

# Course content

The course content includes the following areas of physics:

## **Our dynamic Universe**

The topics covered are:

- ◆ motion — equations and graphs
- ◆ forces, energy and power
- ◆ collisions, explosions, and impulse
- ◆ gravitation
- ◆ special relativity
- ◆ the expanding Universe

## **Particles and waves**

The topics covered are:

- ◆ forces on charged particles
- ◆ the Standard Model
- ◆ nuclear reactions
- ◆ inverse square law
- ◆ wave-particle duality
- ◆ interference
- ◆ spectra
- ◆ refraction of light

## **Electricity**

The topics covered are:

- ◆ monitoring and measuring AC
- ◆ current, potential difference, power, and resistance
- ◆ electrical sources and internal resistance
- ◆ capacitors
- ◆ semiconductors and p-n junctions

# 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:

- ◆ demonstrating knowledge and understanding of physics by making accurate statements
- ◆ describing information, providing explanations and integrating knowledge
- ◆ applying physics knowledge to new situations, interpreting information and solving problems
- ◆ planning and designing experiments/practical investigations to test given hypotheses or to illustrate particular effects
- ◆ carrying out experiments/practical investigations safely, recording detailed observations and collecting data
- ◆ selecting information from a variety of sources
- ◆ presenting information appropriately in a variety of forms
- ◆ processing information (using calculations, significant figures and units, where appropriate)
- ◆ making predictions from evidence/information
- ◆ drawing valid conclusions and giving explanations supported by evidence/justification
- ◆ quantifying sources of uncertainty
- ◆ evaluating experimental procedures and suggesting improvements
- ◆ communicating findings/information effectively

## Skills, knowledge and understanding for the course assessment

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

### Our dynamic Universe

#### Motion — equations and graphs

Use of appropriate relationships to solve problems involving distance, displacement, speed, velocity, and acceleration for objects moving with constant acceleration in a straight line.

$$d = \bar{v}t$$

$$s = \bar{v}t$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{1}{2}(u + v)t$$

Interpretation and drawing of motion-time graphs for motion with constant acceleration in a straight line, including graphs for bouncing objects and objects thrown vertically upwards.

Knowledge of the interrelationship of displacement-time, velocity-time and acceleration-time graphs.

Calculation of distance, displacement, speed, velocity, and acceleration from appropriate graphs (graphs restricted to constant acceleration in one dimension, inclusive of change of direction).

Description of an experiment to measure the acceleration of an object down a slope.

## **Forces, energy and power**

Use of vector addition and appropriate relationships to solve problems involving balanced and unbalanced forces, mass, acceleration, and gravitational field strength.

$$F = ma$$

$$W = mg$$

Knowledge of the effects of friction on a moving object (no reference to static and dynamic friction).

Explanation, in terms of forces, of an object moving with terminal velocity.

Interpretation of velocity-time graphs for a falling object when air resistance is taken into account.

Use of Newton's first and second laws to explain the motion of an object.

Use of free body diagrams and appropriate relationships to solve problems involving friction and tension.

$$F = ma$$

$$W = mg$$

Resolution of a vector into two perpendicular components.

Resolution of the weight of an object on a slope into component forces parallel and normal to the surface of the slope.

Use of the principle of conservation of energy and appropriate relationships to solve problems involving work done, potential energy, kinetic energy, and power.

$$E_w = Fd, \text{ or } W = Fd$$

$$E_p = mgh$$

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

$$P = \frac{E}{t}$$

### **Collisions, explosions, and impulse**

Use of the principle of conservation of momentum and an appropriate relationship to solve problems involving the momentum, mass and velocity of objects interacting in one dimension.

$$p = mv$$

Knowledge of energy interactions involving the total kinetic energy of systems of objects undergoing inelastic collisions, elastic collisions, and explosions.

Use of an appropriate relationship to solve problems involving the total kinetic energy of systems of interacting objects.

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

Use of Newton's third law to explain the motion of objects involved in interactions.

Interpretation of force-time graphs involving interacting objects.

Knowledge that the impulse of a force is equal to the area under a force-time graph and is equal to the change in momentum of an object involved in the interaction.

Use of data from a force-time graph to solve problems involving the impulse of a force, the average force and its duration.

Use of an appropriate relationship to solve problems involving mass, change in velocity, average force and duration of the force for an object involved in an interaction.

$$Ft = mv - mu$$

## Gravitation

Description of an experiment to measure the acceleration of a falling object.

Knowledge that the horizontal motion and the vertical motion of a projectile are independent of each other.

Knowledge that satellites are in free fall around a planet/star.

Resolution of the initial velocity of a projectile into horizontal and vertical components and their use in calculations.

Use of resolution of vectors, vector addition, and appropriate relationships to solve problems involving projectiles.

$$d = \bar{v}t$$

$$s = \bar{v}t$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

$$s = \frac{1}{2}(u + v)t$$

Use of Newton's Law of Universal Gravitation to solve problems involving force, masses and their separation.

$$F = G \frac{m_1 m_2}{r^2}$$

## Special relativity

Knowledge that the speed of light in a vacuum is the same for all observers.

Knowledge that measurements of space, time and distance for a moving observer are changed relative to those for a stationary observer, giving rise to time dilation and length contraction.

Use of appropriate relationships to solve problems involving time dilation, length contraction and speed.

$$t' = \frac{t}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

$$l' = l \sqrt{1 - \left(\frac{v}{c}\right)^2}$$

## The expanding Universe

Knowledge that the Doppler effect causes shifts in wavelengths of sound and light.

Use of an appropriate relationship to solve problems involving the observed frequency, source frequency, source speed and wave speed.

$$f_o = f_s \left( \frac{v}{v \pm v_s} \right)$$

Knowledge that the light from objects moving away from us is shifted to longer wavelengths (redshift).

Knowledge that the redshift of a galaxy is the change in wavelength divided by the emitted wavelength. For slowly moving galaxies, redshift is the ratio of the recessional velocity of the galaxy to the velocity of light.

Use of appropriate relationships to solve problems involving redshift, observed wavelength, emitted wavelength, and recessional velocity.

$$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$$

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

Use of an appropriate relationship to solve problems involving the Hubble constant, the recessional velocity of a galaxy and its distance from us.

$$v = H_o d$$

Knowledge that the Hubble-Lemaître Law allows us to estimate the age of the Universe.

Knowledge that measurements of the velocities of galaxies and their distance from us lead to the theory of the expanding Universe.

Knowledge that the mass of a galaxy can be estimated by the orbital speed of stars within it.

Knowledge that evidence supporting the existence of dark matter comes from estimations of the mass of galaxies.

Knowledge that evidence supporting the existence of dark energy comes from the accelerating rate of expansion of the Universe.

Knowledge that the temperature of stellar objects is related to the distribution of emitted radiation over a wide range of wavelengths.

Knowledge that the peak wavelength of this distribution is shorter for hotter objects than for cooler objects.

Knowledge that hotter objects emit more radiation per unit surface area per unit time than cooler objects.

Knowledge of evidence supporting the Big Bang theory and subsequent expansion of the Universe: cosmic microwave background radiation, the abundance of the elements hydrogen and helium, the darkness of the sky (Olbers' paradox) and the large number of galaxies showing redshift rather than blueshift.

## **Particles and waves**

### **Forces on charged particles**

Knowledge that charged particles experience a force in an electric field.

Knowledge that electric fields exist around charged particles and between charged parallel plates.

Sketch electric field patterns for single-point charges, systems of two-point charges and between two charged parallel plates (ignore end effects).

Determination of the direction of movement of charged particles in an electric field.

Definition of voltage (potential difference) in terms of work done and charge.

Use of appropriate relationships to solve problems involving the charge, mass, speed, and energy of a charged particle in an electric field and the potential difference through which it moves.

$$W = QV$$

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

Knowledge that a moving charge produces a magnetic field.

Determination of the direction of the force on a charged particle moving in a magnetic field for negative and positive charges.

Knowledge of the basic operation of particle accelerators in terms of acceleration by electric fields, deflection by magnetic fields and high-energy collisions of charged particles to produce other particles.



## The Standard Model

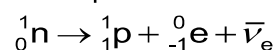
Knowledge that the Standard Model is a model of fundamental particles and interactions.

Use of orders of magnitude and awareness of the range of orders of magnitude of length from the very small (sub-nuclear) to the very large (distance to furthest known celestial objects).

Knowledge that evidence for the existence of quarks comes from high-energy collisions between electrons and nucleons, carried out in particle accelerators.

Knowledge that in the Standard Model, every particle has an antiparticle and that the production of energy in the annihilation of particles is evidence for the existence of antimatter.

Description of beta decay as the first evidence for the neutrino.



( $\beta^+$  decay not required)

Knowledge that fermions, the matter particles, consist of quarks (six types: up, down, strange, charm, top, bottom) and leptons (electron, muon and tau, together with their neutrinos).

Knowledge that hadrons are composite particles made of quarks.

Knowledge that baryons are made of three quarks.

Knowledge that mesons are made of quark–antiquark pairs.

Knowledge that the force-mediating particles are bosons: photons (electromagnetic force), W- and Z-bosons (weak force), and gluons (strong force).

## Nuclear reactions

Use of nuclear equations to describe radioactive decay, fission (spontaneous and induced) and fusion reactions, with reference to mass and energy equivalence.

Use of an appropriate relationship to solve problems involving the mass loss and the energy released by a nuclear reaction.

$$E = mc^2$$

Knowledge that nuclear fusion reactors require charged particles at a very high temperature (plasma) which have to be contained by magnetic fields.

### **Inverse square law**

Knowledge that irradiance is the power per unit area incident on a surface.

Use of an appropriate relationship to solve problems involving irradiance, the power of radiation incident on a surface and the area of the surface.

$$I = \frac{P}{A}$$

Knowledge that irradiance is inversely proportional to the square of the distance from a point source.

Description of an experiment to verify the inverse square law for a point source of light.

Use of an appropriate relationship to solve problems involving irradiance and distance from a point source of light.

$$I = \frac{k}{d^2}$$

$$I_1 d_1^2 = I_2 d_2^2$$

### **Wave-particle duality**

Knowledge that the photoelectric effect is evidence for the particle model of light.

Knowledge that photons of sufficient energy can eject electrons from the surface of materials (photoemission).

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

$$E = hf$$

Knowledge that the threshold frequency is the minimum frequency of a photon required for photoemission.

Knowledge that the work function of a material is the minimum energy of a photon required to cause photoemission.

Use of appropriate relationships to solve problems involving the mass, maximum kinetic energy and speed of photoelectrons, the threshold frequency of the material, and the frequency and wavelength of the photons.

$$E_k = hf - hf_0$$

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

$$v = f\lambda$$

## Interference

Knowledge that interference is evidence for the wave model of light.

Knowledge that coherent waves have a constant phase relationship.

Description of the conditions for constructive and destructive interference in terms of the phase difference between two waves.

Knowledge that maxima and minima are produced when the path difference between waves is a whole number of wavelengths or an odd number of half-wavelengths respectively.

Use of an appropriate relationship to solve problems involving the path difference between waves, wavelength and order number.

$$\text{path difference} = m\lambda \text{ or } \left(m + \frac{1}{2}\right)\lambda \text{ where } m = 0, 1, 2, \dots$$

Use of an appropriate relationship to solve problems involving grating spacing, wavelength, order number and angle to the maximum.

$$d \sin \theta = m\lambda$$

## Spectra

Knowledge of the Bohr model of the atom.

Knowledge of the terms *ground state*, *energy levels*, *ionisation* and *zero potential energy* in relation to the Bohr model of the atom.

Knowledge of the mechanism of production of line emission spectra, continuous emission spectra and absorption spectra in terms of electron energy level transitions.

Use of appropriate relationships to solve problems involving energy levels and the frequency of the radiation emitted/absorbed.

$$E_2 - E_1 = hf$$

$$E = hf$$

Knowledge that the absorption lines (Fraunhofer lines) in the spectrum of sunlight provide evidence for the composition of the Sun's outer atmosphere.

## Refraction of light

Definition of absolute refractive index of a medium as the ratio of the speed of light in a vacuum to the speed of light in the medium.

Use of an appropriate relationship to solve problems involving absolute refractive index, the angle of incidence and the angle of refraction.

$$n = \frac{\sin \theta_1}{\sin \theta_2}$$

Description of an experiment to determine the refractive index of a medium.

Use of appropriate relationships to solve problems involving the angles of incidence and refraction, the wavelength of light in each medium, the speed of light in each medium, and the frequency, including situations where light is travelling from a more dense to a less dense medium.

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$
$$v = f\lambda$$

Knowledge that the refractive index of a medium increases as the frequency of incident radiation increases.

Definition of critical angle as the angle of incidence which produces an angle of refraction of  $90^\circ$ .

Knowledge that total internal reflection occurs when the angle of incidence is greater than the critical angle.

Use of an appropriate relationship to solve problems involving critical angle and absolute refractive index.

$$\sin \theta_c = \frac{1}{n}$$

## Electricity

### Monitoring and measuring AC

Knowledge that AC is a current which changes direction and instantaneous value with time.

Use of appropriate relationships to solve problems involving root mean square (rms) and peak values.

$$V_{rms} = \frac{V_{peak}}{\sqrt{2}}$$

$$I_{rms} = \frac{I_{peak}}{\sqrt{2}}$$

Determination of frequency, peak and rms values from graphical data.

$$T = \frac{1}{f}$$

### Current, potential difference, power, and resistance

Use of appropriate relationships to solve problems involving potential difference, current, power, and resistance. Solutions may involve several steps.

$$V = IR$$

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

$$R_T = R_1 + R_2 + \dots$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

Use of appropriate relationships to solve problems involving potential divider circuits.

$$V_1 = \left( \frac{R_1}{R_1 + R_2} \right) V_S$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

## Electrical sources and internal resistance

Knowledge of the terms *electromotive force (EMF)*, *internal resistance*, *lost volts*, *terminal potential difference (t.p.d.)*, *ideal supplies*, *short circuit* and *open circuit*.

Use of appropriate relationships to solve problems involving EMF, lost volts, t.p.d., current, external resistance, and internal resistance.

$$E = V + Ir$$

$$V = IR$$

Description of an experiment to measure the EMF and internal resistance of a cell.

Determination of EMF, internal resistance and short circuit current using graphical analysis.

## Capacitors

Knowledge that a capacitor of 1 farad will store 1 coulomb of charge when the potential difference across it is 1 volt.

Use of an appropriate relationship to solve problems involving capacitance, charge and potential difference.

$$C = \frac{Q}{V}$$

Use of an appropriate relationship to determine the charge stored on a capacitor for a constant charging current.

$$Q = It$$

Knowledge that the total energy stored in a charged capacitor is equal to the area under a charge-potential difference graph.

Use of appropriate relationships to solve problems involving energy, charge, capacitance, and potential difference.

$$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

Knowledge of the variation of current and potential difference with time for both charging and discharging cycles of a capacitor in an RC circuit (charging and discharging curves).

Knowledge of the effect of resistance and capacitance on charging and discharging curves in an RC circuit.

Description of experiments to investigate the variation of current in a capacitor and voltage across a capacitor with time, for the charging and discharging of capacitors.

## **Semiconductors and p-n junctions**

Knowledge of the terms *conduction band* and *valence band*.

Knowledge that solids can be categorised into conductors, semiconductors or insulators by their band structure and their ability to conduct electricity. Every solid has its own characteristic energy band structure. For a solid to be conductive, both free electrons and accessible empty states must be available.

Qualitative explanation of the electrical properties of conductors, insulators and semiconductors using the electron population of the conduction and valence bands and the energy difference between the conduction and valence bands. (Reference to Fermi levels is not required.)

The electrons in atoms are contained in energy levels. When the atoms come together to form solids, the electrons then become contained in energy bands separated by gaps.

For metals we have the situation where one or more bands are partially filled. Some metals have free electrons and partially filled valence bands, therefore they are highly conductive.

Some metals have overlapping valence and conduction bands. Each band is partially filled and therefore they are conductive.

In an insulator, the highest occupied band (called the valence band) is full. The first unfilled band above the valence band is the conduction band. For an insulator, the gap between the valence band and the conduction band is large and at room temperature there is not enough energy available to move electrons from the valence band into the conduction band where they would be able to contribute to conduction. There is no electrical conduction in an insulator.

In a semiconductor, the gap between the valence band and conduction band is smaller and at room temperature there is sufficient energy available to move some electrons from the valence band into the conduction band allowing some conduction to take place. An increase in temperature increases the conductivity of a semiconductor.

Knowledge that, during manufacture, semiconductors may be doped with specific impurities to increase their conductivity, resulting in two types of semiconductor: p-type and n-type.

Knowledge that, when a semiconductor contains the two types of doping (p-type and n-type) in adjacent layers, a p-n junction is formed. There is an electric field in the p-n junction. The electrical properties of this p-n junction are used in a number of devices.

Knowledge of the terms *forward bias* and *reverse bias*. Forward bias reduces the electric field; reverse bias increases the electric field in the p-n junction.

Knowledge that LEDs are forward biased p-n junction diodes that emit photons. The forward bias potential difference across the junction causes electrons to move from the conduction band of the n-type semiconductor towards the conduction band of the p-type semiconductor. Photons are emitted when electrons 'fall' from the conduction band into the valence band either side of the junction.

Knowledge that solar cells are p-n junctions designed so that a potential difference is produced when photons are absorbed. (This is known as the photovoltaic effect.) The absorption of photons provides energy to 'raise' electrons from the valence band of the semiconductor to the conduction band. The p-n junction causes the electrons in the conduction band to move towards the n-type semiconductor and a potential difference is produced across the solar cell.

## Units, prefixes and uncertainties

### Units, prefixes and scientific notation

Appropriate use of units and prefixes.

SI units should be used with all physical quantities, where appropriate. Prefixes should be used where appropriate. These include pico (p), nano (n), micro ( $\mu$ ), milli (m), kilo (k), mega (M), giga (G) and tera (T).

Use of the appropriate number of significant figures in final answers. This means that the final answer can have no more significant figures than the value with least number of significant figures used in the calculation.

Appropriate use of scientific notation.

### Uncertainties

Knowledge of scale reading, random, and systematic uncertainties in a measured quantity.

All measurements of physical quantities are liable to uncertainty, which should be expressed in absolute or percentage form.

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

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

Use of an appropriate relationship to determine the approximate random uncertainty in a value using repeated measurements.

$$\text{random uncertainty} = \frac{\text{max. value} - \text{min. value}}{\text{number of values}}$$

or

$$\Delta R = \frac{R_{\max} - R_{\min}}{n}$$



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

The mean of a set of repeated measurements is the best estimate of the 'true' value of the quantity being measured. When systematic uncertainties are present, the mean value will be offset. When mean values are used, the approximate random uncertainty should be calculated.

Appropriate use of uncertainties in data analysis.

When an experiment is being undertaken and more than one physical quantity is measured, the quantity with the largest percentage uncertainty should be identified and this may often be used as a good estimate of the percentage uncertainty in the final numerical result of an experiment. The numerical result of an experiment should be expressed in the form *final value*  $\pm$  *uncertainty*.

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 can be found 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

1.2 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.