Advanced Higher
Course
Specification

# Advanced Higher Physics

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| **Course code:** | C857 77 |
| **Course assessment code:** | X857 77 |
| **SCQF:** | level 7 (32 SCQF credit points) |
| **Valid from:** | session 2019–20 |

This document provides detailed information about the course and course assessment to ensure consistent and transparent assessment year on year. It describes the structure of the course and the course assessment in terms of the skills, knowledge and understanding that are assessed.

This document is for teachers and lecturers and contains all the mandatory information required to deliver the course.

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# Contents

# Course overview

This course consists of 32 SCQF credit points, which includes time for preparation for course assessment. The notional length of time for candidates to complete the course is 160 hours.

The course assessment has two components.

| Component | Marks | Scaled mark | Duration |
|---|---|---|---|
| Component 1: question paper | 155 | 120 | 3 hours |
| Component 2: project | 30 | 40 | see 'Course assessment' section |

| Recommended entry | Progression |
|---|---|
| Entry to this course is at the discretion of the centre.<br><br>Candidates should have achieved the Higher Physics course or equivalent qualifications and/or experience prior to starting this course. | ♦ an Higher National Diploma (HND) or degree in physics or a related area, such as engineering, electronics, computing, design, architecture, or medicine<br>♦ a career in a physics-based discipline or a related area, such as renewable energy, oil and gas exploration, construction, transport, or telecommunications<br>♦ further study, employment and/or training |

## Conditions of award

The grade awarded is based on the total marks achieved across both course assessment components.

# Course rationale

National Courses reflect Curriculum for Excellence values, purposes and principles. They offer flexibility, provide time for learning, focus on skills and applying learning, and provide scope for personalisation and choice.

Every course provides opportunities for candidates to develop breadth, challenge and application. The focus and balance of assessment is tailored to each subject area.

In this course there is an emphasis on developing an understanding of physics concepts and applying this to familiar and unfamiliar contexts. The course also gives candidates the opportunity to develop and apply skills of scientific inquiry.

The course develops candidates' ability to think analytically, creatively and independently, and to make reasoned evaluations. It gives candidates the opportunity to apply critical thinking to solve problems.

The course also develops candidates' communication skills.

As our understanding of physics and its potential applications is constantly evolving, our success as a technological society depends on the development of young people who are secure in their knowledge of physics, and who are resilient, adaptable, creative, and inventive.

# Purpose and aims

The course develops the skills, knowledge and understanding necessary to analyse and solve problems in familiar and unfamiliar contexts. It offers opportunities for collaborative and independent learning set within familiar and unfamiliar contexts. It also seeks to illustrate and emphasise situations where the principles of physics are used and applied, thus promoting the candidates' awareness that physics involves interaction between theory and practice. The course allows candidates an opportunity to engage in some independent research.

Candidates are encouraged to make critical and evaluative comment, and to accept that physics is a developing subject.

The study of Advanced Higher Physics should also foster an interest in current developments in, and applications of, physics.

The course aims to:

- develop a critical understanding of the role of physics in scientific issues and relevant applications of physics
- extend and apply knowledge, understanding and skills of physics
- develop and apply the skills to carry out complex practical scientific activities, including the use of risk assessments, technology, equipment, and materials
- develop and apply scientific inquiry and investigative skills, including planning and experimental design

- develop and apply analytical thinking skills, including critical evaluation of experimental procedures in a physics context
- extend and apply problem-solving skills in a physics context
- further develop an understanding of scientific literacy, using a wide range of resources, in order to communicate complex ideas and issues and to make scientifically informed choices
- extend and apply skills of autonomous working in physics

# Who is this course for?

The course is suitable for candidates who are secure in their attainment of Higher Physics or an equivalent qualification. It is designed for candidates who can respond to a level of challenge, especially those considering further study or a career in physics and related disciplines.

The course emphasises practical and experiential learning opportunities, with a strong skills-based approach to learning. It takes account of the needs of all candidates, and provides sufficient flexibility to enable candidates to achieve in different ways.

# Course content

The course content includes the following areas of physics:

### Rotational motion and astrophysics

The topics covered are:

- kinematic relationships
- angular motion
- rotational dynamics
- gravitation
- general relativity
- stellar physics

### Quanta and waves

The topics covered are:

- introduction to quantum theory
- particles from space
- simple harmonic motion
- waves
- interference
- polarisation

### Electromagnetism

The topics covered are:

- fields
- circuits
- electromagnetic radiation

### Units, prefixes and uncertainties

The topics covered are:

- units, prefixes and scientific notation
- uncertainties
- data analysis
- evaluation and significance of experimental uncertainties

# Skills, knowledge and understanding

## Skills, knowledge and understanding for the course

The following provides a broad overview of the subject skills, knowledge and understanding developed in the course:

- extending and applying knowledge of physics to new situations, interpreting and analysing information to solve complex problems
- planning and designing physics experiments/investigations, using reference material and including risk assessments, to test a hypothesis or to illustrate particular effects
- carrying out complex experiments in physics safely, recording systematic detailed observations and collecting data
- selecting information from a variety of sources and presenting detailed information, appropriately, in a variety of forms
- processing and analysing physics data/information (using calculations, significant figures and units, where appropriate)
- making reasoned predictions from a range of evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- critically evaluating experimental procedures by identifying sources of uncertainty, suggesting and implementing improvements
- drawing on knowledge and understanding of physics to make accurate statements, describe complex information, provide detailed explanations and integrate knowledge
- communicating physics findings/information fully and effectively
- analysing and evaluating scientific publications and media reports

## Skills, knowledge and understanding for the course assessment

The following provides details of skills, knowledge and understanding sampled in the course assessment.

| Rotational motion and astrophysics |
| --- |
| **Kinematic relationships** |
| Knowledge that differential calculus notation is used to represent rate of change.<br><br>Knowledge that velocity is the rate of change of displacement with time, acceleration is the rate of change of velocity with time, and acceleration is the second differential of displacement with time.<br><br>Derivation of the equations of motion $v = u + at$ and $s = ut + \frac{1}{2}at^2$, using calculus methods.<br><br>Use of calculus methods to calculate instantaneous displacement, velocity and acceleration for straight line motion with a constant or varying acceleration.<br><br>Use of appropriate relationships to carry out calculations involving displacement, velocity, acceleration, and time for straight line motion with constant or varying acceleration.<br><br>$v = \frac{ds}{dt}$<br>$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$<br>$\left.\begin{array}{l} v = u + at \\ s = ut + \frac{1}{2}at^2 \\ v^2 = u^2 + 2as \end{array}\right\}$ for constant acceleration only<br><br>Knowledge that the gradient of a curve (or a straight line) on a motion–time graph represents instantaneous rate of change, and can be found by differentiation.<br><br>Knowledge that the gradient of a curve (or a straight line) on a displacement–time graph is the instantaneous velocity and that the gradient of a curve (or a straight line) on a velocity–time graph is the instantaneous acceleration.<br><br>Knowledge that the area under a line on a graph can be found by integration.<br><br>Knowledge that the area under an acceleration–time graph between limits is the change in velocity and that the area under a velocity–time graph between limits is the displacement.<br><br>Determination of displacement, velocity or acceleration by the calculation of the gradient of the line on a graph or the calculation of the area under the line between limits on a graph. |

## Rotational motion and astrophysics (continued)

### Angular motion

Use of the radian as a measure of angular displacement.

Conversion between degrees and radians.

Use of appropriate relationships to carry out calculations involving angular displacement, angular velocity, angular acceleration, and time.

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

$$\left.\begin{aligned} \omega &= \omega_o + \alpha t \\ \omega^2 &= \omega_o^2 + 2\alpha\theta \\ \theta &= \omega_o t + \tfrac{1}{2}\alpha t^2 \end{aligned}\right\}$$ for constant angular acceleration only

Use of appropriate relationships to carry out calculations involving angular and tangential motion.

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

Use of appropriate relationships to carry out calculations involving constant angular velocity, period and frequency.

$$\omega = \frac{2\pi}{T}$$

$$\omega = 2\pi f$$

Knowledge that a centripetal (radial or central) force acting on an object is necessary to maintain circular motion, and results in centripetal (radial or central) acceleration of the object.

## Rotational motion and astrophysics (continued)

### Angular motion (continued)

Use of appropriate relationships to carry out calculations involving centripetal acceleration and centripetal force.

$$a_r = \frac{v^2}{r} = r\omega^2$$

$$F = \frac{mv^2}{r} = mr\omega^2$$

### Rotational dynamics

Knowledge that an unbalanced torque causes a change in the angular (rotational) motion of an object.

Definition of moment of inertia of an object as a measure of its resistance to angular acceleration about a given axis.

Knowledge that moment of inertia depends on mass and the distribution of mass about a given axis of rotation.

Use of an appropriate relationship to calculate the moment of inertia for a point mass.

$$I = mr^2$$

Use of an appropriate relationship to calculate the moment of inertia for discrete masses.

$$I = \sum mr^2$$

Use of appropriate relationships to calculate the moment of inertia for rods, discs and spheres about given axes.

| | |
|---|---|
| rod about centre | $I = \frac{1}{12}ml^2$ |
| rod about end | $I = \frac{1}{3}ml^2$ |
| disc about centre | $I = \frac{1}{2}mr^2$ |
| sphere about centre | $I = \frac{2}{5}mr^2$ |

## Rotational motion and astrophysics (continued)

### Rotational dynamics (continued)

Use of appropriate relationships to carry out calculations involving torque, perpendicular force, distance from the axis, angular acceleration, and moment of inertia.

$$\tau = Fr$$

$$\tau = I\alpha$$

Use of appropriate relationships to carry out calculations involving angular momentum, angular velocity, moment of inertia, tangential velocity, mass and its distance from the axis.

$$L = mvr = mr^2\omega$$

$$L = I\omega$$

Statement of the principle of conservation of angular momentum.

Use of the principle of conservation of angular momentum to solve problems.

Use of appropriate relationships to carry out calculations involving potential energy, rotational kinetic energy, translational kinetic energy, angular velocity, linear velocity, moment of inertia, and mass.

$$E_{k(rotational)} = \frac{1}{2}I\omega^2$$

$$E_P = E_{k(translational)} + E_{k(rotational)}$$

### Gravitation

Conversion between astronomical units (AU) and metres and between light-years (ly) and metres.

Definition of gravitational field strength as the gravitational force acting on a unit mass.

Sketch of gravitational field lines and field line patterns around astronomical objects and astronomical systems involving two objects.

Use of an appropriate relationship to carry out calculations involving gravitational force, masses and their separation.

$$F = \frac{GMm}{r^2}$$

Use of appropriate relationships to carry out calculations involving period of satellites in circular orbit, masses, orbit radius, and satellite speed.

$$F = \frac{GMm}{r^2} = \frac{mv^2}{r} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$$

| Rotational motion and astrophysics (continued) |
|---|
| **Gravitation (continued)** |
| Definition of the gravitational potential of a point in space as the work done in moving unit mass from infinity to that point.<br><br>Knowledge that the energy required to move mass between two points in a gravitational field is independent of the path taken.<br><br>Use of appropriate relationships to carry out calculations involving gravitational potential, gravitational potential energy, masses and their separation.<br><br>$V = -\frac{GM}{r}$<br><br>$E_P = Vm = -\frac{GMm}{r}$<br><br>Definition of escape velocity as the minimum velocity required to allow a mass to escape a gravitational field to infinity, where the mass achieves zero kinetic energy and maximum (zero) potential energy.<br><br>Derivation of the relationship $v_{esc} = \sqrt{\frac{2GM}{r}}$ .<br><br>Use of an appropriate relationship to carry out calculations involving escape velocity, mass and distance.<br><br>$v_{esc} = \sqrt{\frac{2GM}{r}}$ |
| **General relativity** |
| Knowledge that special relativity deals with motion in inertial (non-accelerating) frames of reference and that general relativity deals with motion in non-inertial (accelerating) frames of reference.<br><br>Statement of the equivalence principle (that it is not possible to distinguish between the effects on an observer of a uniform gravitational field and of a constant acceleration) and knowledge of its consequences. |

| Rotational motion and astrophysics (continued) |
|---|
| **General relativity (continued)** |
| Consideration of spacetime as a unified representation of three dimensions of space and one dimension of time.<br><br>Knowledge that general relativity leads to the interpretation that mass curves spacetime, and that gravity arises from the curvature of spacetime.<br><br>Knowledge that light or a freely moving object follows a geodesic (the path with the shortest distance between two points) in spacetime.<br><br>Representation of world lines for objects which are stationary, moving with constant velocity and accelerating.<br><br>Knowledge that the escape velocity from the event horizon of a black hole is equal to the speed of light.<br><br>Knowledge that, from the perspective of a distant observer, time appears to be frozen at the event horizon of a black hole.<br><br>Knowledge that the Schwarzschild radius of a black hole is the distance from its centre (singularity) to its event horizon.<br><br>Use of an appropriate relationship to solve problems relating to the Schwarzschild radius of a black hole.<br><br>$r_{Schwarzschild} = \frac{2GM}{c^2}$ |
| **Stellar physics** |
| Use of appropriate relationships to solve problems relating to luminosity, apparent brightness $b$, distance between the observer and the star, power per unit area, stellar radius, and stellar surface temperature. (Using the assumption that stars behave as black bodies.)<br><br>$b = \frac{L}{4\pi d^2}$<br><br>$\frac{P}{A} = \sigma T^4$<br><br>$L = 4\pi r^2 \sigma T^4$<br><br>Knowledge that stars are formed in interstellar clouds when gravitational forces overcome thermal pressure and cause a molecular cloud to contract until the core becomes hot enough to sustain nuclear fusion, which then provides a thermal pressure that balances the gravitational force. |

## Rotational motion and astrophysics (continued)

### Stellar physics (continued)

Knowledge of the stages in the proton–proton chain (p–p chain) in stellar fusion reactions which convert hydrogen to helium. One example of a p–p chain is:

$${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + {}^{0}_{+1}\mathrm{e} + \nu_{\mathrm{e}}$$

$${}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma$$

$${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2{}^{1}_{1}\mathrm{H}$$

Knowledge that Hertzsprung-Russell (H-R) diagrams are a representation of the classification of stars.

Classification of stars and position in Hertzsprung-Russell (H-R) diagrams, including main sequence, giant, supergiant, and white dwarf.

Use of Hertzsprung-Russell (H-R) diagrams to determine stellar properties, including prediction of colour of stars from their position in an H-R diagram.

Knowledge that the fusion of hydrogen occurs in the core of stars in the main sequence of a Hertzsprung-Russell (H-R) diagram.

Knowledge that hydrogen fusion in the core of a star supplies the energy that maintains the star’s outward thermal pressure to balance inward gravitational forces. When the hydrogen in the core becomes depleted, nuclear fusion in the core ceases. The gas surrounding the core, however, will still contain hydrogen. Gravitational forces cause both the core, and the surrounding shell of hydrogen to shrink. In a star like the Sun, the hydrogen shell becomes hot enough for hydrogen fusion in the shell of the star. This leads to an increase in pressure which pushes the surface of the star outwards, causing it to cool. At this stage, the star will be in the giant or supergiant regions of a Hertzspung-Russell (H-R) diagram.

Knowledge that, in a star like the Sun, the core shrinks and will become hot enough for the helium in the core to begin fusion.

Knowledge that the mass of a star determines its lifetime.

Knowledge that every star ultimately becomes a white dwarf, a neutron star or a black hole. The mass of the star determines its eventual fate.

## Quanta and waves

### Introduction to quantum theory

Knowledge of experimental observations that cannot be explained by classical physics, but can be explained using quantum theory:

- black-body radiation curves (ultraviolet catastrophe)
- the formation of emission and absorption spectra
- the photoelectric effect

Use of an appropriate relationship to solve problems involving photon energy and frequency.

$$E = hf$$

Knowledge of the Bohr model of the atom in terms of the quantisation of angular momentum, the principal quantum number $n$ and electron energy states, and how this explains the characteristics of atomic spectra.

Use of an appropriate relationship to solve problems involving the angular momentum of an electron and its principal quantum number.

$$mvr = \frac{nh}{2\pi}$$

Description of experimental evidence for the particle-like behaviour of ‘waves’ and for the wave-like behaviour of ‘particles’.

Use of an appropriate relationship to solve problems involving the de Broglie wavelength of a particle and its momentum.

$$\lambda = \frac{h}{p}$$

Knowledge that it is not possible to know the position and the momentum of a quantum particle simultaneously.

Knowledge that it is not possible to know the lifetime of a quantum particle and the associated energy change simultaneously.

Use of appropriate relationships to solve problems involving the uncertainties in position, momentum, energy, and time. The lifetime of a quantum particle can be taken as the uncertainty in time.

$$\Delta x \Delta p_x \geq \frac{h}{4\pi}$$

$$\Delta E \Delta t \geq \frac{h}{4\pi}$$

## Quanta and waves (continued)

### Introduction to quantum theory (continued)

Knowledge of implications of the Heisenberg uncertainty principle, including the concept of quantum tunnelling, in which a quantum particle can exist in a position that, according to classical physics, it has insufficient energy to occupy.

### Particles from space

Knowledge of the origin and composition of cosmic rays and the interaction of cosmic rays with Earth's atmosphere.

Knowledge of the composition of the solar wind as charged particles in the form of plasma.

Explanation of the helical motion of charged particles in the Earth's magnetic field.

Use of appropriate relationships to solve problems involving the force on a charged particle, its charge, its mass, its velocity, the radius of its path, and the magnetic induction of a magnetic field.

$$F = qvB$$

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

### Simple harmonic motion (SHM)

Definition of SHM in terms of the restoring force and acceleration proportional to, and in the opposite direction to, the displacement from the rest position.

Use of calculus methods to show that expressions in the form of $y = A\sin\omega t$ and $y = A\cos\omega t$ are consistent with the definition of SHM ($a = -\omega^2 y$).

Derivation of the relationships $v = \pm\omega\sqrt{\left(A^2 - y^2\right)}$ and $E_k = \frac{1}{2}m\omega^2\left(A^2 - y^2\right)$.

## Quanta and waves (continued)

### Simple harmonic motion (SHM) (continued)

Use of appropriate relationships to solve problems involving the displacement, velocity, acceleration, force, mass, spring constant $k$, angular frequency, period, and energy of an object executing SHM.

$$F = -ky$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$a = \frac{d^2y}{dt^2} = -\omega^2 y$$

$y = A\cos\omega t$ or $y = A\sin\omega t$

$$v = \pm\omega\sqrt{\left(A^2 - y^2\right)}$$

$$E_k = \frac{1}{2}m\omega^2\left(A^2 - y^2\right)$$

$$E_P = \frac{1}{2}m\omega^2 y^2$$

Knowledge of the effects of damping in SHM to include underdamping, critical damping and overdamping.

### Waves

Use of an appropriate relationship to solve problems involving the energy transferred by a wave and its amplitude.

$$E = kA^2$$

Knowledge of the mathematical representation of travelling waves.

Use of appropriate relationships to solve problems involving wave motion, phase difference and phase angle.

$$y = A\sin 2\pi\left(ft - \frac{x}{\lambda}\right)$$

$$\phi = \frac{2\pi x}{\lambda}$$

Knowledge that stationary waves are formed by the interference of two waves, of the same frequency and amplitude, travelling in opposite directions. A stationary wave can be described in terms of nodes and antinodes.

## Quanta and waves (continued)

### Interference

Knowledge that two waves are coherent if they have a constant phase relationship.

Knowledge of the conditions for constructive and destructive interference in terms of coherence and phase.

Use of an appropriate relationship to solve problems involving optical path difference $opd$, geometrical path difference $gpd$ and refractive index.

$$opd = n \times gpd$$

Knowledge that a wave experiences a phase change of $\pi$ when it is travelling in a less dense medium and reflects from an interface with a more dense medium.

Knowledge that a wave does not experience a phase change when it is travelling in a more dense medium and reflects from an interface with a less dense medium.

Explanation of interference by division of amplitude, including optical path length, geometrical path length, phase difference, and optical path difference.

Knowledge of thin film interference and wedge fringes.

For light interfering by division of amplitude, use of an appropriate relationship to solve problems involving the optical path difference between waves, wavelength and order number.

$opd = m\lambda$ or $\left(m + \frac{1}{2}\right)\lambda$ where $m = 0,1,2...$

Knowledge that a coated (bloomed) lens can be made non-reflective for a specific wavelength of light.

Derivation of the relationship $d = \frac{\lambda}{4n}$ for glass lenses with a coating such as magnesium fluoride.

Use of appropriate relationships to solve problems involving interference of waves by division of amplitude.

$$\Delta x = \frac{\lambda l}{2d}$$

$$d = \frac{\lambda}{4n}$$

Explanation of interference by division of wavefront.

## Quanta and waves (continued)

### Interference (continued)

Knowledge of Young's slits interference.

Use of an appropriate relationship to solve problems involving interference of waves by division of wavefront.

$$\Delta x = \frac{\lambda D}{d}$$

### Polarisation

Knowledge of what is meant by a plane-polarised wave.

Knowledge of the effect on light of polarisers and analysers.

Knowledge that when a ray of unpolarised light is incident on the surface of an insulator at Brewster's angle the reflected ray becomes plane-polarised.

Derivation of the relationship $n = \tan i_p$.

Use of an appropriate relationship to solve problems involving Brewster's angle and refractive index.

$$n = \tan i_p$$

## Electromagnetism

### Fields

Knowledge that an electric field is the region that surrounds electrically charged particles in which a force is exerted on other electrically charged particles.

Definition of electric field strength as the electrical force acting on unit positive charge.

Sketch of electric field patterns around single point charges, a system of charges and in a uniform electric field.

Definition of electrical potential at a point as the work done in moving unit positive charge from infinity to that point.

Knowledge that the energy required to move charge between two points in an electric field is independent of the path taken.

## Electromagnetism (continued)

### Fields (continued)

Use of appropriate relationships to solve problems involving electrical force, electrical potential and electric field strength around a point charge and a system of charges.

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_o r^2}$$

$$V = \frac{Q}{4\pi\varepsilon_o r}$$

$$E = \frac{Q}{4\pi\varepsilon_o r^2}$$

Use of appropriate relationships to solve problems involving charge, energy, potential difference, and electric field strength in situations involving a uniform electric field.

$$F = QE$$

$$V = Ed$$

$$W = QV$$

Knowledge of Millikan's experimental method for determining the charge on an electron.

Use of appropriate relationships to solve problems involving the motion of charged particles in uniform electric fields.

$$F = QE$$

$$V = Ed$$

$$W = QV$$

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

## Electromagnetism (continued)

### Fields (continued)

Knowledge that the electronvolt (eV) is the energy acquired when one electron accelerates through a potential difference of one volt.

Conversion between electronvolts and joules.

Knowledge that electrons are in motion around atomic nuclei and individually produce a magnetic effect.

Knowledge that, for example, iron, nickel, cobalt, and some rare earths exhibit a magnetic effect called ferromagnetism, in which magnetic dipoles can be made to align, resulting in the material becoming magnetised.

Sketch of magnetic field patterns between magnetic poles, and around solenoids, including the magnetic field pattern around Earth.

Comparison of gravitational, electrostatic, magnetic, and nuclear forces in terms of their relative strength and range.

Use of an appropriate relationship to solve problems involving magnetic induction around a current-carrying wire, the current in the wire and the distance from the wire.

$$B = \frac{\mu_o I}{2\pi r}$$

Explanation of the helical path followed by a moving charged particle in a magnetic field.

Use of appropriate relationships to solve problems involving the forces acting on a current-carrying wire in a magnetic field and a charged particle in a magnetic field.

$$F = IlB\sin\theta$$

$$F = qvB$$

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

## Electromagnetism (continued)

### Circuits

Knowledge of the variation of current and potential difference with time in an RC circuit during charging and discharging.

Definition of the time constant for an RC circuit as the time to increase the charge stored by 63% of the difference between initial charge and full charge, or the time taken to discharge the capacitor to 37% of initial charge.

Use of an appropriate relationship to determine the time constant for an RC circuit.

$$\tau = RC$$

Knowledge that, in an RC circuit, an uncharged capacitor can be considered to be fully charged after a time approximately equal to $5\tau$ .

Knowledge that, in an RC circuit, a fully charged capacitor can be considered to be fully discharged after a time approximately equal to $5\tau$ .

Graphical determination of the time constant for an RC circuit.

Knowledge that capacitive reactance is the opposition of a capacitor to changing current.

Use of appropriate relationships to solve problems involving capacitive reactance, voltage, current, frequency, and capacitance.

$$X_C = \frac{V}{I}$$

$$X_C = \frac{1}{2\pi fC}$$

Knowledge of the growth and decay of current in a DC circuit containing an inductor.

Explanation of the self-inductance (inductance) of a coil.

Knowledge of Lenz's law and its implications.

Definition of inductance and of back EMF.

Knowledge that energy is stored in the magnetic field around a current-carrying inductor.

Knowledge of the variation of current with frequency in an AC circuit containing an inductor.

Knowledge that inductive reactance is the opposition of an inductor to changing current.

## Electromagnetism (continued)

### Circuits (continued)

Use of appropriate relationships to solve problems relating to inductive reactance, voltage, current, frequency, energy, and self-inductance (inductance).

$$\varepsilon = -L\frac{dI}{dt}$$

$$E = \frac{1}{2}LI^2$$

$$X_L = \frac{V}{I}$$

$$X_L = 2\pi fL$$

### Electromagnetic radiation

Knowledge of the unification of electricity and magnetism.

Knowledge that electromagnetic radiation exhibits wave properties as it transfers energy through space. It has both electric and magnetic field components which oscillate in phase, perpendicular to each other and to the direction of energy propagation.

Use of an appropriate relationship to solve problems involving the speed of light, the permittivity of free space and the permeability of free space.

$$c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$$

## Units, prefixes and uncertainties

### Units, prefixes and scientific notation

Appropriate use of units, including electronvolt (eV), light-year (ly) and astronomical unit (AU).

Use of SI units with all physical quantities, where appropriate.

Use of prefixes where appropriate. These include femto (f), pico (p), nano (n), micro (μ), milli (m), kilo (k), mega (M), giga (G), tera (T), and peta (P).

## Units, prefixes and uncertainties (continued)

### Units, prefixes and scientific notation (continued)

Use of the appropriate number of significant figures in final answers. The final answer can have no more significant figures than the data with the fewest number of significant figures used in the calculation.

Appropriate use of scientific notation.

### Uncertainties

Knowledge and use of uncertainties, including systematic uncertainties, scale reading uncertainties, random uncertainties, and calibration uncertainties.

Systematic uncertainty occurs when readings taken are either all too small or all too large. This can arise due to faulty measurement techniques or experimental design.

Scale reading uncertainty is an indication of how precisely an instrument scale can be read.

Random uncertainty arises when measurements are repeated and slight variations occur. Random uncertainty may be reduced by increasing the number of repeated measurements.

Calibration uncertainty arises when there is a difference between a manufacturer's claim for the accuracy of an instrument when compared with an approved standard.

Solve problems involving absolute uncertainties and fractional/percentage uncertainties.

Appropriate use of significant figures in absolute uncertainties. Absolute uncertainty should normally be rounded to one significant figure. In some instances, a second significant figure may be retained.

### Data analysis

Combination of various types of uncertainties to obtain the total uncertainty in a measurement.

Knowledge that, when uncertainties in a single measurement are combined, an uncertainty can be ignored if it is less than one-third of one of the other uncertainties in the measurement.

Use of an appropriate relationship to determine the total uncertainty in a measured value.

$$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

## Units, prefixes and uncertainties (continued)

**Data analysis (continued)**

Combination of uncertainties in measured values to obtain the total uncertainty in a calculated value.

Knowledge that, when uncertainties in measured values are combined, a fractional/percentage uncertainty in a measured value can be ignored if it is less than one-third of the fractional/percentage uncertainty in another measured value.

Use of an appropriate relationship to determine the total uncertainty in a value calculated from the product or quotient of measured values.

$$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$$

Use of an appropriate relationship to determine the uncertainty in a value raised to a power.

$$\left(\frac{\Delta W^n}{W^n}\right) = n\left(\frac{\Delta W}{W}\right)$$

Use of error bars to represent absolute uncertainties on graphs.

Estimation of uncertainty in the gradient and intercept of the line of best fit on a graph.

Correct use of the terms accuracy and precision in the context of an evaluation of experimental results. The accuracy of a measurement compares how close the measurement is to the ‘true’ or accepted value. The uncertainty in a measurement gives an indication of the precision of the measurement.

**Evaluation and significance of experimental uncertainties**

Identification of the dominant uncertainty/uncertainties in an experiment or in experimental data.

Suggestion of potential improvements to an experiment, which may reduce the dominant uncertainty/uncertainties.

Skills, knowledge and understanding included in the course are appropriate to the SCQF level of the course. The SCQF level descriptors give further information on characteristics and expected performance at each SCQF level, and are available on the SCQF website.

## Skills for learning, skills for life and skills for work

This course helps candidates to develop broad, generic skills. These skills are based on SQA's Skills Framework: Skills for Learning, Skills for Life and Skills for Work and draw from the following main skills areas:

**1 Literacy**
1.1 Reading
1.2 Writing

**2 Numeracy**
2.1 Number processes
2.2 Money, time and measurement
2.3 Information handling

**5 Thinking skills**
5.3 Applying
5.4 Analysing and evaluating
5.5 Creating

Teachers and/or lecturers must build these skills into the course at an appropriate level, where there are suitable opportunities.

# Course assessment

Course assessment is based on the information in this course specification.

The course assessment meets the purposes and aims of the course by addressing:

- breadth — drawing on knowledge and skills from across the course
- challenge — requiring greater depth or extension of knowledge and/or skills
- application — requiring application of knowledge and/or skills in practical or theoretical contexts as appropriate

This enables candidates to apply:

- breadth and depth of skills, knowledge and understanding from across the course to answer questions in physics
- skills of scientific inquiry, using related knowledge, to carry out a meaningful and appropriately challenging project in physics and communicate findings

## Course assessment structure: question paper

### Question paper 155 marks

The question paper has 155 marks. This is scaled by SQA to represent 75% of the overall marks for the course assessment.

The question paper contains restricted-response and extended-response questions.

A data sheet and a relationships sheet are provided.

The majority of the marks are awarded for applying knowledge and understanding. The other marks are awarded for applying skills of scientific inquiry, scientific analytical thinking and problem solving.

The question paper gives candidates an opportunity to demonstrate the following skills, knowledge and understanding:

- making accurate statements
- providing descriptions and explanations and integrating knowledge
- applying knowledge of physics to new situations, interpreting information and solving problems
- planning or designing experiments/investigations, including safety measures, to test given hypothesis or to illustrate given effects
- selecting information from a variety of sources
- presenting information appropriately, in a variety of forms
- processing information/data (using calculations, significant figures and units, where appropriate)

- making predictions based on evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- identifying sources of uncertainty and suggesting improvements to experiments

### Setting, conducting and marking the question paper

The question paper is set and marked by SQA, and conducted in centres under conditions specified for external examinations by SQA.

Candidates have 3 hours to complete the question paper.

Specimen question papers for Advanced Higher courses are published on SQA's website. These illustrate the standard, structure and requirements of the question papers. The specimen papers also include marking instructions.

# Course assessment structure: project

## Project 30 marks

The project has 30 marks. This is scaled by SQA to represent 25% of the overall marks for the course assessment.

The purpose of the project is to allow the candidate to carry out an in-depth investigation of a physics topic and produce a project report. Candidates are required to plan and carry out a physics investigation.

Candidates should keep a record of their work (daybook) as this will form the basis of their project report. This record should include details of their research, experiments and recorded data.

The project assesses the application of skills of scientific inquiry and related physics knowledge and understanding. It gives candidates an opportunity to demonstrate the following skills, knowledge and understanding:

- extending and applying knowledge of physics to new situations, interpreting and analysing information to solve more complex problems
- planning and designing physics experiments/investigations, using reference material, to test a hypothesis or to illustrate particular effects
- recording systematic detailed observations and collecting data
- selecting information from a variety of sources
- presenting detailed information appropriately in a variety of forms
- processing and analysing physics data (using calculations, significant figures and units, where appropriate)
- making reasoned predictions from a range of evidence/information
- drawing valid conclusions and giving explanations supported by evidence/justification
- critically evaluating experimental procedures by identifying sources of uncertainty, and suggesting and implementing improvements
- drawing on knowledge and understanding of physics to make accurate statements, describe complex information, provide detailed explanations, and integrate knowledge
- communicating physics findings/information fully and effectively
- analysing and evaluating scientific publications and media reports

### Project overview

Candidates carry out an in-depth investigation of a physics topic. Candidates choose their topic and **individually** investigate/research its underlying physics. Candidates must discuss potential topics with their teacher and/or lecturer to ensure that they do not waste time researching unsuitable topics. This is an open-ended task that may involve candidates carrying out a significant part of the work without supervision.

Throughout the project candidates work autonomously, making independent and rational decisions based on evidence and interpretation of scientific information, which involves analysing and evaluating results. Through this, candidates further develop and enhance their scientific literacy skills.

The project offers challenge by requiring candidates to apply skills, knowledge and understanding in a context that is one or more of the following:

- unfamiliar
- familiar but investigated in greater depth
- integrating a number of familiar contexts

Candidates will produce a project report that has a logical structure.

Refer to the *Advanced Higher Physics Project Assessment Task* for detailed advice on the content of the project report.

## Setting, conducting and marking the project

### Setting

This project is set:

- by centres within SQA guidelines
- at a time appropriate to the candidate's needs
- within teaching and learning and includes experimental work at a level appropriate to Advanced Higher

### Conducting

The project is conducted:

- under some supervision and control
- in time to meet a submission date set by SQA
- independently by the candidate

### Marking

The project has 30 marks.

The following table gives the mark allocation for each section of the project report.

| Section | Expected response | Mark allocation |
|---|---|---|
| Abstract | A brief abstract (summary) stating the overall aim and findings/conclusion(s) of the project. | 1 |
| Underlying physics | A description of the underlying physics that:<br><br>♦ is relevant to the project<br>♦ demonstrates an understanding of the physics theory underpinning the project<br>♦ is of an appropriate level and commensurate with the demands of Advanced Higher Physics | 4 |
| Procedures | Labelled diagrams and/or descriptions of apparatus, as appropriate. | 2 |
| | Clear descriptions of how the apparatus was used to obtain experimental readings. | 2 |
| | Procedures are at an appropriate level of complexity and demand. Factors to be considered include:<br>♦ range of procedures<br>♦ control of variables<br>♦ accuracy and precision<br>♦ originality of approach and/or experimental techniques<br>♦ degree of sophistication of experimental design and/or equipment | 3 |
| Results (including uncertainties) | Data is sufficient and relevant to the aim of the project. | 1 |
| | Appropriate analysis of data, for example, quality of graphs, lines of best fit, calculations. | 4 |
| | Uncertainties in individual readings and final results. | 3 |
| Discussion (conclusion(s) and evaluation) | Valid conclusion(s) that relate to the aim of the project. | 1 |
| | Evaluations of experimental procedures to include, as appropriate, comment on:<br><br>♦ accuracy and precision of experimental measurements<br>♦ adequacy of repeated readings<br>♦ adequacy of range over which variables are altered<br>♦ adequacy of control of variables<br>♦ limitations of equipment<br>♦ reliability of methods<br>♦ sources of uncertainties | 3 |

| Section | Expected response | Mark allocation |
|---|---|---|
| | Coherent discussion of overall conclusion(s) and critical evaluation of the project as a whole, to include, as appropriate, comment on**:**<br><br>♦ selection of procedures<br>♦ problems encountered during planning<br>♦ modifications to planned procedures<br>♦ interpretation and significance of findings<br>♦ suggestions for further improvements to procedures<br>♦ suggestions for further work | 3 |
| | A report which indicates a quality project. | 1 |
| Presentation | Appropriate structure, including informative title, contents page and page numbers. | 1 |
| | References cited in the text and listed at an appropriate point in the report. Citing and listing using either Vancouver or Harvard referencing system. | 1 |
| **Total** | | **30** |

The project report is submitted to SQA for external marking.

All marking is quality assured by SQA.

## Assessment conditions

### Time

Candidates should start their project at an appropriate point in the course.

SQA does not prescribe a maximum time allocation for the project but it is expected that candidates will spend 10-15 hours on experimental work. Candidates may choose to spend additional time on experimental work.

### Supervision, control and authentication

The project is conducted under some supervision and control. This means that candidates may complete part of the work outwith the learning and teaching setting.

Teachers and lecturers must make sure candidates understand the requirements of the project from the outset.

Teachers and lecturers must put in place mechanisms to ensure that the project is the work of the individual candidate, for example by:

- having regular progress meetings with candidates
- conducting spot-check interviews with candidates

- regularly reviewing candidates' daybooks
- completing checklists to record candidates' progress

Teachers and lecturers must exercise their professional responsibility to ensure that the project report submitted by a candidate is the candidate's own work.

### Resources

There are no restrictions on the resources to which candidates may have access.

### Reasonable assistance

The term 'reasonable assistance' is used to try to balance the need for support with the need to avoid giving too much assistance, for example, drawing out or teasing out points without leading candidates. Candidates sometimes get stuck at a particular part of a task. In such cases, a teacher or lecturer could assist by raising other questions that make the candidate think about the original problem, therefore giving them the opportunity to answer their own questions without supplying the actual answers.

Teachers and lecturers must be careful that the integrity of the assessment is not compromised. Teachers and lecturers must not provide model answers.

## Evidence to be gathered

The following candidate evidence is required for this assessment:

- a project report

The project report is submitted to SQA, within a given timeframe, for marking.

The same project report cannot be submitted for more than one subject.

### Volume

The project report should be between 2500 and 4500 words in length, excluding the title page, contents page, tables of data, graphs, diagrams, calculations, references and acknowledgements.

Candidates must include their word count on the project report flyleaf.

If the word count exceeds the maximum by 10%, a penalty is applied.

# Grading

Candidates' overall grades are determined by their performance across the course assessment. The course assessment is graded A–D on the basis of the total mark for all course assessment components.

### Grade description for C

For the award of grade C, candidates will typically have demonstrated successful performance in relation to the skills, knowledge and understanding for the course by:

- retaining knowledge and scientific skills over an extended period of time
- integrating knowledge and understanding and scientific skills acquired throughout the course
- applying knowledge and understanding and scientific skills in a variety of contexts
- applying knowledge and understanding and scientific skills to solve problems
- selecting, analysing and presenting relevant information collected through experimental, observational or research work
- reporting in a scientific manner that communicates the physics

### Grade description for A

For the award of grade A, candidates will typically have demonstrated a consistently high level of performance in relation to the skills, knowledge and understanding for the course by:

- retaining an extensive range of knowledge and scientific skills over an extended period of time
- integrating an extensive range of knowledge and understanding and scientific skills acquired throughout the course
- applying knowledge and understanding and scientific skills in a variety of complex contexts
- integrating knowledge and understanding and scientific skills to solve problems in a variety of complex contexts
- showing proficiency in selecting, analysing and presenting relevant information, collected through experimental, observational or research work
- showing proficiency in reporting in a scientific manner, which communicates the physics by analysing and interpreting information in a critical and scientific manner, and demonstrating depth of knowledge and understanding

# Equality and inclusion

This course is designed to be as fair and as accessible as possible with no unnecessary barriers to learning or assessment.

Guidance on assessment arrangements for disabled candidates and/or those with additional support needs is available on the assessment arrangements web page: www.sqa.org.uk/assessmentarrangements.

# Further information

- Advanced Higher Physics subject page
- Assessment arrangements web page
- Building the Curriculum 3–5
- Guide to Assessment
- Guidance on conditions of assessment for coursework
- SQA Skills Framework: Skills for Learning, Skills for Life and Skills for Work
- Coursework Authenticity: A Guide for Teachers and Lecturers
- Educational Research Reports
- SQA Guidelines on e-assessment for Schools
- SQA e-assessment web page

The SCQF Framework, level descriptors and handbook are available on the SCQF website.

# Appendix: course support notes

## Introduction

These support notes are not mandatory. They provide advice and guidance to teachers and lecturers on approaches to delivering the course. Please read these course support notes in conjunction with the course specification, the specimen question paper and the project assessment task.

## Developing skills, knowledge and understanding

This section provides further advice and guidance about skills, knowledge and understanding that are included in the course. Teachers and lecturers have considerable flexibility to select contexts that stimulate and challenge candidates, offering both breadth and depth. Flexibility and differentiation of tasks should be built into the course to allow candidates of differing abilities to demonstrate achievement.

Learning and teaching should build on candidates' prior knowledge, skills and understanding. Candidates should be given opportunities to take responsibility for their learning.

An investigative approach is encouraged in physics, with candidates actively involved in developing their skills, knowledge and understanding. A holistic approach should be adopted to encourage the simultaneous development of candidates' conceptual understanding and skills.

Investigative and experimental work is an important part of the scientific method of working and can fulfil a number of educational purposes. Where appropriate, investigative work/experiments in physics should allow candidates the opportunity to select activities and/or carry out extended study.

Learning and teaching should offer opportunities for candidates to work collaboratively. Practical activities and investigative work can offer opportunities for group work. **However, group work is not allowed in the project. The project must be the work of the individual candidate.**

Laboratory work should include the use of technology and equipment to reflect current practices in physics. Teachers and lecturers are responsible for ensuring that appropriate risk assessment has been undertaken.

In addition to the programmed learning time of 160 hours, candidates are expected to contribute time of their own.

Effective partnership working can enhance the learning experience. Guest speakers from industry, further education and higher education could be invited to share their knowledge of particular aspects of physics.

Technology makes a significant contribution to the physics course. In addition to using computers as a learning tool, computer animations and simulations can help develop candidates' understanding of physics principles and processes. Computer interfacing equipment can detect changes in variables, allowing experimental results to be recorded and processed. Results can also be displayed in real time, which helps to improve understanding.

# Approaches to learning and teaching

Assessment is integral to learning and teaching. Candidates can benefit from self- and peer-assessment techniques, wherever appropriate. Assessment information can be used to set learning targets and next steps, and provide supportive feedback.

Teaching should involve a range of approaches to develop skills, knowledge and understanding. The mandatory content **can be taught in any order** and may be integrated into a sequence of activities, centred on an idea, theme or application of physics, or based on a variety of discrete contexts.

Examples of possible learning and teaching activities can be found in the following table. The first column matches the 'Skills, knowledge and understanding for the course assessment' section in the course specification. The second column offers suggested activities that could be used to enhance learning and teaching. All resources named are correct at the time of publication, and may be subject to change.

Learning should be experiential, active, challenging, and enjoyable. It must include appropriate practical experimental work.

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Kinematic relationships** | |
| Knowledge that differential calculus notation is used to represent rate of change.<br><br>Knowledge that velocity is the rate of change of displacement with time, acceleration is the rate of change of velocity with time, and acceleration is the second differential of displacement with time.<br><br>Derivation of the equations of motion $v = u + at$ and $s = ut + \frac{1}{2}at^2$, using calculus methods.<br><br>Use of calculus methods to calculate instantaneous displacement, velocity and acceleration for straight line motion with a constant or varying acceleration.<br><br>Use of appropriate relationships to carry out calculations involving displacement, velocity, acceleration, and time for straight line motion with constant or varying acceleration. | |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
| --- | --- |
| **Kinematic relationships (continued)** | |
| $v = \frac{ds}{dt}$<br>$a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$<br>$\left.\begin{array}{l} v = u + at \\ s = ut + \frac{1}{2}at^2 \\ v^2 = u^2 + 2as \end{array}\right\}$ for constant acceleration only | |
| Knowledge that the gradient of a curve (or a straight line) on a motion-time graph represents instantaneous rate of change, and can be found by differentiation. | |
| Knowledge that the gradient of a curve (or a straight line) on a displacement-time graph is the instantaneous velocity, and that the gradient of a curve (or a straight line) on a velocity-time graph is the instantaneous acceleration. | |
| Knowledge that the area under a line on a graph can be found by integration. | Using motion sensors, data logging and video analysis to enable graphical representation of motion. |
| Knowledge that the area under an acceleration-time graph between limits is the change in velocity and that the area under a velocity-time graph between limits is the displacement. | |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Kinematic relationships (continued)** | |
| Determination of displacement, velocity or acceleration by the calculation of the gradient of the line on a graph or the calculation of the area under the line between limits on a graph. | |
| **Angular motion** | |
| Use of the radian as a measure of angular displacement.<br><br>Conversion between degrees and radians.<br><br>Use of appropriate relationships to carry out calculations involving angular displacement, angular velocity, angular acceleration, and time. | Introduce angular motion by considering the rotational equivalents of displacement, velocity and acceleration.<br><br>Experiment to determine the average angular velocity of a rotating object. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Angular motion (continued)** | |
| $\omega = \frac{d\theta}{dt}$<br><br>$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$<br><br>$\left.\begin{array}{l}\omega = \omega_o + \alpha t \\ \omega^2 = \omega_o^2 + 2\alpha\theta \\ \theta = \omega_o t + \frac{1}{2}\alpha t^2\end{array}\right\}$ for constant angular acceleration only<br><br>Use of appropriate relationships to carry out calculations involving angular and tangential motion.<br><br>$s = r\theta$<br><br>$v = r\omega$<br><br>$a_t = r\alpha$ | Experiment to determine the angular acceleration of an object rotating with constant angular acceleration. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Angular motion (continued)** | |
| Use of appropriate relationships to carry out calculations involving constant angular velocity, period and frequency.<br><br>$\omega = \frac{2\pi}{T}$<br><br>$\omega = 2\pi f$<br><br>Knowledge that a centripetal (radial or central) force acting on an object is necessary to maintain circular motion, and results in centripetal (radial or central) acceleration of the object.<br><br>Use of appropriate relationships to carry out calculations involving centripetal acceleration and centripetal force.<br><br>$a_r = \frac{v^2}{r} = r\omega^2$<br><br>$F = \frac{mv^2}{r} = mr\omega^2$ | Investigate factors that determine size of centripetal (radial or central) force required to maintain circular motion.<br><br>Experiment to verify the relationship $F = mr\omega^2$<br><br>Consider centripetal forces acting in 'loop-the-loop' experiments, conical pendulum aircraft banking, cycle velodromes, and theme park rides. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Rotational dynamics** | |
| Knowledge that an unbalanced torque causes a change in the angular (rotational) motion of an object. | |
| Definition of moment of inertia of an object as a measure of its resistance to angular acceleration about a given axis. | Compare mass of an object (measured on a balance) with its inertial mass (determined using a wig-wag machine). |
| Knowledge that moment of inertia depends on mass and the distribution of mass about a given axis of rotation. | |
| Use of an appropriate relationship to calculate the moment of inertia for a point mass.<br><br>$I = mr^2$ | |
| Use of an appropriate relationship to calculate the moment of inertia for discrete masses.<br><br>$I = \sum mr^2$ | Experiment using a variable inertia bar. |
| Use of appropriate relationships to calculate the moment of inertia for rods, discs and spheres about given axes. | Compare qualitatively the calculated moment of inertia of different objects with the torque required to change their rotational motion. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Rotational dynamics (continued)** | |
| rod about centre $I = \frac{1}{12}ml^2$<br><br>rod about end $I = \frac{1}{3}ml^2$<br><br>disc about centre $I = \frac{1}{2}mr^2$<br><br>sphere about centre $I = \frac{2}{5}mr^2$ | |
| Use of appropriate relationships to carry out calculations involving torque, perpendicular force, distance from the axis, angular acceleration, and moment of inertia.<br><br>$\tau = Fr$<br><br>$\tau = I\alpha$ | Investigate the relationship between the torque applied to a turntable and the angular acceleration of the turntable.<br><br>Consider the operation of a torque wrench.<br><br>Consider the meaning of the term engine torque. |
| Use of appropriate relationships to carry out calculations involving angular momentum, angular velocity , moment of inertia, tangential velocity, mass and its distance from the axis. | |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Rotational dynamics (continued)** | |
| $L = mvr = mr^2\omega$<br><br>$L = I\omega$<br><br>Statement of the principle of conservation of angular momentum. | Determination of the moment of inertia of an object from a graph, drawn using experimental data, of angular acceleration against applied torque. |
| Use of the principle of conservation of angular momentum to solve problems.<br><br>Use of appropriate relationships to carry out calculations involving potential energy, rotational kinetic energy, translational kinetic energy, angular velocity, linear velocity, moment of inertia, and mass.<br><br>$E_{k\ (\text{rotational})} = \frac{1}{2}I\omega^2$<br><br>$E_P = E_{k\ (\text{translational})} + E_{k\ (\text{rotational})}$ | Experiment to determine the angular momentum of a point mass $m$ rotating at velocity $v$ and distance $r$ about an axis. (Mass on end of string.)<br><br>Experiment to verify the principle of conservation of angular momentum.<br><br>Experiment to demonstrate the conservation of angular momentum using a rotating platform, added mass and a data logger to plot a graph of angular velocity against time.<br><br>Demonstrate the conservation of angular momentum using a person rotating on an office chair, with arms pulled in and then extended. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Rotational dynamics (continued)** | |
| | Consider the application of the principle of conservation of angular momentum in gyroscopes, bicycle wheels, spinning tops, ice skaters, divers, and gymnasts.<br><br>Experiment to determine the moment of inertia of a cylinder rolling down a slope.<br><br>Experiment to determine the moment of inertia of a flywheel.<br><br>Compare the motions of a solid cylinder and a hollow cylinder, of the same radius and mass, rolling down a slope.<br><br>Consider the increase in rotational kinetic energy when a rotating system increases angular velocity, for example work done by a skater pulling their arms inwards. |
| **Gravitation** | |
| Conversion between astronomical units (AU) and metres and between light-years (ly) and metres. | |
| Definition of gravitational field strength as the gravitational force acting on a unit mass. | Consider Maskelyne's Schiehallion experiment.<br><br>Consider Cavendish/Boys experiment. |
| Sketch of gravitational field lines and field line patterns around astronomical objects and astronomical systems involving two objects. | Consideration of the effects of the force of gravity on tides, tidal forces and sustainable tidal energy. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Gravitation (continued)** | |
| Use of an appropriate relationship to carry out calculations involving gravitational force, masses and their separation.<br><br>$F = \frac{GMm}{r^2}$ | |
| Use of appropriate relationships to carry out calculations involving period of satellites in circular orbit, masses, orbit radius, and satellite speed.<br><br>$F = \frac{GMm}{r^2} = \frac{mv^2}{r} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$ | Consider the relationship between the force of gravity and the orbital altitude and period of a satellite.<br><br>Consider the altitude and orbital periods of different types of satellite, for example data gathering, weather, telecommunications, mapping and surveying. |
| Definition of the gravitational potential of a point in space as the work done in moving unit mass from infinity to that point.<br><br>Knowledge that the energy required to move mass between two points in a gravitational field is independent of the path taken. | |
| Use of appropriate relationships to carry out calculations involving gravitational potential, gravitational potential energy, masses and their separation. | Consideration of gravitational potential and gravitational potential energy having the value zero at infinity and of gravitational potential wells used as an illustration of the capture of masses. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Gravitation (continued)** | |
| $V = -\frac{GM}{r}$<br><br>$E_P = Vm = -\frac{GMm}{r}$<br><br>Definition of escape velocity as the minimum velocity required to allow a mass to escape a gravitational field to infinity, where the mass achieves zero kinetic energy and maximum (zero) potential energy. | Consider changes in potential, potential energy and kinetic energy when the altitude of a satellite changes. |
| Derivation of the relationship $v_{esc} = \sqrt{\frac{2GM}{r}}$ .<br>Use of an appropriate relationship to carry out calculations involving escape velocity, mass and distance.<br><br>$v_{esc} = \sqrt{\frac{2GM}{r}}$ . | Consider the link between the composition of a planet's atmosphere and its escape velocity. For example, consideration of the low abundance of helium in Earth's atmosphere.<br><br>Consider the implications of the escape velocity of a planet for space flight. |
| **General relativity** | |
| Knowledge that special relativity deals with motion in inertial (non-accelerating) frames of reference and that general relativity deals with motion in non-inertial (accelerating) frames of reference. | Compare the implications of general relativity and special relativity. |

| **Rotational motion and astrophysics**<br>**Mandatory content** | **Suggested activities** |
|---|---|
| **General relativity (continued)** | |
| Statement of the equivalence principle (that it is not possible to distinguish between the effects on an observer of a uniform gravitational field and of a constant acceleration) and knowledge of its consequences.<br><br>Consideration of spacetime as a unified representation of three dimensions of space and one dimension of time.<br><br>Knowledge that general relativity leads to the interpretation that mass curves spacetime, and that gravity arises from the curvature of spacetime.<br><br>Knowledge that light or a freely moving object follows a geodesic (the path with the shortest distance between two points) in spacetime. | View videos showing simulations of the effects of general relativity and special relativity.<br><br>Consider clocks in non-inertial frames of reference, for example accelerating spacecraft, and the application of the equivalence principle. This leads to the conclusion that, for a distant observer, time runs more slowly at lower altitudes than at higher altitudes in a gravitational field. (This explains the need for GPS clock adjustment.)<br><br>Consider the reasons for the precession of the perihelion of Mercury. |
| Representation of world lines for objects which are stationary, moving with constant velocity and accelerating. | Use a rubber sheet and masses to demonstrate the effect of masses on spacetime. |
| Knowledge that the escape velocity from the event horizon of a black hole is equal to the speed of light. | View videos showing simulations of black holes. |
| Knowledge that, from the perspective of a distant observer, time appears to be frozen at the event horizon of a black hole. | Consider the phenomenon of gravitational lensing. |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **General relativity (continued)** | |
| Knowledge that the Schwarzschild radius of a black hole is the distance from its centre (singularity) to its event horizon.<br><br>Use of an appropriate relationship to solve problems relating to the Schwarzschild radius of a black hole.<br><br>$r_{Schwarzschild} = \frac{2GM}{c^2}$ | |
| **Stellar physics** | |
| Use of appropriate relationships to solve problems relating to luminosity, apparent brightness $b$, distance between the observer and the star, power per unit area, stellar radius, and stellar surface temperature. (Using the assumption that stars behave as black bodies.)<br><br>$b = \frac{L}{4\pi d^2}$<br><br>$\frac{P}{A} = \sigma T^4$<br><br>$L = 4\pi r^2 \sigma T^4$ | |

| Rotational motion and astrophysics<br>Mandatory content | Suggested activities |
|---|---|
| **Stellar physics (continued)** | |
| Knowledge that stars are formed in interstellar clouds when gravitational forces overcome thermal pressure and cause a molecular cloud to contract until the core becomes hot enough to sustain nuclear fusion, which then provides a thermal pressure that balances the gravitational force.<br><br>Knowledge of the stages in the proton-proton chain (p-p chain) in stellar fusion reactions which convert hydrogen to helium. One example of a p-p chain is:<br><br>$^{1}_{1}\text{H} + ^{1}_{1}\text{H} \rightarrow ^{2}_{1}\text{H} + ^{0}_{+1}\text{e} + \nu_e$<br><br>$^{2}_{1}\text{H} + ^{1}_{1}\text{H} \rightarrow ^{3}_{2}\text{He} + \gamma$<br><br>$^{3}_{2}\text{He} + ^{3}_{2}\text{He} \rightarrow ^{4}_{2}\text{He} + 2^{1}_{1}\text{H}$<br><br>Knowledge that Hertzsprung-Russell (H-R) diagrams are a representation of the classification of stars.<br><br>Classification of stars and position in Hertzsprung-Russell (H-R) diagrams, including main sequence, giant, supergiant, and white dwarf.<br><br>Use of Hertzsprung-Russell (H-R) diagrams to determine stellar properties, including prediction of colour of stars from their position in an H-R diagram. | View videos describing and explaining stellar evolution.<br><br>View videos describing H-R diagrams.<br><br>Consider the range of data that can be displayed in an H-R diagram. |

| **Rotational motion and astrophysics**<br>**Mandatory content** | **Suggested activities** |
|---|---|
| **Stellar physics (continued)** | |
| Knowledge that the fusion of hydrogen occurs in the core of stars in the main sequence of a Hertzsprung-Russell (H-R) diagram.<br><br>Knowledge that hydrogen fusion in the core of a star supplies the energy that maintains the star's outward thermal pressure to balance inward gravitational forces. When the hydrogen in the core becomes depleted, nuclear fusion in the core ceases. The gas surrounding the core, however, will still contain hydrogen. Gravitational forces cause both the core and the surrounding shell of hydrogen to shrink. In a star like the Sun, the hydrogen shell becomes hot enough for hydrogen fusion in the shell of the star. This leads to an increase in pressure which pushes the surface of the star outwards, causing it to cool. At this stage, the star will be in the giant or supergiant regions of a Hertzspung-Russell (H-R) diagram.<br><br>Knowledge that, in a star like the Sun, the core shrinks and will become hot enough for the helium in the core to begin fusion.<br><br>Knowledge that the mass of a star determines its lifetime.<br><br>Knowledge that every star ultimately becomes a white dwarf, a neutron star or a black hole. The mass of the star determines its eventual fate. | |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Introduction to quantum theory** | |
| Knowledge of experimental observations that cannot be explained by classical physics, but can be explained using quantum theory:<br><br>♦ black-body radiation curves (ultraviolet catastrophe)<br>♦ the formation of emission and absorption spectra<br>♦ the photoelectric effect | Analyse black body radiation curves.<br><br>Observe emission and absorption spectra.<br><br>Use a spectroscope/spectrometer to examine line emission spectra. |
| Use of an appropriate relationship to solve problems involving photon energy and frequency.<br><br>$E = hf$ | Experimental observation of the photoelectric effect |
| Knowledge of the Bohr model of the atom in terms of the quantisation of angular momentum, the principal quantum number $n$ and electron energy states, and how this explains the characteristics of atomic spectra.<br><br>Use of an appropriate relationship to solve problems involving the angular momentum of an electron and its principal quantum number.<br><br>$mvr = \frac{nh}{2\pi}$ | Observe stationary waves in wire loops. |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Introduction to quantum theory (continued)** | |
| Description of experimental evidence for the particle-like behaviour of ‘waves’ and for the wave-like behaviour of ‘particles’.<br><br>Use of an appropriate relationship to solve problems involving the de Broglie wavelength of a particle and its momentum.<br><br>$\lambda = \frac{h}{p}$<br><br>Knowledge that it is not possible to know the position and the momentum of a quantum particle simultaneously.<br><br>Knowledge that it is not possible to know the lifetime of a quantum particle and the associated energy change simultaneously.<br><br>Use of appropriate relationships to solve problems involving the uncertainties in position, momentum, energy, and time. The lifetime of a quantum particle can be taken as the uncertainty in time.<br><br>$\Delta x \Delta p_x \geq \frac{h}{4\pi}$<br><br>$\Delta E \Delta t \geq \frac{h}{4\pi}$ | View videos showing simulations of double-slit experiments with single particles (photons or electrons).<br><br>Examine evidence of wave-particle duality — for example electron diffraction, photoelectric effect and Compton scattering.<br><br>View videos of explanations and demonstrations of the Heisenberg uncertainty principle.<br><br>View videos showing simulations of quantum tunnelling.<br><br>Consider frustrated total internal reflection as an optical analogue of quantum tunnelling. |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Introduction to quantum theory (continued)** | |
| Knowledge of implications of the Heisenberg uncertainty principle, including the concept of quantum tunnelling, in which a quantum particle can exist in a position that, according to classical physics, it has insufficient energy to occupy. | Class discussion, allowing each individual to describe their understanding of quantum physics and of the Heisenberg uncertainty principle. |
| **Particles from space** | |
| Knowledge of the origin and composition of cosmic rays and the interaction of cosmic rays with Earth's atmosphere.<br><br>Knowledge of the composition of the solar wind as charged particles in the form of plasma.<br><br>Explanation of the helical motion of charged particles in the Earth's magnetic field.<br><br>Use of appropriate relationships to solve problems involving the force on a charged particle, its charge, its mass, its velocity, the radius of its path, and the magnetic induction of a magnetic field. | View videos showing an aurora.<br><br>Research on how an aurora is produced in the upper atmosphere.<br><br>Research on the solar cycle and solar flares, for example the Carrington flare of 1859. |

| **Quanta and waves**<br>**Mandatory content** | **Suggested activities** |
|---|---|
| **Particles from space (continued)** | |
| $F = qvB$<br><br>$F = \frac{mv^2}{r}$ | |
| **Simple harmonic motion (SHM)** | |
| Definition of SHM in terms of the restoring force and acceleration proportional to, and in the opposite direction to, the displacement from the rest position.<br><br>Use of calculus methods to show that expressions in the form of $y = A\sin\omega t$ and $y = A\cos\omega t$ are consistent with the definition of SHM ($a = -\omega^2 y$).<br><br>Derivation of the relationships $v = \pm\omega\sqrt{(A^2 - y^2)}$ and $E_k = \frac{1}{2}m\omega^2(A^2 - y^2)$ .<br><br>Use of appropriate relationships to solve problems involving the displacement, velocity, acceleration, force, mass, spring constant $k$, angular frequency, period, and energy of an object executing SHM. | Investigate different oscillating SHM systems, for example simple pendulum, compound pendulum, mass on a spring, trolley and two spring system, and loaded test tube in water.<br><br>Demonstrate the link between circular motion and SHM.<br><br>Experiment using SHM to measure the acceleration due to gravity.<br><br>Investigate the factors affecting the period of oscillation of an object moving with SHM.<br><br>Investigate the relationship between force applied and extension of a spring. |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Simple harmonic motion (SHM) (continued)** | |
| $F = -ky$<br><br>$\omega = 2\pi f = \frac{2\pi}{T}$<br><br>$a = \frac{d^2y}{dt^2} = -\omega^2 y$<br><br>$y = A\cos\omega t$ or $y = A\sin\omega t$<br><br>$v = \pm\omega\sqrt{(A^2 - y^2)}$<br><br>$E_k = \frac{1}{2}m\omega^2(A^2 - y^2)$<br><br>$E_P = \frac{1}{2}m\omega^2 y^2$<br><br>Knowledge of the effects of damping in SHM to include underdamping, critical damping and overdamping. | Investigate the relationship between kinetic and potential energy for an object moving with SHM.<br><br>Investigate damped and undamped systems using a motion sensor or a smartphone as an accelerometer. |
| **Waves** | |
| Use of an appropriate relationship to solve problems involving the energy transferred by a wave and its amplitude.<br><br>$E = kA^2$ | |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Waves (continued)** | |
| Knowledge of the mathematical representation of travelling waves.<br><br>Use of appropriate relationships to solve problems involving wave motion, phase difference and phase angle.<br><br>$y = A\sin 2\pi\left(ft - \frac{x}{\lambda}\right)$<br><br>$\phi = \frac{2\pi x}{\lambda}$ | Simulation of a transverse wave leading to understanding of the mathematical representation. |
| Knowledge that stationary waves are formed by the interference of two waves, of the same frequency and amplitude, travelling in opposite directions. A stationary wave can be described in terms of nodes and antinodes. | Demonstrate stationary waves using a slinky.<br><br>Investigate stationary waves using vibrator and elastic string, using Melde's experiment.<br><br>Experiment to measure the wavelength of sound or of microwaves, using stationary waves.<br><br>Experiment to determine the speed of sound in air using stationary waves, using a resonance tube.<br><br>Investigate synthesisers, related to the addition of waves, leading to Fourier analysis. |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Waves (continued)** | |
| | Investigate the source of sound from wind- and string-musical instruments.<br><br>Investigate fundamental and harmonic frequencies.<br><br>Investigate the use of beats to tune musical instruments. |
| **Interference** | |
| Knowledge that two waves are coherent if they have a constant phase relationship.<br><br>Knowledge of the conditions for constructive and destructive interference in terms of coherence and phase.<br><br>Use of an appropriate relationship to solve problems involving optical path difference $opd$, geometrical path difference $gpd$ and refractive index.<br><br>$opd = n \times gpd$ | |
| Knowledge that a wave experiences a phase change of $\pi$ when it is travelling in a less dense medium and reflects from an interface with a more dense medium. | Slinky demonstration of a phase change of $\pi$ in a wave reflected from a boundary. |
| Knowledge that a wave does not experience a phase change when it is travelling in a more dense medium and reflects from an interface with a less dense medium. | Slinky demonstration of no phase change in a wave reflected from a boundary. |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Interference (continued)** | |
| Explanation of interference by division of amplitude, including optical path length, geometrical path length, phase difference, and optical path difference. | |
| Knowledge of thin film interference and wedge fringes. | Investigate thin-film interference in oil films or soap bubbles using an extended light source.<br><br>Investigate Newton's Rings. |
| For light interfering by division of amplitude, use of an appropriate relationship to solve problems involving the optical path difference between waves, wavelength and order number.<br><br>$opd = m\lambda$ or $\left(m+\frac{1}{2}\right)\lambda$ where $m = 0,1,2...$ | Wiener's experiment<br><br>Experiment to determine the thickness of a sheet of paper or a human hair using wedge fringes. |
| Knowledge that a coated (bloomed) lens can be made non-reflective for a specific wavelength of light.<br><br>Derivation of the relationship $d = \frac{\lambda}{4n}$ for glass lenses with a coating such as magnesium fluoride. | |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Interference (continued)** | |
| Use of appropriate relationships to solve problems involving interference of waves by division of amplitude.<br><br>$\Delta x = \frac{\lambda l}{2d}$<br><br>$d = \frac{\lambda}{4n}$<br><br>Explanation of interference by division of wavefront.<br><br>Knowledge of Young's slits interference.<br><br>Use of an appropriate relationship to solve problems involving interference of waves by division of wavefront.<br><br>$\Delta x = \frac{\lambda D}{d}$ | <br><br><br><br><br><br><br><br><br><br><br>Experiment to determine the wavelength of laser light using Young's slits. |
| **Polarisation** | |
| Knowledge of what is meant by a plane-polarised wave.<br><br>Knowledge of the effect on light of polarisers and analysers. | Use a polariser and analyser to observe the difference between plane-polarised and unpolarised waves.<br><br>Investigate the polarisation of microwaves and light. |

| Quanta and waves<br>Mandatory content | Suggested activities |
|---|---|
| **Polarisation (continued)** | |
| Knowledge that when a ray of unpolarised light is incident on the surface of an insulator at Brewster's angle the reflected ray becomes plane-polarised. | Investigate reflected laser (polarised) light from a glass surface through a polarising filter, as the angle of incidence is varied. |
| Derivation of the relationship $n = \tan i_p$ . | Research liquid crystal displays, computer/phone displays, polarising lenses, optical activity, photoelasticity, and saccharimetry. |
| Use of an appropriate relationship to solve problems involving Brewster's angle and refractive index.<br><br>$n = \tan i_p$ | Stress analysis of Perspex models of structures. |

| Electromagnetism<br>Mandatory content | Suggested activities |
|---|---|
| **Fields** | |
| Knowledge that an electric field is the region that surrounds electrically charged particles in which a force is exerted on other electrically charged particles.<br><br>Definition of electric field strength as the electrical force acting on unit positive charge.<br><br>Sketch of electric field patterns around single point charges, a system of charges and in a uniform electric field.<br><br>Definition of electrical potential at a point as the work done in moving unit positive charge from infinity to that point.<br><br>Knowledge that the energy required to move charge between two points in an electric field is independent of the path taken.<br><br>Use of appropriate relationships to solve problems involving electrical force, electrical potential and electric field strength around a point charge and a system of charges. | Observe field lines around charged objects.<br><br>Research the physics underlying electrostatic spray painting<br><br>Research the physics underlying the operation of virtual-reality (VR) goggles. |

| Electromagnetism<br>Mandatory content | Suggested activities |
|---|---|
| **Fields (continued)** | |
| $F = \frac{Q_1Q_2}{4\pi\varepsilon_o r^2}$<br><br>$V = \frac{Q}{4\pi\varepsilon_o r}$<br><br>$E = \frac{Q}{4\pi\varepsilon_o r^2}$<br><br>Use of appropriate relationships to solve problems involving charge, energy, potential difference, and electric field strength in situations involving a uniform electric field.<br><br>$F = QE$<br><br>$V = Ed$<br><br>$W = QV$ | |
| Knowledge of Millikan's experimental method for determining the charge on an electron. | View videos showing simulations of Millikan's experiment.<br><br>Carry out Millikan's experiment. |
| Use of appropriate relationships to solve problems involving the motion of charged particles in uniform electric fields. | Investigate the motion of charged particles in uniform electric fields, using a Teltron deflection tube.<br><br>Research particle accelerators, cosmic rays, Compton scattering, and oscilloscope deflecting plates. |

| Electromagnetism<br>Mandatory content | Suggested activities |
|---|---|
| **Fields (continued)** | |
| $F = QE$<br><br>$V = Ed$<br><br>$W = QV$<br><br>$E_k = \frac{1}{2}mv^2$<br><br>Knowledge that the electronvolt (eV) is the energy acquired when one electron accelerates through a potential difference of one volt.<br><br>Conversion between electronvolts and joules<br><br>Knowledge that electrons are in motion around atomic nuclei and individually produce a magnetic effect.<br><br>Knowledge that, for example, iron, nickel, cobalt, and some rare earths exhibit a magnetic effect called ferromagnetism, in which magnetic dipoles can be made to align, resulting in the material becoming magnetised.<br><br>Sketch of magnetic field patterns between magnetic poles, and around solenoids, including the magnetic field pattern around Earth. | Investigate field patterns around permanent magnets and electromagnets, for example a straight wire and a coil. |

| **Electromagnetism**<br>**Mandatory content** | **Suggested activities** |
|---|---|
| **Fields (continued)** | |
| Comparison of gravitational, electrostatic, magnetic, and nuclear forces in terms of their relative strength and range.<br><br>Use of an appropriate relationship to solve problems involving magnetic induction around a current-carrying wire, the current in the wire and the distance from the wire.<br><br>$B = \frac{\mu_o I}{2\pi r}$<br><br>Explanation of the helical path followed by a moving charged particle in a magnetic field.<br><br>Use of appropriate relationships to solve problems involving the forces acting on a current-carrying wire in a magnetic field and a charged particle in a magnetic field.<br><br>$F = IlB\sin\theta$<br><br>$F = qvB$<br><br>$F = \frac{mv^2}{r}$ | Investigate the magnetic induction at a distance from a long current-carrying wire, using a Hall probe, smartphone or search coil.<br><br>Investigate factors affecting the magnitude of the force on a current-carrying conductor in a magnetic field. |

| Electromagnetism<br>Mandatory content | Suggested activities |
|---|---|
| **Circuits** | |
| Knowledge of the variation of current and potential difference with time in an RC circuit during charging and discharging.<br><br>Definition of the time constant for an RC circuit as the time to increase the charge stored by 63% of the difference between initial charge and full charge, or the time taken to discharge the capacitor to 37% of initial charge.<br><br>Use of an appropriate relationship to determine the time constant for an RC circuit.<br><br>$\tau = RC$<br><br>Knowledge that, in an RC circuit, an uncharged capacitor can be considered to be fully charged after a time approximately equal to $5\tau$ .<br><br>Knowledge that, in an RC circuit, a fully charged capacitor can be considered to be fully discharged after a time approximately equal to $5\tau$ .<br><br>Graphical determination of the time constant for an RC circuit.<br><br>Knowledge that capacitive reactance is the opposition of a capacitor to changing current. | Investigate the variation of the current and potential difference with time in RC circuits during charging and discharging.<br><br>Research applications of capacitors in DC circuits.<br><br>Experiment to determine the time constant $(\tau)$ of an RC circuit.<br><br>Experiment to investigate the relationship between voltage, current and capacitive reactance. |

| Electromagnetism<br>Mandatory content | Suggested activities |
|---|---|
| **Circuits (continued)** | |
| Use of appropriate relationships to solve problems involving capacitive reactance, voltage, current, frequency, and capacitance.<br><br>$X_C = \frac{V}{I}$<br><br>$X_C = \frac{1}{2\pi fC}$ | Experiment to investigate the relationship between current, frequency and capacitive reactance. |
| Knowledge of the growth and decay of current in a DC circuit containing an inductor. | Investigate the factors affecting the size of the back EMF in a coil |
| Explanation of the self-inductance (inductance) of a coil.<br><br>Knowledge of Lenz's law and its implications.<br><br>Definition of inductance and of back EMF.<br><br>Knowledge that energy is stored in the magnetic field around a current-carrying inductor.<br><br>Knowledge of the variation of current with frequency in an AC circuit containing an inductor.<br><br>Knowledge that inductive reactance is the opposition of an inductor to changing current. | Demonstrate electromagnetic braking by dropping neodymium magnets through an aluminium tube.<br><br>Demonstrate the effect of back EMF in an inductive circuit, for example a neon bulb lit from 1·5 V cell.<br><br>Investigate the growth and decay of current in a DC circuit containing an inductor.<br><br>Experiment to determine the self-inductance (inductance) of a coil by use of datalogging or waveform capture. |

| Electromagnetism<br>Mandatory content | Suggested activities |
|---|---|
| **Circuits (continued)** | |
| Use of appropriate relationships to solve problems relating to inductive reactance, voltage, current, frequency, energy, and self-inductance (inductance).<br><br>$\varepsilon = -L\frac{dI}{dt}$<br><br>$E = \frac{1}{2}LI^2$<br><br>$X_L = \frac{V}{I}$<br><br>$X_L = 2\pi fL$ | Experiments to investigate the relationship between current, frequency and inductive reactance.<br><br>Research applications of inductors, for example induction hobs, hearing-aid loops, electromagnetic braking, LC filters, and tuned circuits. |

| Electromagnetism<br>Mandatory content | Suggested activities |
|---|---|
| **Electromagnetic radiation** | |
| Knowledge of the unification of electricity and magnetism.<br><br>Knowledge that electromagnetic radiation exhibits wave properties as it transfers energy through space. It has both electric and magnetic field components which oscillate in phase, perpendicular to each other and to the direction of energy propagation.<br><br>Use of an appropriate relationship to solve problems involving the speed of light, the permittivity of free space and the permeability of free space.<br><br>$c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$ | Research the nature of electromagnetic radiation.<br><br>Estimate the speed of light in air by determining permittivity using a parallel plate capacitor and determining permeability using a current balance. |

| Units, prefixes and uncertainties<br>Mandatory content | Suggested activities |
|---|---|
| **Units, prefixes and scientific notation** | |
| Appropriate use of units, including electronvolt (eV), light-year (ly) and astronomical unit (AU).<br><br>Use of SI units with all physical quantities, where appropriate.<br><br>Use of prefixes where appropriate. These include femto (f), pico (p), nano (n), micro (µ), milli (m), kilo (k), mega (M), giga (G), tera (T), and peta (P).<br><br>Use of the appropriate number of significant figures in final answers. The final answer can have no more significant figures than the data with the fewest number of significant figures used in the calculation.<br><br>Appropriate use of scientific notation. | |
| **Uncertainties** | |
| Knowledge and use of uncertainties, including systematic uncertainties, scale reading uncertainties, random uncertainties, and calibration uncertainties. | |

| Units, prefixes and uncertainties<br>Mandatory content | Suggested activities |
|---|---|
| **Uncertainties (continued)** | |
| Systematic uncertainty occurs when readings taken are either all too small or all too large. This can arise due to faulty measurement techniques or experimental design.<br><br>Scale reading uncertainty is an indication of how precisely an instrument scale can be read.<br><br>Random uncertainty arises when measurements are repeated and slight variations occur. Random uncertainty may be reduced by increasing the number of repeated measurements.<br><br>Calibration uncertainty arises when there is a difference between a manufacturer's claim for the accuracy of an instrument when compared with an approved standard.<br><br>Solve problems involving absolute uncertainties and fractional/percentage uncertainties.<br><br>Appropriate use of significant figures in absolute uncertainties. Absolute uncertainty should normally be rounded to one significant figure. In some instances, a second significant figure may be retained. | |

| Units, prefixes and uncertainties<br>Mandatory content | Suggested activities |
|---|---|
| **Data analysis** | |
| Combination of various types of uncertainties to obtain the total uncertainty in a measurement.<br><br>Knowledge that, when uncertainties in a single measurement are combined, an uncertainty can be ignored if it is less than one-third of one of the other uncertainties in the measurement.<br><br>Use of an appropriate relationship to determine the total uncertainty in a measured value.<br><br>$\Delta W = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$<br><br>Combination of uncertainties in measured values to obtain the total uncertainty in a calculated value.<br><br>Knowledge that, when uncertainties in measured values are combined, a fractional/percentage uncertainty in a measured value can be ignored if it is less than one-third of the fractional/percentage uncertainty in another measured value.<br><br>Use of an appropriate relationship to determine the total uncertainty in a value calculated from the product or quotient of measured values. | |

| Units, prefixes and uncertainties<br>Mandatory content | |
|---|---|
| **Data analysis (continued)** | |
| $$\frac{\Delta W}{W} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2 + \left(\frac{\Delta Z}{Z}\right)^2}$$<br><br>Use of an appropriate relationship to determine the uncertainty in a value raised to a power.<br><br>$$\left(\frac{\Delta W^n}{W^n}\right) = n\left(\frac{\Delta W}{W}\right)$$<br><br>Use of error bars to represent absolute uncertainties on graphs.<br><br>Estimation of uncertainty in the gradient and intercept of the line of best fit on a graph.<br><br>Correct use of the terms accuracy and precision in the context of an evaluation of experimental results. The accuracy of a measurement compares how close the measurement is to the 'true' or accepted value. The uncertainty in a measurement gives an indication of the precision of the measurement. | |

| **Units, prefixes and uncertainties**<br>**Mandatory content** | |
|---|---|
| **Evaluation of significance of experimental uncertainties** | |
| Identification of the dominant uncertainty/uncertainties in an experiment or in experimental data.<br><br>Suggestion of potential improvements to an experiment, which may reduce the dominant uncertainty/uncertainties. | |

# Preparing for course assessment

Each course has additional time which may be used at the discretion of teachers and/or lecturers to enable candidates to prepare for course assessment. This time may be used near the start of the course and at various points throughout the course for consolidation and support. It may also be used towards the end of the course for further integration, revision and preparation.

This course is assessed by using a question paper and a project.

The question paper assesses a selection of knowledge and skills acquired in the course. It also provides opportunities to apply skills in a range of contexts, some of which may be unfamiliar.

During delivery of the course, teachers and lecturers should give candidates opportunities to:

- identify particular aspects of work requiring reinforcement and support
- develop skills of scientific inquiry and investigation in preparation for the project
- practise responding to short-answer, extended-answer and open-ended questions
- improve exam technique

# Developing skills for learning, skills for life and skills for work

Teachers and/or lecturers should identify opportunities throughout the course for candidates to develop skills for learning, skills for life and skills for work.

Candidates should be aware of the skills they are developing and you can provide advice on opportunities to practise and improve them.

SQA does not formally assess skills for learning, skills for life and skills for work.

There may also be opportunities to develop additional skills depending on the approach centres use to deliver the course. This is for individual teachers and lecturers to manage.

During this course, candidates should significantly develop the following skills for learning, skills for life and skills for work:

**Literacy**
Writing means the ability to create texts which communicate ideas, opinions and information to meet a purpose, and within a context. In this context, ‘texts’ are defined as word-based materials (sometimes with supporting images) which are written, printed, Braille or displayed on screen. These will be technically accurate for the purpose, audience and context.

**1.1 Reading**
Candidates understand and interpret a variety of scientific texts.

**1.2 Writing**
Candidates use skills to effectively communicate key areas of physics, make informed decisions and clearly explain physics issues in various media forms. Candidates have the opportunity to communicate applied knowledge and understanding throughout the course.

There are opportunities to develop the literacy skills of listening and reading when gathering and processing information in physics.

**Numeracy**
This is the ability to use numbers in order to solve problems by counting, doing calculations, measuring, and understanding graphs and charts. This is also the ability to understand the results.

Candidates have opportunities to extract, process and interpret information presented in numerous formats including tabular and graphical. Practical work will provide opportunities to develop time and measurement skills.

**2.1 Number processes**
Number processes mean solving problems arising in everyday life through carrying out calculations when dealing with data and results from experiments/investigations and everyday class work, making informed decisions based on the results of these calculations, and understanding these results.

**2.2 Money, time and measurement**
The accuracy of measurements is important when handling data in a variety of physics contexts, including practical and investigative. Consideration should be given to uncertainties.

**2.3 Information handling**
Information handling means being able to gather and interpret physics data in tables, charts and other graphical displays to draw sensible conclusions throughout the course. It involves interpreting the data and considering its reliability in making reasoned deductions and informed decisions. It also involves an awareness and understanding of the chance of events happening.

**Thinking skills**
This is the ability to develop the cognitive skills of remembering and identifying, understanding and applying.

The course allows candidates to develop skills of applying, analysing and evaluating. Candidates can analyse and evaluate practical work and data by reviewing the process, identifying issues and forming valid conclusions. They can demonstrate understanding and application of key areas and explain and interpret information and data.

**5.3 Applying**
Applying is the ability to use existing information to solve physics problems in different contexts, and to plan, organise and complete a task, such as an investigation.

**5.4 Analysing and evaluating**
This covers the ability to identify and weigh-up the features of a situation or issue in physics and to draw valid conclusions. It includes reviewing and considering any potential solutions.

**5.5 Creating**
This is the ability to design something innovative or to further develop an existing thing by adding new dimensions or approaches. Candidates can demonstrate their creativity, in particular, when planning and designing physics experiments or investigations. Candidates have the opportunity to be innovative in their approach. Candidates also have opportunities to make, write, say or do something new.

Candidates also have opportunities to develop working with others and citizenship.

**Working with others**
Learning activities provide many opportunities, in all areas of the course, for candidates to work with others. Practical activities and investigations, in particular, offer opportunities for group work, which is an important aspect of physics, and should be encouraged. The project, including the practical work, must be the individual work of the candidate, and not group work.

**Citizenship**
Candidates develop citizenship skills when considering the applications of physics in our lives, as well as the implications for the environment and/or society.

# Administrative information

**Published:** August 2019 (version 2.0)

## History of changes

| Version | Description of change | Date |
|---|---|---|
| 2.0 | Course support notes added as appendix. | August 2019 |
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| | | |

Note: please check SQA's website to ensure you are using the most up-to-date version of this document.

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