GCE

Rewarding Learning

CCEA GCE Specification in

Physics

Version 2: 13 October 2017

For first teaching from September 2016
For first award of AS level in Summer 2017
For first award of A level in Summer 2018
Subject Code: 1210

Contents

Subject Code	1210
QAN AS Level	601/8520/X
QAN A Level	601/8519/3

This specification is available online at www.ccea.org.uk

1 Introduction

This specification sets out the content and assessment details for our Advanced Subsidiary (AS) and Advanced GCE courses in Physics. First teaching is from September 2016.

Students can take:

- the AS course as a final qualification; or
- the AS units plus the A2 units for a full GCE A level qualification.

We assess the AS units at a standard appropriate for students who have completed the first part of the full course. A2 units have an element of synoptic assessment (to assess students' understanding of the subject as a whole), as well as more emphasis on assessment objectives that reflect higher order thinking skills.

The full Advanced GCE award is based on students' marks from the AS (40 percent) and the A2 (60 percent). The guided learning hours for this specification, as for all GCEs, are:

- 180 hours for the Advanced Subsidiary level award; and
- 360 hours for the Advanced level award.

We will make the first AS awards for the specification in 2017 and the first A level awards in 2018. The specification builds on the broad objectives of the Northern Ireland Curriculum.

If there are any major changes to this specification, we will notify centres in writing. The online version of the specification will always be the most up to date; to view and download this please go to www.ccea.org.uk

1.1 Aims

This 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 competence in a range of practical, mathematical and problem-solving skills;
- develop and demonstrate a deeper appreciation of scientific skills, and knowledge and understanding of how science works;
- develop essential knowledge and understanding of different areas of the subject and how they relate to each other; and
- develop advanced study skills that help them prepare for third level education.

1.2 Key features

The following are important features of this specification.

- It includes six assessment units that are all externally assessed.
- It allows students to develop their subject knowledge, understanding and skills.
- It provides a firm grounding for students wishing to progress to higher education in physics or related subjects such as engineering or electronics, as higher education courses in these subjects usually require an A level qualification in physics for entry.
- Assessment at A2 includes synoptic assessment that encourages students to develop their understanding of the subject as a whole. Assessment at A2 is less structured and consequently stretches and challenges the students.
- A range of support is available, including specimen assessment materials, exemplar schemes of work and teacher guidance.

1.3 Prior attainment

Students do not need to have reached a particular level of attainment before beginning to study this specification. The specification builds on knowledge, understanding and skills developed in both GCSE Double Award Science and GCSE Physics. The knowledge and understanding from GCSE Mathematics is also very relevant.

1.4 Classification codes and subject combinations

Every specification has a national classification code that indicates its subject area. The classification code for this qualification is 1210.

Please note that if a student takes two qualifications with the same classification code, universities and colleges that they apply to may take the view that they have achieved only one of the two GCEs. The same may occur with any two GCE qualifications that have a significant overlap in content, even if the classification codes are different. Because of this, students who have any doubts about their subject combinations should check with the universities and colleges that they would like to attend before beginning their studies.

2 Specification at a Glance

The table below summarises the structure of the AS and A level courses:

Content	Assessment	Weightings
AS 1: Forces, Energy and Electricity	**1 hour 45 mins** Students complete a written examination consisting of compulsory short answer questions and some that require extended writing. **Externally assessed written paper**	40% of AS 16% of A level
AS 2: Waves, Photons and Astronomy	**1 hour 45 mins** Students complete a written examination consisting of compulsory short answer questions and some that require extended writing. **Externally assessed written paper**	40% of AS 16% of A level
AS 3: Practical Techniques and Data Analysis	**2 (1 hour) components** Students complete an externally assessed test of practical skills consisting of short tasks, and a separate paper requiring the analysis of experimental results. **Externally assessed**	20% of AS 8% of A level
A2 1: Deformation of Solids, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics	**2 hours** Students complete a written examination consisting of compulsory short answer questions and some that require extended writing. The questions have elements of synoptic assessment, drawing together different strands of the specification. **Externally assessed written paper**	24% of A level
A2 2: Fields, Capacitors and Particle Physics	**2 hours** Students complete a written examination consisting of compulsory short answer questions and some that require extended writing. The questions have elements of synoptic assessment, drawing together different strands of the specification. **Externally assessed written paper**	24% of A level

Content	Assessment	Weightings
A2 3: Practical Techniques and Data Analysis	**2 (1 hour) components** Students take an externally assessed test of practical skills, consisting of **two** experimental tests, and a separate paper requiring the analysis of experimental results. **Externally assessed**	12% of A level

Mathematical content

Students must be competent in the areas of mathematics listed in Appendix 1 to develop their skills, knowledge and understanding of physics.

Data and formulae sheets

The data and formulae in Appendices 2 and 3 will be available in the AS and A2 examinations respectively.

Experiment list

Appendix 4 is a list of experiments that the short tasks for AS 3A are based on.

Generic experiments may also be set to test the direct use of apparatus listed in this specification.

3 Subject Content

We have divided this course into six units: three units at AS level and three units at A2. This section sets out the content and learning outcomes for each unit.

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 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	Students should be able to: 1.1.1 describe all physical quantities as consisting of a numerical magnitude and unit; 1.1.2 state the base units of mass, length, time, current, temperature, and amount of substance and be able to express other quantities in terms of these units; 1.1.3 recall and use the prefixes T, G, M, k, c, m, μ, n, p and f, and present these in standard form;
1.2 Scalars and vectors	1.2.1 distinguish between and give examples of scalar and vector quantity; 1.2.2 resolve a vector into two perpendicular components; 1.2.3 calculate the resultant of two coplanar vectors by calculation or scale drawing, with calculations limited to two perpendicular vectors; 1.2.4 solve problems that include two or three coplanar forces acting at a point, in the context of equilibrium;
1.3 Principle of moments	1.3.1 define the moment of a force about a point; 1.3.2 use the concept of centre of gravity; and 1.3.3 recall and use the principle of moments.

Content	Learning Outcomes
1.4 Linear motion	Students should be able to: 1.4.1 define displacement, velocity, average velocity and acceleration; 1.4.2 recall and use the equations of motion for uniform acceleration; 1.4.3 describe an experiment using light gates and computer software to measure acceleration of free fall, g; 1.4.4 interpret, qualitatively and quantitatively, velocity-time and displacement-time graphs for motion with uniform and non-uniform acceleration;
1.5 Dynamics	1.5.1 describe projectile motion; 1.5.2 explain projectile motion as being caused by a uniform velocity in one direction and a uniform acceleration in a perpendicular direction; 1.5.3 apply the equations of motion to projectile motion, excluding air resistance;
1.6 Newton's laws of motion	1.6.1 state Newton's laws of motion; 1.6.2 apply the laws to simple situations; 1.6.3 recall and use the equation $F = ma$, where mass is constant; and 1.6.4 demonstrate an understanding that friction is a force that opposes motion.

Content	Learning Outcomes
1.7 Linear momentum and impulse	Students should be able to: 1.7.1 define momentum; 1.7.2 calculate momentum; 1.7.3 apply the principle of the conservation of linear momentum; 1.7.4 perform calculations involving collisions in one dimension; 1.7.5 describe and confirm collisions as elastic or inelastic by calculation; 1.7.6 define impulse as the product $F \times t$; 1.7.7 recall and use the equation $Ft = mv - mu$; 1.7.8 apply the impulse-momentum relationship to impact situations; 1.7.9 define Newton's second law in terms of momentum;
1.8 Work done, potential energy and kinetic energy	1.8.1 define work done, potential energy and kinetic energy; 1.8.2 show that when work is done, energy is transferred from one form to another; 1.8.3 calculate the work done for constant forces, including forces not along the line of motion; 1.8.4 recall and use the equations $\Delta p.e. = mg\Delta h$ and $k.e. = \frac{1}{2} mv^2$; and 1.8.5 state the principle of conservation of energy and use it to calculate exchanges between gravitational potential energy and kinetic energy.

Content	Learning Outcomes
1.8 Work done, potential energy and kinetic energy (cont.)	Students should be able to: 1.8.6 use the equation $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force; 1.8.7 recall and use $P=\frac{\text{Work done}}{\text{time taken}}$, $P = Fv$ and $efficiency = \frac{useful\ energy(power)output}{energy(power)input}$; 1.8.8 demonstrate an understanding of the importance to society of energy conservation and energy efficiency;
1.9 Electric current, charge, potential difference and electromotive force	1.9.1 recall and use the equation $I = \frac{Q}{t}$; 1.9.2 recall and use the equations $V = \frac{W}{q}$, $V = \frac{P}{I}$; 1.9.3 define the volt; 1.9.4 define electromotive force, E; 1.9.5 distinguish between electromotive force and potential difference;
1.10 Resistance and resistivity	1.10.1 perform experiments to confirm the relationships between current, voltage and resistance in series and parallel circuits; 1.10.2 recall and use the equations for resistors in series and in parallel; 1.10.3 recall and use the equations $R = \frac{V}{I}$ and $P = I^2R$; 1.10.4 define resistivity; 1.10.5 recall and use the equation $R = \frac{\rho l}{A}$ 1.10.6 perform and describe an experiment to measure resistivity; 1.10.7 demonstrate knowledge and simple understanding of superconductivity; and 1.10.8 state Ohm's law.

Content	Learning Outcomes
1.10 Resistance and resistivity (cont.)	Students should be able to: 1.10.9 distinguish between ohmic and non-ohmic behaviour; 1.10.10 perform experiments to determine the current-voltage characteristics for metallic conductors, including wire at a constant temperature and the filament of a bulb; 1.10.11 sketch and describe the current-voltage characteristics for a metallic conductor, a diode and a negative temperature coefficient (ntc) thermistor; 1.10.12 sketch and explain the variation with temperature of the resistance of a metallic conductor and a negative temperature coefficient (ntc) thermistor; 1.10.13 perform an experiment to show the variation with temperature of the resistance of a negative temperature coefficient (ntc) thermistor;
1.11 Internal resistance and electromotive force	1.11.1 demonstrate an understanding of the simple consequences of internal resistance of a source for external circuits; 1.11.2 use the equation $V = E - Ir$; 1.11.3 perform and describe an experiment to measure internal resistance and the electromotive force;
1.12 Potential divider circuits	1.12.1 demonstrate an understanding of the use of a potential divider to supply variable potential difference from a fixed power supply; 1.12.2 demonstrate knowledge and understanding of the use of the potential divider in lighting and heating control circuits; and 1.12.3 calculate the output voltages in loaded circuits using the equation $V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$.

3.2 Unit AS 2: Waves, Photons and Astronomy

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.

Content	Learning Outcomes
2.1 Waves	Students should be able to: 2.1.1 demonstrate knowledge and understanding of the terms transverse wave and longitudinal wave; 2.1.2 categorise waves as transverse or longitudinal; 2.1.3 analyse graphs to obtain data on amplitude, period, frequency, wavelength and phase; 2.1.4 demonstrate an understanding that polarisation is a phenomenon associated with transverse waves; 2.1.5 recall and use the equations $f = \frac{1}{T}$ and $v = f\lambda$; 2.1.6 recall radio waves, microwaves, infrared, visible, ultraviolet, X-rays and gamma rays as regions of the electromagnetic spectrum; 2.1.7 state typical wavelengths for each of these regions; 2.1.8 recall that the wavelength of violet light is 400 nm and red light is 700 nm;
2.2 Refraction	2.2.1 perform and describe an experiment to verify Snell's law and measure the refractive index; 2.2.2 recall and use the equations $n = \frac{\sin i}{\sin r} = \frac{c_1}{c_2}$; 2.2.3 demonstrate knowledge and understanding of total internal reflection; and 2.2.4 recall and use the equation $\sin c = \frac{1}{n}$.

Content	Learning Outcomes
2.2 Refraction (cont.)	Students should be able to: 2.2.5 demonstrate an understanding of the physical principle of the step index optical fibre, including total internal reflection at the core/cladding boundary and the speed in the core; 2.2.6 describe the structure of a flexible endoscope and discuss examples of its application in medicine and industry;
2.3 Lenses	2.3.1 draw ray diagrams for converging and diverging lenses; 2.3.2 use the equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ for converging and diverging lenses; 2.3.3 verify experimentally the lens equation and the evaluation of *f*, the focal length of a converging lens, for real images only; 2.3.4 define m as the ratio of the image height to the object height, or $m = \frac{h_i}{h_0}$; 2.3.5 recall and use the equation $m = \frac{v}{u}$; 2.3.6 describe the use of lenses to correct myopia and hypermetropia; 2.3.7 perform calculations on the correction of long and short sight, including a calculation of the new range of vision; and 2.3.8 perform calculations involving the power of lenses.

Content	Learning Outcomes
2.4 Superposition, interference and diffraction	Students should be able to: 2.4.1 illustrate the concept of superposition by the graphical addition of two sinusoidal waves; 2.4.2 demonstrate an understanding of the conditions required to produce standing waves; 2.4.3 demonstrate knowledge and understanding of the graphical representation of standing waves in stretched strings, and air in pipes closed at one end; 2.4.4 identify, graphically, the modes of vibration of stretched strings and air in a pipe closed at one end, without reference to overtone and harmonic terminology; 2.4.5 identify node and antinode positions; 2.4.6 perform and describe an experiment to measure the speed of sound in air using a resonance tube (end correction is **not** required); 2.4.7 demonstrate an understanding of the conditions for observable interference; 2.4.8 demonstrate an understanding of the significance of path difference and phase difference in explaining interference effects; 2.4.9 describe Young's slits interference experiment to measure the wavelength of monochromatic light; 2.4.10 use the equation $\lambda = \frac{ay}{d}$; 2.4.11 describe and explain diffraction phenomena at a single slit; 2.4.12 state qualitatively and draw diagrams to illustrate the effect of aperture size on diffraction; and 2.4.13 use the equation $d \sin \Theta = n\lambda$ for a diffraction grating.

Content	Learning Outcomes
2.4 Superposition, interference and diffraction (cont.)	Students should be able to: 2.4.14 describe the use of a diffraction grating and a laser to measure wavelength;
2.5 Quantum physics	2.5.1 recall and use the equation $E_{photon} = hf$; 2.5.2 use the photon model to explain the photoelectric effect qualitatively using the terms photon energy and work function; 2.5.3 use the equation $½mv_{max}^2 = hf - hf_0$; 2.5.4 demonstrate an understanding that electrons exist in energy levels in atoms; 2.5.5 recall and use the equation $hf = \Delta E$; 2.5.6 provide a simple explanation of laser action, using the terms population inversion, stimulated emission and metastable state; 2.5.7 demonstrate an understanding of the production of X-rays by the process of electron movement between energy levels; 2.5.8 describe the physical principles of CT scanning and conventional X-rays;
2.6 Wave-particle duality	2.6.1 categorise electromagnetic wave phenomena as being explained by the wave model, the photon model or both; 2.6.2 describe electron diffraction; and 2.6.3 use the de Broglie equation $\lambda = \frac{h}{p}$.

Content	**Learning Outcomes**
2.7 Astronomy	Students should be able to: 2.7.1 recall, demonstrate an understanding of and apply the classical equations for Doppler shift to find the wavelength of the waves received by a stationary observer from a moving source; 2.7.2 demonstrate an understanding of the difference between cosmological red shift and Doppler red shift; 2.7.3 calculate the red shift parameter, z, of a receding galaxy using the equation $z = \frac{\Delta\lambda}{\lambda}$ and use the equation $z = \frac{v}{c}$ to find the recession speed v, where $v << c$; 2.7.4 use Hubble's Law $v = H_0 d$ to estimate the distance, d, to a distant galaxy, given the value of its speed of recession, v, and the Hubble constant, $H_0 \approx 2.4 \times 10^{-18}\ s^{-1}$; and 2.7.5 recall and use $T = \frac{1}{H_0}$ to estimate the age of the universe.

3.3 Unit AS 3: Practical Techniques and Data Analysis

In this unit, students acquire essential practical techniques, including implementing, analysis, evaluation, design and communication. Note that the learning outcomes in this section relate to practical techniques and skills rather than to details of content topics, as in the rest of this specification.

In practical classes, students should consider the health and safety aspects of their work. This includes, but is not limited to, the procedures, techniques, apparatus and materials employed in every activity.

Content	Learning Outcomes
3.1 Implementing	Students should be able to: 3.1.1 assemble and use measuring apparatus correctly, skilfully and effectively with full regard for safety, including: – spring and top-pan balances (mass); – rule, micrometer and calipers (length); – graduated cylinder (liquid volume); – clock and stopwatch (time); – thermometer and sensor (temperature); – ammeter (electric current); – voltmeter (potential difference); – multimeter (resistance, p.d., current); and – protractor (angle); (Note: digital versions of the apparatus are acceptable) 3.1.2 make and record sufficient relevant, reliable and valid observations and measurements to the appropriate degree of precision and accuracy, using data loggers where suitable; 3.1.3 show familiarity with both analogue and digital displays;
3.2 Analysis	3.2.1 present work appropriately in written, tabular, graphical or other forms; and 3.2.2 analyse, interpret and explain their own and others' experimental and investigative activities, using ICT and other methods.

Content	Learning Outcomes
3.2 Analysis (cont.)	Students should be able to: 3.2.3 show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data; 3.2.4 draw valid conclusions by applying knowledge and understanding of physics;
3.3 Evaluation	3.3.1 assess the reliability of data, results and conclusions drawn from the data; 3.3.2 evaluate the methodology used in and the impact of the experimental activity, and demonstrate an appreciation of their limitations; 3.3.3 calculate the absolute and percentage uncertainty in a quantity;
3.4 Refinement	3.4.1 suggest improved effective and safe procedures, after considering quantitative and qualitative methods; 3.4.2 modify procedures in response to serious sources of systematic and random error in order to generate results that are as accurate and reliable as the apparatus allows; and
3.5 Communication	3.5.1 communicate observations, measurements, results and conclusions in an appropriate and effective manner.

3.4 Unit A2 1: Deformation of Solids, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

This unit's content on circular motion and oscillations extends the mechanics foundation included in Unit AS 1. Thermal physics connects the properties of gases to the basic principles of kinetic theory. 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 Deformation of solids	Students should be able to: 4.1.1 state Hooke's law and use $F = kx$ to solve simple problems; 4.1.2 demonstrate an understanding of the terms elastic and plastic deformation and elastic limit; 4.1.3 distinguish between limit of proportionality and elastic limit; 4.1.4 define stress, strain and the Young modulus; 4.1.5 perform and describe an experiment to determine the Young modulus; 4.1.6 use the equation for strain energy, $E = ½Fx = ½kx^2$; 4.1.7 demonstrate an understanding of the importance of the stress, strain and Young modulus of a material when making design and economic decisions about materials use;
4.2 Thermal physics	4.2.1 describe simple experiments on the behaviour of gases to show that pV = *constant* for a fixed mass of gas at constant temperature, $\frac{p}{T}$ *constant* for a fixed mass of gas at constant volume, and $\frac{V}{T}$ = *constant* for a fixed mass of gas at constant pressure, leading to the equation $\frac{pV}{T}$ = constant; 4.2.2 recall and use the ideal gas equation $pV = nRT$; and 4.2.3 recall and use the ideal gas equation in the form $pV = NkT$.

Content	Learning Outcomes
4.2 Thermal physics (cont.)	Students should be able to: 4.2.4 demonstrate an understanding of the concept of internal energy and the random distribution of potential and kinetic energy among molecules; 4.2.5 use the equation $pV = \frac{1}{3} Nm < c^2 >$; 4.2.6 use the equation for average molecular kinetic energy, $\frac{1}{2} m < c^2 > = \frac{3}{2} kT$; 4.2.7 demonstrate an understanding of the concept of absolute zero of temperature; 4.2.8 perform and describe an electrical method for determining specific heat capacity; 4.2.9 use the equation $Q = mc\Delta\Theta$;
4.3 Uniform circular motion	4.3.1 demonstrate an understanding of the concept of angular velocity; 4.3.2 recall and use the equation $v=r\omega$; 4.3.3 apply the relationship $F = ma = \frac{mv^2}{r}$ to motion in a circle at constant speed;
4.4 Simple harmonic motion	4.4.1 define simple harmonic motion (SHM) recalling the equations $a = -\omega^2 x$, where $\omega = 2\pi f$; 4.4.2 perform calculations using the equation $x = A \cos \omega t$; 4.4.3 investigate experimentally and graphically the motion of the simple pendulum and the loaded spiral spring; 4.4.4 use the equations $T = 2\pi \sqrt{\frac{l}{g}}$ and $T = 2\pi \sqrt{\frac{m}{k}}$; and 4.4.5 demonstrate an understanding of SHM graphs, including measuring velocity from the gradient of a displacement-time graph.

Content	Learning Outcomes
4.4 Simple harmonic motion (cont.)	Students should be able to: 4.4.6 use the terms free vibrations, forced vibrations, resonance and damping in this context; 4.4.7 demonstrate an understanding of the concepts of light damping, over-damping and critical damping; 4.4.8 describe mechanical examples of resonance and damping;
4.5 The nucleus	4.5.1 describe alpha-particle scattering as evidence of the existence of atomic nuclei; 4.5.2 interpret the variation of nuclear radius with nucleon number; 4.5.3 use the equation $r = r_0 A^{\frac{1}{3}}$ to estimate the density of nuclear matter;
4.6 Nuclear decay	4.6.1 demonstrate an understanding of how the nature of alpha particles, beta particles and gamma radiation determines their penetration and range; 4.6.2 calculate changes to nucleon number and proton number as a result of emissions; 4.6.3 demonstrate an understanding of the random and exponential nature of radioactive decay; 4.6.4 use the equation $A = -\lambda N$, where λ is defined as the fraction per second of the decaying atoms; 4.6.5 use the equation $A = A_0 e^{-\lambda t}$, where A is the activity; 4.6.6 define half-life; 4.6.7 use the equation $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$; and 4.6.8 describe an experiment to measure half-life of a radioactive source.

Content	**Learning Outcomes**
4.7 Nuclear energy	Students should be able to: 4.7.1 demonstrate an understanding of the equivalence of mass and energy; 4.7.2 recall and use the equation $E = \Delta mc^2$ and demonstrate an understanding that it applies to all energy changes; 4.7.3 describe how the binding energy per nucleon varies with mass number; 4.7.4 describe the principles of fission and fusion with reference to the binding energy per nucleon curve;
4.8 Nuclear fission and fusion	4.8.1 demonstrate an understanding of the terms chain reaction, critical size, moderators, control rods, cooling system and reactor shielding, as used in describing a fission reactor; 4.8.2 demonstrate an understanding of the social, environmental, security and economic issues surrounding the use of nuclear power as a solution to a future energy crisis; 4.8.3 describe the ITER (tokamak concept) fusion reactor in terms of fuel, D-T reaction, temperature required, plasma, three methods of plasma heating, vacuum vessel, blanket, magnetic confinement of plasma, difficulties of achieving fusion on a practical terrestrial scale, and advantages and disadvantages of fusion; and 4.8.4 describe the following methods of plasma confinement: gravitational, inertial and magnetic.

3.5 Unit A2 2: Fields, Capacitors and Particle Physics

Field is a fundamental area of physics that has numerous applications in everyday life. Students learn about 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, using field lines to describe the field, indicate its direction and show the field strength;
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, $F = \frac{G\,Mm}{r^2}$; 5.2.5 recall and apply the equation for gravitational field strength, $g = \frac{GM}{r^2}$, and use this equation to calculate the mass, m; 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 Newton's law of universal gravitation; 5.2.8 demonstrate an understanding of the unique conditions of period, position and direction of rotation required of a geostationary satellite;
5.3 Electric fields	5.3.1 define electric field strength; and 5.3.2 recall and use the equation $E = \frac{F}{q}$.

Content	Learning Outcomes
5.3 Electric fields (cont.)	Students should be able to: 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, $F = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2} = \dfrac{kq_1 q_2}{r^2}$, where $k = \dfrac{1}{4\pi\varepsilon_0}$; and ε_0 is the permittivity of a vacuum; 5.3.5 recall and use the equation for the electric field strength due to a point charge, $E = \dfrac{q}{4\pi\varepsilon_0 r^2} = \dfrac{kq}{r^2}$; 5.3.6 recall that for a uniform electric field, the field strength is constant, and recall and use the equation $E = \dfrac{V}{d}$; 5.3.7 state the similarities and differences in gravitational and electric fields;
5.4 Capacitors	5.4.1 define capacitance; 5.4.2 recall and use the equation $C = \dfrac{Q}{V}$; 5.4.3 define the unit of capacitance, the farad; 5.4.4 recall and use the equation $\frac{1}{2}QV$ or its equivalent for calculating the energy of a charged capacitor; 5.4.5 recall and use the equations for capacitors in series and in parallel; 5.4.6 perform and describe experiments to demonstrate the charge and discharge of a capacitor; and 5.4.7 confirm the exponential nature of capacitor discharge using V or I discharge curves.

Content	**Learning Outcomes**
5.4 Capacitors (cont.)	Students should be able to: 5.4.8 use the equations $Q = Q_0 e^{-t/CR}$, $V = V_0 e^{-t/CR}$ and $I = I_0 e^{-t/CR}$; 5.4.9 define time constant and use the equation $\tau = CR$; 5.4.10 perform and describe an experiment to determine the time constant for R-C circuits; 5.4.11 apply knowledge and understanding of time constants and stored energy to electronic flash guns and defibrillators;
5.5 Magnetic fields	5.5.1 describe the shape and direction of the magnetic field produced by the current in a coil of wire and a long straight wire; 5.5.2 demonstrate an understanding 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; 5.5.3 demonstrate an understanding that the forces produced on a current-carrying coil in a magnetic field is the principle behind the electric motor; 5.5.4 recall and use the equation $F = BIl$; 5.5.5 define magnetic flux density; 5.5.6 demonstrate an understanding of the concepts of magnetic flux and magnetic flux linkage; 5.5.7 recall and use the equations for magnetic flux, $\phi = BA$, and magnetic flux linkage, $N\phi = NBA$; 5.5.8 state, use and demonstrate experimentally Faraday's and Lenz's laws of electromagnetic induction; 5.5.9 recall and calculate average induced e.m.f. as rate of change of flux linkage with time; and 5.5.10 demonstrate an understanding of the simple a.c. generator and use the equation $E = BAN\omega \sin\omega t$.

Content	Learning Outcomes
5.5 Magnetic fields (cont.)	Students should be able to: 5.5.11 describe how a transformer works; 5.5.12 recall and use the equation $\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$ for transformers; 5.5.13 explain power losses in transformers and the advantages of high-voltage transmission of electricity;
5.6 Deflection of charged particles in electric and magnetic fields	5.6.1 demonstrate an understanding that a charge in a uniform electric field experiences a force; 5.6.2 recall and use the equation $F = qE$ to calculate the magnitude of the force and determine the direction of the force; 5.6.3 demonstrate an understanding that a moving charge in a uniform, perpendicular magnetic field experiences a force; 5.6.4 recall and use the equation $F = Bqv$ to calculate the magnitude of the force, and determine the direction of the force;
5.7 Particle accelerators	5.7.1 describe the basic principles of operation of a synchrotron; 5.7.2 demonstrate an understanding of the concept of a relativistic mass increase as particles are accelerated towards the speed of light; 5.7.3 demonstrate an understanding of the concept of antimatter and that it can be produced using the collisions of high-energy particles from the accelerators; and 5.7.4 describe the process of annihilation in terms of photon emission, and conservation of charge, energy and momentum.

Content	Learning Outcomes
5.8 Fundamental particles	Students should be able to: 5.8.1 explain the concept of a fundamental particle; 5.8.2 identify the four fundamental forces and their associated exchange particles; 5.8.3 classify particles as gauge bosons, leptons and hadrons (mesons and baryons); 5.8.4 state examples of each class of particle; 5.8.5 describe the structure of hadrons in terms of quarks; 5.8.6 demonstrate an understanding of the concept of conservation of: – charge; – lepton number; and – baryon number; and 5.8.7 describe β-decay in terms of the basic quark model.

3.6 Unit A2 3: Practical Techniques and Data Analysis

In this unit, students build on the essential practical techniques, including implementing, analysis, evaluation, design and communication. Note that the learning outcomes in this section relate to practical techniques and skills rather than to details of content topics, as in the rest of this specification.

In practical classes, students should consider the health and safety aspects of their work. This includes, but is not limited to, the procedures, techniques, apparatus and materials employed in every activity.

Content	Learning Outcomes
6.1 Implementing	Students should be able to: 6.1.1 assemble and use apparatus correctly, skilfully and effectively with full regard for safety; including: – spring and top-pan balances (mass); – rule, micrometer and calipers (length); – graduated cylinder (liquid volume); – clock and stopwatch (time); – thermometer and sensor (temperature); – ammeter (electric current); – voltmeter (potential difference); – multimeter (resistance, p.d., current); and – protractor (angle); (Note: digital versions of the apparatus are acceptable) 6.1.2 use and describe how the cathode ray oscilloscope (CRO) can be used to determine the voltage and frequency; 6.1.3 make and record sufficient relevant, reliable and valid observations and measurements to the appropriate degree of precision and accuracy, using data loggers where suitable; 6.1.4 show familiarity with both analogue and digital displays;
6.2 Analysis	6.2.1 present work appropriately in written, tabular, graphical or other forms; and 6.2.2 analyse, interpret and explain their own and others' experimental and investigative activities, using ICT and other methods.

Content	Learning Outcomes
6.2 Analysis (cont.)	Students should be able to: 6.2.3 show awareness of the limitations of experimental measurements when commenting on trends and patterns in the data; 6.2.4 draw valid conclusions by applying knowledge and understanding of physics;
6.3 Evaluation	6.3.1 assess the reliability of data, results and conclusions drawn from the data; 6.3.2 evaluate and demonstrate an appreciation of the limitations of the methodology used in and the impact of the experimental activity; 6.3.3 calculate the absolute and percentage uncertainty in a quantity;
6.4 Refinement	6.4.1 suggest improved effective and safe procedures, after considering quantitative and qualitative methods; 6.4.2 modify procedures in response to serious sources of systematic and random error in order to generate results that are as accurate and reliable as the apparatus allows; and
6.5 Communication	6.5.1 communicate observations, measurements, results and conclusions in an appropriate and effective manner.

4 Scheme of Assessment

4.1 Assessment opportunities

Each unit is available for assessment in summer each year. It is possible to resit individual AS and A2 assessment units once and count the better result for each unit towards an AS or A level qualification. Candidates' results for individual assessment units can count towards a qualification until we withdraw the specification.

4.2 Assessment objectives

There are three assessment objectives (AOs) for this specification. Candidates must:

AO1	• demonstrate knowledge and understanding of physics ideas, processes, techniques and procedures;
AO2	• apply knowledge and understanding of physics ideas, processes, techniques and procedures: – in a range of theoretical and practical contexts; – when handling qualitative and quantitative data; and – to solve scientific problems; and
AO3	• analyse, interpret and evaluate a range of physics information, ideas and evidence to: – make judgements and reach conclusions (including in relation to issues); – refine practical design and procedures; and – make, record and communicate reliable and valid observations and measurements with appropriate precision and accuracy.

4.3 Assessment objective weightings

The table below sets out the assessment objective weightings for each assessment unit and the overall A level qualification:

Percentage Assessment Objective Weightings					
	AO1	**AO2**	**AO3**	**AS**	**A level**
AS 1	6.8	6.8	2.4	16	16
AS 2	6.8	6.8	2.4	16	16
AS 3	1.6	2.4	4.0	8	8
A2 1	7.9	12.0	4.1		24
A2 2	7.9	12.0	4.1		24
A2 3	1.4	2.9	7.7		12
Total	**32.4**	**42.9**	**24.7**	**40**	**100**

4.4 Quality of written communication

In A level Physics, candidates must demonstrate their quality of written communication. They need to:

- 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 that suit their purpose and complex subject matter; and
- organise information clearly and coherently, using specialist vocabulary where appropriate.

Quality of written communication is assessed in responses to questions and tasks that require extended writing in any one or more of the A2 units.

4.5 Synoptic assessment at A2

The A2 assessment units include some synoptic assessment, which encourages candidates to develop their understanding of the subject as a whole. In our GCE Physics, synoptic assessment involves:

- building on material from the AS units;
- bringing together and making connections between areas of knowledge and skills that they have explored throughout the course; and
- applying knowledge and understanding of more than one area to a particular situation or context.

4.6 Higher order thinking skills

The A2 assessment units provide opportunities to demonstrate higher order thinking skills by incorporating:

- less structured questions;
- more demanding evaluative tasks; and
- questions that require candidates to make more connections between sections of the specification.

4.7 Reporting and grading

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

We award AS qualifications on a five grade scale from A to E, with A being the highest. We award A level qualifications on a six grade scale from A* to E, with A* being the highest. To determine candidates' grades, we add the uniform marks obtained in individual assessment units.

To be awarded an A*, candidates need to achieve a grade A on their full A level qualification and at least 90 percent of the maximum uniform marks available for the A2 units. If candidates fail to attain a grade E, we report their results as unclassified (U).

The grades we award match the grade descriptions in Section 5 of this specification.

5 Grade Descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates awarded particular grades. The descriptions must be interpreted in relation to the content in the specification; they are not designed to define that content. The grade awarded depends in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of candidates' performance in the assessment may be balanced by better performances in others.

The requirement for all A level specifications to assess candidates' quality of written communication will be met through all three assessment objectives.

AS Grade Descriptions

Grade	Description
AS **Grade A**	For AO1, candidates characteristically: • demonstrate knowledge of most principles, concepts and facts from the AS units; • show understanding of most principles, concepts and facts from the AS units; • select relevant information from the AS units; and • organise and present information clearly in appropriate forms using scientific terminology. For AO2, candidates characteristically: • apply principles and concepts in familiar and new contexts involving only a few steps in the argument; • describe significant trends and patterns shown by data presented in tabular or graphical form; • explain and interpret phenomena with few errors and present arguments and evaluations clearly; and • carry out structured calculations with few errors and demonstrate good understanding of the underlying relationships between physical quantities. For AO3, candidates characteristically: • devise and refine experimental and investigative activities, selecting appropriate techniques; • demonstrate safe and skilful practical techniques; • make observations and measurements with appropriate precision and record these methodically; and • interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

Grade	Description
AS **Grade E**	For AO1, candidates characteristically: • demonstrate knowledge of some principles and facts from the AS units; • show understanding of some principles and facts from the AS units; • select some relevant information from the AS units; and • present information using basic terminology from the AS units. For AO2, candidates characteristically: • apply a given principle to material presented in familiar or closely related contexts, involving only a few steps in the argument; • describe some trends or patterns shown by data presented in tabular or graphical form; • provide basic explanations and interpretations of some phenomena, presenting very limited evaluations; and • carry out some steps in calculations. For AO3, candidates characteristically: • devise and refine some aspects of experimental and investigative activities; • demonstrate safe practical techniques; • make observations and measurements, and record them; and • interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

A2 Grade Descriptions

Grade	Description
A2 **Grade A**	For AO1, candidates characteristically: • demonstrate detailed knowledge of most principles, concepts and facts from this specification; • show understanding of most principles, concepts and facts from this specification; • select relevant information from this specification; and • organise and present information clearly in appropriate forms using scientific terminology. For AO2, candidates characteristically: • apply principles and concepts in familiar and new contexts, involving several steps in the argument; • 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; • carry out extended calculations, with little or no guidance, and demonstrate good understanding of the underlying relationships between physical quantities; • select a wide range of facts, principles and concepts from this specification; and • link together appropriate facts, principles and concepts from different areas of this specification. For AO3, candidates characteristically: • devise and plan experimental and investigative activities, selecting appropriate techniques; • demonstrate safe and skilful practical techniques; • make observations and measurements with appropriate precision and record these methodically; and • interpret, explain, evaluate and communicate the results of their own and others' experimental and investigative activities, in appropriate contexts.

Grade	Description
A2 **Grade E**	For AO1, candidates characteristically: • demonstrate knowledge of some principles and facts from this specification; • show understanding of some principles and facts from this specification; • select some relevant information from this specification; and • present information using basic terminology from this specification. For AO2, candidates characteristically: • apply given principles or concepts in familiar and new contexts, involving a few steps in the argument; • describe, and provide a limited explanation of, trends or patterns shown by complex data presented in tabular or graphical form; • provide basic explanations and interpretations of some phenomena, presenting very limited arguments and evaluations; • carry out routine calculations, where guidance is given; • select some facts, principles and concepts from this specification; and • link together some facts, principles and concepts from different areas of this specification. For AO3, candidates characteristically: • devise and plan some aspects of experimental and investigative activities; • demonstrate safe practical techniques; • make observations and measurements and record them; and • interpret, explain and communicate some aspects of the results of their own and others' experimental and investigative activities, in appropriate contexts.

6 Guidance on Practical Assessment

6.1 Setting the tasks

We set the assessment tasks. AS 3A and A2 3A each involve a practical test that we send to centres before the test date.

For both AS 3A and A2 3A, centres have the flexibility to register their candidates for different sessions on a prescribed date.

The assessment for Unit AS 3 involves two papers: AS 3A and AS 3B.

AS 3A

AS 3A has short tasks that test candidates' ability to carry out the experiments contained in the specification. We test candidates' skill in manipulating the apparatus listed in the specification. We also test their ability to take and record sufficient relevant readings precisely enough to give sufficiently accurate and reliable results. To prepare for these short tasks, teachers should ensure that candidates have experience in measuring the basic physical quantities of mass, length, time (including the timing of oscillations), potential difference and current in a wide variety of situations. Note also that the learning outcomes require candidates to have performed certain experiments.

AS 3B

AS 3B has a series of questions that require candidates to analyse a set of results, use graphical and other methods, calculate uncertainties and evaluate and refine experimental activities.

The assessment for Unit A2 3 involves two papers: A2 3A and A2 3B.

A2 3A

A2 3A has **two** practical exercises that are longer and more complex than those in AS 3A. They test skills of implementing, graph work and analysis. As in Unit AS 3, teachers can prepare candidates for the two practical exercises by giving them experience in measuring physical quantities in a number of experiments.

A2 3B

The questions in A2 3B are similar to those in AS 3B, but with less emphasis on graphical work. This paper may test the use of a CRO as an instrument to measure voltage and determine frequency. If questions are set in an unfamiliar context, there will be sufficient guidance on the necessary theory.

6.2 Supervising the students

During the practical tests AS 3A and A2 3A, the supervisor or invigilator must:

- supervise the general progress of the test to ensure all apparatus performs as required; and
- ensure that candidates move on from one task to the next at the correct times, as identified in the Apparatus and Materials List.

6.3 Assessment conditions

AS 3A and A2 3A take place in the school laboratory. AS 3B and A2 3B take place in the examination hall.

6.4 Confidentiality

Teachers and technicians must ensure that instructions, apparatus and materials lists are kept confidential.

Apparatus and Materials List and Confidential Instructions

In April of each year, we will send centres a copy of the Apparatus and Materials List and Confidential Instructions for both AS 3A and A2 3A. The Confidential Instructions give detailed guidance on setting up and testing the apparatus and materials for use in the assessments. **Teachers and technicians must ensure that candidates have no advance knowledge of the Confidential Instructions or of the apparatus and materials required for the assessments.** If candidates undergo assessment in more than one session, teachers must ensure that those who have taken the assessment do not meet with those who have yet to take it.

Final apparatus testing

AS 3A and A2 3A papers will be made available to the head of department **two** working days before the timetabled starting time. This gives teachers and technicians time to carry out a final test to ensure that the results from experiments fall within the range stated in the Confidential Instructions.

After the practical assessments

When the individual exam sessions have finished, please return the AS 3A and A2 3A practical scripts together with the corresponding advice notes to the examinations officer (EO). We will collect these by the day after the examination. If we don’t, please contact us immediately to arrange another time for collection.

Where the centre finds that a candidate may have been disadvantaged because the apparatus did not function as intended, the supervising teachers must make a report to the EO. The EO will forward the confidential report on the issue to the centre support section at CCEA for special consideration. The supervising teachers must identify candidates by their examination number.

7 Links and Support

7.1 Support

The following resources are available to support this specification:

- our Physics microsite at www.ccea.org.uk
- specimen assessment materials.

We also intend to provide:

- past papers and mark schemes;
- Chief Examiner's reports;
- fact files;
- schemes of work;
- centre support visits;
- support days for teachers;
- bridging resource for mathematics;
- a resource list; and
- exemplification of standards.

7.2 Curriculum objectives

This specification supports centres to build on the broader Northern Ireland Curriculum objectives to develop the young person:

- as an individual;
- as a contributor to society; and
- as a contributor to the economy and environment.

It can contribute to meeting the requirements of the Northern Ireland Entitlement Framework at post-16 and the provision of a broad and balanced curriculum.

Curriculum Progression from Key Stage 4

This specification builds on learning from Key Stage 4 and gives students opportunities to develop their subject knowledge and understanding further.

Students will also have opportunities to continue to develop the **Cross-Curricular Skills** and the **Thinking Skills and Personal Capabilities** shown below. The extent of this development depends on the teaching and learning methodology the teacher uses.

Cross-Curricular Skills

- Communication:
  - Talking and Listening
  - Reading
  - Writing
- Using Mathematics
- Using ICT

Thinking Skills and Personal Capabilities
- Problem Solving
- Working with Others
- Self-Management

For further guidance on the skills and capabilities in this subject, please refer to the supporting schemes of work.

7.3 Examination entries

Entry codes for this subject and details on how to make entries are available on our Qualifications Administration Handbook microsite, which you can access at www.ccea.org.uk

Alternatively, you can telephone our Examination Entries, Results and Certification team using the contact details provided.

7.4 Equality and inclusion

We have considered the requirements of equality legislation in developing this specification and designed it to be as free as possible from ethnic, gender, religious, political and other forms of bias.

GCE qualifications often require the assessment of a broad range of competences. This is because they are general qualifications that prepare students for a wide range of occupations and higher level courses.

During the development process, an external equality panel reviewed the specification to identify any potential barriers to equality and inclusion. Where appropriate, we have considered measures to support access and mitigate barriers.

We can make reasonable adjustments for students with disabilities to reduce barriers to accessing assessments. For this reason, very few students will have a complete barrier to any part of the assessment.

It is important to note that where access arrangements are permitted, they must not be used in any way that undermines the integrity of the assessment. You can find information on reasonable adjustments in the Joint Council for Qualifications document *Access Arrangements and Reasonable Adjustments: General and Vocational Qualifications*, available at www.jcq.org.uk

In practical classes, students should consider the health and safety aspects of their work. This includes, but is not limited to, the procedures, techniques, apparatus and materials employed in every activity.

7.5 Contact details

If you have any queries about this specification, please contact the relevant CCEA staff member or department:

- Specification Support Officer: Nuala Tierney
  (telephone: (028) 9026 1200 extension 2292, email: ntierney@ccea.org.uk)

- Subject Officer: Gavin Gray
  (telephone: (028) 9026 1200, extension 2270, email: ggray@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
  (telephone: (028) 9026 1242, email: cceadistribution@ccea.org.uk)

- Support Events Administration
  (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)

- Moderation
  (telephone: (028) 9026 1200, extension 2236, email: moderationteam@ccea.org.uk)

- Business Assurance (Complaints and Appeals Manager: Heather Clarke)
  (telephone: (028) 9026 1244, email: hclarke@ccea.org.uk).

Appendix 1

Mathematical content

Material in **bold type** is for A2 modules only.

MC1 Arithmetic and numerical computation
Students should be able to:
(a) recognise and use expressions in decimal and standard form;
(b) use ratios, fractions and percentages;
(c) use calculators to find and use power, exponential and logarithmic functions; and
(d) use calculators to handle sin *x*, cos *x* and tan *x*, when *x* is expressed in degrees or **radians**.

MC2 Handling data
Students should be able to:
(a) show an awareness of the order of magnitude of physical quantities and make order of magnitude calculations;
(b) use an appropriate number of significant figures; and
(c) find arithmetic means.

MC3 Algebra
Students should be able to:
(a) understand and use the symbols =, <, <<, >>, >, α, and ≈;
(b) change the subject of an equation;
(c) substitute numerical values into algebraic equations using appropriate units for physical quantities; and
(d) solve simple algebraic equations.

MC4 Graphs
Students should be able to:
(a) translate information between graphical, numerical and algebraic forms;
(b) plot two variables from experimental or other data;
(c) understand that $y = mx + c$ represents a linear relationship;
(d) determine the slope and intercept of a linear graph;
(e) draw and use the slope of a tangent to a curve as a measure of rate of change;
(f) 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;
(g) **use logarithmic plots to test exponential and power law variations**; and
(h) sketch simple functions including

$$y = \frac{k}{x},\ y = kx^2,\ y = \frac{k}{x^2},\ y = \sin x,\ y = \cos x \text{ and } \mathbf{y = e^{-x}}.$$

MC5 Geometry and trigonometry

Students should be able to:

(a) calculate areas of triangles; circumferences and areas of circles; and surface areas and volumes of rectangular blocks, cylinders and spheres;

(b) use Pythagoras' theorem and the angle sum of a triangle;

(c) use sin, cos and tan in physical problems; and

(d) **understand the relationship between degrees and radians and translate from one to the other**.

Appendix 2

Data and formulae sheet for Units AS 1 and AS 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\ m\ s^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} C$
the Planck constant	$h = 6.63 \times 10^{-34}\ J\ s$
mass of electron	$m_e = 9.11 \times 10^{-31}\ kg$
mass of proton	$m_p = 1.67 \times 10^{-27}\ kg$
acceleration of free fall on the Earth's surface	$g = 9.81\ m\ s^{-2}$
electron volt	$1\ eV = 1.60 \times 10^{-19}\ J$
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18}\ s^{-1}$

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

Waves

two-source interference $\lambda = ay/d$

diffraction grating $d \sin \theta = n\lambda$

Light

lens equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Electricity

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

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

Particles and photons

Einstein's equation $\frac{1}{2}mv_{max}^2 = hf - hf_0$

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

Astronomy

red shift $z = \frac{\Delta\lambda}{\lambda}$

recession speed $z = \frac{v}{c}$

Hubble's Law $v = H_0 d$

Appendix 3

Data and formulae sheet for Units A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8} m\ s^{-1}$
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}\ F\ m^{-1}$
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ F^{-1}\ m\right)$
elementary charge	$e = 1.60 \times 10^{-19} C$
the Planck constant	$h = 6.63 \times 10^{-34}\ J\ s$
(unified) atomic mass unit	$1u = 1.66 \times 10^{-27}\ kg$
mass of electron	$m_e = 9.11 \times 10^{-31}\ kg$
mass of proton	$m_p = 1.67 \times 10^{-27}\ kg$
molar gas constant	$R = 8.31\ J\ K^{-1}\ mol^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\ mol^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ J\ K^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ N\ m^{2}\ kg^{-2}$
acceleration of free fall on the Earth's surface	$g = 9.81\ m\ s^{-2}$
electron volt	$1\ eV = 1.60 \times 10^{-19}\ J$
the Hubble constant	$H_0 \approx 2.4 \times 10^{-18}\ s^{-1}$

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)
strain energy	$E = ½Fx = ½kx^2$

Uniform circular motion

centripetal force	$F = ma = \frac{mv^2}{r}$

Simple harmonic motion

displacement	$x = A \cos \omega t$
simple pendulum	$T = 2\pi \sqrt{\frac{l}{g}}$
loaded spiral spring	$T = 2\pi \sqrt{\frac{m}{k}}$

Waves

two-source interference	$\lambda = ay/d$
diffraction grating	$d \sin \theta = n\lambda$

Thermal physics

average kinetic energy of a molecule	$\frac{1}{2} m < c^2 > = \frac{3}{2} kT$
kinetic theory	$pV = \frac{1}{3} Nm < c^2 >$
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	$\tau = CR$
capacitor discharge	$Q = Q_0 e^{-t/CR}$ or $V = V_0 e^{-t/CR}$ or $I = I_0 e^{-t/CR}$

Light

lens equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Electricity

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

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

a.c. generator $E = BAN\omega \sin\omega t$

Nuclear physics

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

radioactive decay $A = -\lambda N, \quad A = A_0 e^{-\lambda t}$

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

Particles and photons

Einstein's equation $\frac{1}{2}mv_{max}^2 = hf - hf_0$

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

Astronomy

red shift $z = \frac{\Delta\lambda}{\lambda}$

recession speed $z = \frac{v}{c}$

Hubble's Law $v = H_0 d$

Appendix 4

Experiments that the tasks for AS 3A are based on

1. Determine the density of a solid or liquid.
2. Determine the value of an unknown mass using the principle of moments.
3. Determine the mass of a uniform rule using the principle of moments.
4. Determine the acceleration of free fall by means of a falling object and light gates.
5. Verify that a α F.
6. Verify that a α 1/m.
7. Verify the conservation of momentum in a collision.
8. Investigate the energy exchange between potential and kinetic for a falling body.
9. Determine the resistance by the ammeter–voltmeter method and using a multimeter or ohmmeter.
10. Verify the relationships for resistors in series and in parallel.
11. Determine the resistivity of a metal.
12. Determine the I-V characteristic of a metallic conductor at constant temperature.
13. Determine the I-V characteristic of a filament lamp.
14. Determine the resistance–temperature characteristic of a negative temperature coefficient (ntc) thermistor.
15. Determine the e.m.f. and internal resistance of a battery.
16. Verify Snell's law.
17. Determine the refractive index of a material.
18. Determine the critical angle of glass or perspex using a semicircular block.
19. Determine the focal length of a converging lens.
20. Verify that the magnification of a real image is equal to the ratio of the image distance to the object distance.
21. Determine the speed of sound in air using a resonance tube.
22. Determine the wavelength of light using a double slit and a grating.

Generic experiments may be set to test the direct use of the apparatus listed in the specification.

Summary of Changes since First Issue

(Most recent changes are indicated in red on the latest version)

Revision History Number	Date of Change	Page Number	Change Made
Version 1	N/A	N/A	First issue
Version 2	13 October 2017	11 13 15 16 17 18 20 21 22 24 26 29 42 44 45 46 47 48 49	Font changed 'blue' changed to 'violet' symbol changed words inserted 'cosmological' removed line added fonts altered words changed symbol inserted equations altered equation altered line added line bolded and equations altered symbol removed symbol replaced and 'cosmological' removed spaces inserted throughout equations symbol replaced and equation altered 'cosmological' removed lowercase 'p' inserted

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