two parts. One part will contain a number of short tasks intended to test students' ability to:

- consider appropriate methods in the design of an experiment;
- select suitable apparatus; and
- choose effective and safe procedures.

We will test students' skill in setting up apparatus. We will also test students' ability to take and record sufficient relevant readings to the appropriate degree of precision, so as to generate sufficiently accurate and reliable results. The tasks will require students to evaluate techniques used in experimental activities (including consideration of uncertainty in a result). To prepare for these short tasks, you will need to make sure that your students have experience in measuring the basic physical quantities of mass, length, time (including the timing of oscillations) and current in a wide variety of situations. Note that a number of Learning Outcomes in the specification require students to *perform* and describe an experiment. The question in the second part will present students with a set of results that they must analyse using graphical and other methods. Students may be required to assess the reliability of the results.

The A2 3 assessment unit will consist of three questions, including two practical exercises and a question testing planning and design. The practical exercises will be longer and more complex than those in AS 3. They will test skills of implementing, analysis, evaluation (including consideration of uncertainty in a result) and communication. Work encountered in the AS as well as in the A2 specification may inform the practical exercises. As in the AS Assessment Unit, you can prepare your students for the two practical exercises by giving them experience in measuring physical quantities in a number of experiments. Note also that the Learning Outcomes require students to have *performed* certain experiments. The planning/design question is likely to be set in an unfamiliar context. If it is, there will be sufficient guidance on the necessary theory.

5.2 Supervision of students

During the practical tests you must:

- supervise the general progress of the test; and
- ensure that students move on from one task to the next at the correct times.

5.3 Assessment conditions

You may be required to observe and assess students as they carry out certain tasks in the practical tests. For some experiments, you will be told that you may give a certain amount of assistance. You must record the extent of this assistance in their assessment. These assessments form part of the requirement for internal assessment.

5.4 Marking and internal standardisation

The internal assessment requirement includes marking of the script submitted by the students at the end of the practical test. We will provide a straightforward marking scheme. You must complete the marking, and return all scripts and mark sheets to us, by one week after the date of the test.

Full instructions about details of the moderation procedures, the nature of sampling and dates by which marks and samples have to be submitted to CCEA will be issued at the appropriate time.

5.5 Moderation

We will carry out moderation. Our examiners will sample and scrutinise a suitable number of scripts from each centre.

Full instructions about details of the moderation procedures, the nature of sampling and dates by which marks and samples have to be submitted to CCEA will be issued at the appropriate time.

6 Links

6.1 Support materials

We currently provide the following materials to support this specification:

- specimen papers;
- mark schemes;
- a resource list; and
- notes for guidance.

We will expand our range of support materials through a coordinated science programme to include:

- support days for teachers;
- launch events; and
- a microsite.

You can find details of our Annual Support Programme of events and materials for GCE Physics on our website at www.ccea.org.uk.

6.2 Curriculum objectives

This specification addresses and builds upon the broad curriculum objectives for Northern Ireland, England and Wales. In particular, it allows students to:

- address spiritual, moral and cultural issues by introducing students to aspects of both the vastness and smallness of our universe, for example through Kepler's laws of planetary motion (Unit A2 2), which signalled the departure from a geocentric to a heliocentric planetary system and a revolution in the relationship between the Church and Science, learning about the fundamental particles of the atom and of the nucleus (Units A2 1 and A2 2), foreshadowed by Aristotle more than two millennia ago;
- address environmental matters through studies of energy issues including the transmission of electricity (Unit AS 1); the release of energy by nuclear fission and fusion (Unit A2 1); aspects of medical physics (Unit AS 2);
- pay particular attention to health and safety issues throughout their practical work (Units AS 3 and A2 3), and to learn about radiation hazards (Unit A2 1); and
- obtain a prerequisite qualification to gain entry to higher education in the fields of physics, electronics and engineering, or prepare for direct employment in the fields of science, engineering, medicine, communications, computers and information technology.

6.3 Key skills

This specification enables students to develop and generate evidence for assessing the following skills:

- Communication: C3.1a, C3.1b, C3.2, C3.3 – all units;
- Information and Communication Technology: ICT3.1, ICT3.2, ICT3.3 – all units;
- Application of Number: N3.1, N3.2, N3.3 – all units;
- Working with Others: WO3.1, WO3.2, WO3.3 – all units;
- Improving Own Learning and Performance: LP3.1, LP3.2, LP3.3 – all units; and
- Problem-Solving: PS3.1, PS3.2, PS3.3 – all units.

6.4 Performance descriptions

You can obtain performance descriptions for the AS and A2 judgemental A/B and E/U boundaries from the QCA website at www.qca.org.uk.

6.5 Examination entries

The following entry codes apply to individual assessment units and the overall AS and A Level cash-ins in GCE Physics:

AS 1:	AAY11
AS 2:	AAY12
AS 3:	AAY13
AS cash-in:	S1212
A2 1:	AAY21
A2 2:	AAY22
A2 3:	AAY23
A Level cash-in:	A1212

You can view details of how to make entries on our website. Alternatively, you can contact our Entries, Results and Certification Team using the details provided in Section 6.8.

6.6 Students with particular requirements

We have designed this specification to minimise the need to adjust the assessment of students who have particular requirements. Details of the arrangements you can make for such students are available in the Joint Council for Qualifications document *Access Arrangements and Special Consideration: Regulations and Guidance Relating to Candidates Who Are Eligible for Adjustments in Examinations*.

6.7 Disability Discrimination Act (DDA)

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.

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 *Access Arrangements and Special Consideration: Regulations and Guidance Relating to Candidates Who are Eligible for Adjustments in Examinations*.

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 the future.*

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

6.8 Contact details

The following list provides contact details for relevant members of our staff:

- Specification Support Officer: Catriona Skelton
(telephone: (028) 9026 1200, extension 2292, email: cskelton@ccea.org.uk)
- Officer with Subject Responsibility: Kevin Henderson
(telephone: (028) 9026 1200, email: khenderson@ccea.org.uk)
- Examination Entries, Results and Certification
(telephone: (028) 9026 1262, email: entriesandresults@ccea.org.uk)
- Examiner Recruitment
(telephone: (028) 9026 1243, email: appointments@ccea.org.uk)
- Distribution (past papers and support materials)
(telephone: (028) 9026 1228, email: distribution@ccea.org.uk)
- Support Events Administration: Events Information Service
(telephone: (028) 9026 1401, email: events@ccea.org.uk)
- Information Section (including Freedom of Information requests)
(telephone: (028) 9026 1200, email: info@ccea.org.uk)
- Business Assurance (appeals)
(telephone: (028) 9026 1205, email: appealsmanager@ccea.org.uk).

Appendix 1: Mathematical content

Students need to have been taught, and to have acquired competence in, the following areas of mathematics in order to develop their skills, knowledge and understanding in physics:

- MC1 Arithmetic and numerical 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.
- MC2 Handling data
- Show an awareness of the order of magnitude of physical quantities and make order of magnitude calculations.
 - Use an appropriate number of significant figures.
 - Find arithmetic means.
- MC3 Algebra
- Understand and use the symbols: =, <, <<, >>, >, ∞ , \approx .
 - Change the subject of an equation.
 - Substitute numerical values into algebraic equations using appropriate units for physical quantities.
 - Solve simple algebraic equations.
- MC4 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
- $$y = \frac{k}{x}, y = kx^2, y = \frac{k}{x^2}, y = \sin x, y = \cos x, y = e^{-x}.$$
- MC5 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.

Appendix 2: Data and formulae sheet for AS 1 and AS 2

The data and formulae sheet will provide the following information:

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
acceleration of free fall on the Earth's surface	$g = 9.81 \text{ m s}^{-2}$
electron volt	$1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$

Useful formulae

The following equations may be useful in answering some of the questions in the examination:

Mechanics

Conservation of energy	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$	for a constant force
Hooke's Law	$F = kx$	(spring constant k)

Sound

Sound intensity level/dB	$= 10 \lg_{10} \frac{I}{I_0}$
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Waves

Two-source interference	$\lambda = \frac{ay}{d}$
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Light

Lens formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Magnification $m = \frac{v}{u}$

Electricity

Terminal potential difference $V = E - Ir$ (E.m.f E ; Internal Resistance r)

Potential divider $V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$

Particles and photons

de Broglie equation $\lambda = \frac{h}{p}$

Appendix 3: Data and formulae sheet for A2 1 and A2 2

The data and formulae sheet will provide the following information:

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of a vacuum	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of a vacuum	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\left(\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ F}^{-1} \text{ m} \right)$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
(unified) atomic mass unit	$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$
mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall on the Earth's surface	$g = 9.81 \text{ m s}^{-2}$
electron volt	$1 \text{ e V} = 1.60 \times 10^{-19} \text{ J}$

Useful formulae

The following equations may be useful in answering some of the questions in the examination.

Mechanics

Conservation of energy $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force

Hooke's Law $F = kx$ (spring constant k)

Simple harmonic motion

Displacement $x = A \cos \omega t$

Sound

Sound intensity level/dB $= 10 \lg_{10} \frac{I}{I_0}$

Waves

Two-source interference $\lambda = \frac{ay}{d}$

Thermal physics

Average kinetic energy of a molecule $\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$

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

Thermal energy $Q = mc\Delta\theta$

Capacitors

Capacitors in series $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Capacitors in parallel $C = C_1 + C_2 + C_3$

Time constant $\tau = RC$

Light

Lens formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Magnification $m = \frac{v}{u}$

Electricity

Terminal potential difference $V = E - Ir$ (E.m.f E ; Internal Resistance r)

Potential divider $V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$

Particles and photons

Radioactive decay $A = \lambda N$
 $A = A_0 e^{-\lambda t}$

Half-life $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$

de Broglie equation $\lambda = \frac{h}{p}$

The nucleus

Nuclear radius $r = r_0 A^{\frac{1}{3}}$

Summary of Changes since First Issue

(All document changes are marked in red, formula changes are highlighted in yellow)

Revision History Number	Date of Change	Page Number	Change Made
Version 1	N/A	N/A	First Issue
Version 2	3 July 09	9	Formula amended
Version 2	3 July 09	34	Contact details amended
Version 2	3 July 09	35	Appendix 1 amended under Graphs
Version 2	3 July 09	37 and 39	'Terminal potential difference' formula amended
Version 3	3 September 09	9	Formula amended
Version 3	3 September 09	31	Deleted sentence in Moderation section
Version 3	3 September 09	34	Contact details amended
Version 3	3 September 09	35	Appendix 1 amended under Graphs
Version 3	3 September 09	37 and 39	'Terminal potential difference' formula amended