Detailed unit content

In this specification bold text refers to higher tier only content. Italic text refers to practical investigations, which students are required to demonstrate an understanding of.

Throughout the unit

0.1 Use equations given in this unit, or in a given alternate form

0.2 **Use and rearrange equations given in this unit**

0.3 Demonstrate an understanding of which units are required in equations

Topic 1

Visible light and the Solar System

1.1 Describe how ideas about the structure of the Solar System have changed over time, including the change from the geocentric to the heliocentric models and the discovery of new planets

1.2 Demonstrate an understanding of how scientists use waves to find out information about our Universe, including:
- a the Solar System
- b the Milky Way

1.3 Discuss how Galileo’s observations of Jupiter, using the telescope, provided evidence for the heliocentric model of the Solar System

1.4 Compare methods of observing the Universe using visible light, including the naked eye, photography and telescopes

1.5 Explain how to measure the focal length of a converging lens using a distant object

1.6 *Investigate the behaviour of converging lenses, including real and virtual images*

1.7 *Investigate the use of converging lenses to:*
- a *measure the focal length using a distant object*
- b *investigate factors which affect the magnification of a converging lens (formulae are not needed)*

1.8 Explain how the eyepiece of a simple telescope magnifies the image of a distant object produced by the objective lens (ray diagrams are not necessary)

1.9 Describe how a reflecting telescope works

1.10 Recall that waves are reflected and refracted at boundaries between different materials

1.11 **Explain how waves will be refracted at a boundary in terms of the change of speed and direction**

1.12 Describe that waves transfer energy and information without transferring matter

1.13 Use the terms of frequency, wavelength, amplitude and speed to describe waves

1.14 Differentiate between longitudinal and transverse waves by referring to sound, electromagnetic and seismic waves

1.15 Use both the equations below for all waves:

wave speed (metre/second, m/s) = frequency (hertz, Hz) × wavelength (metre, m)
$v = f \times \lambda$

wave speed (metre/second, m/s) = distance (metre, m) / time (second, s)

$v = \frac{x}{t}$

Topic 2

The electromagnetic spectrum

2.1 Demonstrate an understanding of how Herschel and Ritter contributed to the discovery of waves outside the limits of the visible spectrum

2.2 Demonstrate an understanding that all electromagnetic waves are transverse and that they travel at the same speed in a vacuum

2.3 Describe the continuous electromagnetic spectrum including (in order) radio waves, microwaves, infrared, visible (including the colours of the visible spectrum), ultraviolet, X-rays and gamma rays

2.4 Demonstrate an understanding that the electromagnetic spectrum is continuous from radio waves to gamma rays, but the radiations within it can be grouped in order of decreasing wavelength and increasing frequency

2.5 Demonstrate an understanding that the potential danger associated with an electromagnetic wave increases with increasing frequency

2.6 Relate the harmful effects, to life, of excessive exposure to the frequency of the electromagnetic radiation, including:

- a microwaves: internal heating of body cells
- b infrared: skin burns
- c ultraviolet: damage to surface cells and eyes, leading to skin cancer and eye conditions
- d X-rays and gamma rays: mutation or damage to cells in the body

2.7 Describe some uses of electromagnetic radiation

- a radio waves: including broadcasting, communications and satellite transmissions
- b microwaves: including cooking, communications and satellite transmissions
- c infrared: including cooking, thermal imaging, short range communications, optical fibres, television remote controls and security systems
- d visible light: including vision, photography and illumination
- e ultraviolet: including security marking, fluorescent lamps, detecting forged bank notes and disinfecting water
- f X-rays: including observing the internal structure of objects, airport security scanners and medical X-rays
- g gamma rays: including sterilising food and medical equipment, and the detection of cancer and its treatment

2.8 Recall that ionising radiations are emitted all the time by radioactive sources

2.9 Describe that ionising radiation includes alpha and beta particles and gamma rays and that they transfer energy

Topic 3

Waves and the Universe

3.1 Recall that the Solar System is part of the Milky Way galaxy

3.2 Describe a galaxy as a collection of stars

3.3 Recall that the Universe includes all of the galaxies

3.4 Compare the relative sizes of and the distances between the Earth, the Moon, the planets, the Sun, galaxies and the Universe

3.5 Describe the use of other regions of the electromagnetic spectrum by some modern telescopes

3.6 Describe the methods used to gather evidence for life beyond Earth, including space probes, soil experiments by landers, Search for Extraterrestrial Intelligence (SETI)

3.7 Demonstrate an understanding of the impact of data gathered by modern telescopes on our understanding of the Universe, including:

- a the observation of galaxies because of improved magnification
- b the discovery of objects not detectable using visible light
- c the ability to collect more data

3.8 *Construct a simple spectrometer, from a CD or DVD, and use it to analyse common light sources*

3.9 Explain why some telescopes are located outside the Earth's atmosphere

3.10 **Analyse data provided to support the location of telescopes outside the Earth's atmosphere**

3.11 Describe the evolution of stars of similar mass to the Sun through the following stages:

a nebula

b star (main sequence)

c red giant

d white dwarf

3.12 Describe the role of gravity in the life cycle of stars

3.13 **Describe how the evolution of stars with a mass larger than the Sun is different, and may end in a black hole or neutron star**

3.14 Demonstrate an understanding of the Steady State and Big Bang theories

3.15 Describe evidence supporting the Big Bang theory, limited to red-shift and the cosmic microwave background (CMB) radiation

3.16 Recognise that as there is more evidence supporting the Big Bang theory than the Steady State theory, it is the currently accepted model for the origin of the Universe

3.17 Describe that if a wave source is moving relative to an observer there will be a change in the observed frequency and wavelength

3.18 **Demonstrate an understanding that if a wave source is moving relative to an observer there will be a change in the observed frequency and wavelength**

3.19 **Describe the red-shift in light received from galaxies at different distances away from the Earth**

3.20 **Explain why the red-shift of galaxies provides evidence for the Universe expanding**

3.21 **Explain how both the Big Bang and Steady State theories of the origin of the Universe both account for red-shift of galaxies**

3.22 **Explain how the discovery of the CMB radiation led to the Big Bang theory becoming the currently accepted model**

Topic 4

Waves and the Earth

4.1 Recall that sound with frequencies greater than 20 000 hertz, Hz, is known as ultrasound

4.2 Describe uses of ultrasound, including:

a sonar

b communication between animals

c foetal scanning

4.3 Calculate depth or distance from time and velocity of ultrasound

4.4 Recall that sound with frequencies less than 20 hertz, Hz, is known as infrasound

4.5 Describe uses of infrasound, including:

a communication between animals

b detection of animal movement in remote locations

c detection of volcanic eruptions and meteors

4.6 Recall that seismic waves are generated by earthquakes or explosions

4.7 *Investigate the unpredictability of earthquakes, through sliding blocks and weights*

4.8 Explain why scientists find it difficult to predict earthquakes and tsunami waves even with available data

4.9 Recall that seismic waves can be longitudinal (P) waves and transverse (S) waves and that they can be reflected and refracted at boundaries between the crust, mantle and core

4.10 Explain how data from seismometers can be used to identify the location of an earthquake

4.11 **Demonstrate an understanding of how P and S waves travel inside the Earth including reflection and refraction**

4.12 Explain how the Earth's outermost layer is composed of (tectonic) plates and is in relative motion due to convection currents in the mantle

4.13 Demonstrate an understanding of how, at plate boundaries, plates may slide past each other, sometimes causing earthquakes

Topic 5

Generation and transmission of electricity

5.1 Describe current as the rate of flow of charge and voltage as an electrical pressure giving a measure of the energy transferred

5.2 Define power as the energy transferred per second and measured in watts

5.3 Use the equation:

electrical power (watt, W) = current (ampere, A) × potential difference (volt, V)

$P = I \times V$

5.4 *Investigate the power consumption of low-voltage electrical items*

5.5 Discuss the advantages and disadvantages of methods of large-scale electricity production using a variety of renewable and non-renewable resources

5.6 Demonstrate an understanding of the factors that affect the size and direction of the induced current

5.7 *Investigate factors affecting the generation of electric current by induction*

5.8 Explain how to produce an electric current by the relative movement of a magnet and a coil of wire:

a on a small scale

b in the large-scale generation of electrical energy

5.9 Recall that generators supply current which alternates in direction

5.10 Explain the difference between direct and alternating current

5.11 Recall that a transformer can change the size of an alternating voltage

5.12 **Use the turns ratio equation for transformers to predict either the missing voltage or the missing number of turns**

5.13 Explain why electrical energy is transmitted at high voltages, as it improves the efficiency by reducing heat loss in transmission lines

5.14 Explain where and why step-up and step-down transformers are used in the transmission of electricity in the National Grid

5.15 Describe the hazards associated with electricity transmission

5.16 Recall that energy from the mains supply is measured in kilowatt-hours

5.17 Use the equation:

cost (p) = power (kilowatts, kW) × time (hour, h) × cost of 1 kilowatt-hour (p/kW h)

5.18 Demonstrate an understanding of the advantages of the use of low-energy appliances

5.19 Use data to compare and contrast the advantages and disadvantages of energy-saving devices

5.20 Use data to consider cost-efficiency by calculating payback times

5.21 Use the equation:

power (watt, W) = energy used (joule, J) / time taken (second, s)

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

Topic 6

Energy and the future

6.1 Demonstrate an understanding that energy is conserved

6.2 Describe energy transfer chains involving the following forms of energy: thermal (heat), light, electrical, sound, kinetic (movement), chemical, nuclear and potential (elastic and gravitational)

6.3 Demonstrate an understanding of how diagrams can be used to represent energy transfers

6.4 Apply the idea that efficiency is the proportion of energy transferred to useful forms to everyday situations

6.5 Use the efficiency equation:

$$efficiency = \frac{\textit{(useful energy transferred by the device)}}{\textit{(total energy supplied to the device)}} \times 100\%$$

6.6 Demonstrate an understanding that for a system to be at a constant temperature it needs to radiate the same average power that it absorbs

6.7 *Investigate how the nature of a surface affects the amount of thermal energy radiated or absorbed*

Unit P2: Physics for the future

Overview

Content and How Science Works overview

In Unit P2 students study six topics that give them the opportunity to develop their understanding of significant concepts and relate them to important uses both for today and the future. Electricity is explained further, building on Unit P1. Students are introduced to motion, forces and momentum. Nuclear reactions and nuclear power are then discussed, including the uses and dangers of radioactivity.

Practical work in this unit will give students opportunities to plan practical ways to answer scientific questions; devise appropriate methods for the collection of numerical and other data; assess and manage risks when carrying out practical work; collect, process, analyse and interpret primary and secondary data; draw evidence-based conclusions; and evaluate methods of data collection and the quality of the resulting data.

Work on static and current electricity and on nuclear reactions provides opportunities to use models to explain ideas and processes. Students will work quantitatively when studying charge, resistance, electrical power, motion, energy, momentum and half-lives. They will have opportunities to communicate scientific information using scientific and mathematical conventions and symbols during work on resistance and motion.

Work on the applications of static electricity, car safety features, stopping distances, nuclear energy and the uses of radioactivity allow students to consider the role that physics and physicists play in providing safe and useful machines. Students also have the opportunity to consider the advantages, disadvantages and risks of these applications, and the safe uses of radioactive substances.

In Topic 1 students will learn about static electricity before discussing some uses and dangers of electrical charges. Direct current is introduced.

Topic 2 leads students to understand the relationship between current, voltage and resistance. Equations for electrical power and energy transferred are also used. Further investigations lead to an understanding of how current varies with voltage in some common components.

In Topic 3 students will develop an understanding of the motion of objects and Newton's second law of motion. This is then exemplified by considering the motion of an object as it falls through a vacuum and the atmosphere.

In Topic 4 students will learn about conservation of momentum by investigating collisions between bodies. This will enable students to apply ideas about rate of change of momentum to crumple zones, seat belts and air bags. Students will then develop an understanding of the relationship between work done, energy transferred and power.

In Topic 5 students will develop an understanding of radioactive decay, including chain reactions, and difference between fission and fusion. Students will use this context to study the role of the wider scientific community in validating theories.

In Topic 6 students will develop an understanding of the uses of different ionising radiations. They will compare and contrast the advantages and risks involved and use models to investigate radioactive decay. Students will research and discuss the advantages and disadvantages of using nuclear power for generating electricity.

Assessment overview

This unit is externally assessed, through a one hour, 60 mark, tiered written examination, containing six questions.

The examination will contain a mixture of question styles, including objective questions, short answer questions and extended writing questions.

Practical investigations in this unit

Within this unit, students will develop understanding of the process of scientific investigations, including that investigations:

- use hypotheses which are tested
- require assessment and management of risks
- require the collection, presentation, analysis and interpretation of primary and secondary evidence, including the use of appropriate technology
- should include review of methodology to assess fitness for purpose
- should include a review of hypotheses in the light of outcomes.

The following specification points are practical investigations that exemplify the scientific process and may appear in the written examination for this unit:

2.6 *Investigate the relationship between potential difference (voltage), current and resistance*

3.15 *Investigate the relationship between force, mass and acceleration*

4.3 *Investigate the forces required to slide blocks along different surfaces, with differing amounts of friction*

4.8 *Investigate how crumple zones can be used to reduce the forces in collisions*

6.8 *Investigate models which simulate radioactive decay*

The following are further suggestions for practical work within this unit:

- *Investigate forces between charges*
- *Conduct experiments to show the relationship between potential difference (voltage), current and resistance, for a component whose resistance varies with a given factor, such as temperature, light intensity and pressure*
- *Investigate the motion of falling*
- *Investigate momentum during collisions*
- *Investigate power by running up the stairs or lifting objects of different weights*

The controlled assessment task (CAT) for the GCSE in Physics will be taken from any of these practical investigations (specification points and further suggested practical investigations). This task will change every year, so future CATs will be chosen from this list.

Detailed unit content

In this specification bold text refers to higher tier only content. Italic text refers to practical investigations, which students are required to demonstrate an understanding of.

Throughout the unit

0.1 Use equations given in this unit, or in a given alternate form

0.2 **Use and rearrange equations given in this unit**

0.3 Demonstrate an understanding of which units are required in equations

Topic 1

Static and current electricity

1.1 Describe the structure of the atom, limited to the position, mass and charge of protons, neutrons and electrons

1.2 Explain how an insulator can be charged by friction, through the transfer of electrons

1.3 Explain how the material gaining electrons becomes negatively charged and the material losing electrons is left with an equal positive charge

1.4 Recall that like charges repel and unlike charges attract

1.5 Demonstrate an understanding of common electrostatic phenomena in terms of movement of electrons, including:

- a shocks from everyday objects
- b lightning
- c attraction by induction such as a charged balloon attracted to a wall and a charged comb picking up small pieces of paper

1.6 Explain how earthing removes excess charge by movement of electrons

1.7 Explain some of the uses of electrostatic charges in everyday situations, including paint and insecticide sprayers

1.8 Demonstrate an understanding of some of the dangers of electrostatic charges in everyday situations, including fuelling aircraft and tankers together with the use of earthing to prevent the build-up of charge and danger arising

1.9 Recall that an electric current is the rate of flow of charge

1.10 Recall that the current in metals is a flow of electrons

1.11 Use the equation:

charge (coulomb, C) = current (ampere, A) × time (second, s)
$Q = I \times t$

1.12 Recall that cells and batteries supply direct current (d.c.)

1.13 Demonstrate an understanding that direct current (d.c.) is movement of charge in one direction only

Topic 2

Controlling and using electric current

2.1 Describe how an ammeter is placed in series with a component to measure the current, in amps, in the component

2.2 Explain how current is conserved at a junction

2.3 Explain how the current in a circuit depends on the potential difference of the source

2.4 Describe how a voltmeter is placed in parallel with a component to measure the potential difference (voltage), in volts, across it

2.5 **Demonstrate an understanding that potential difference (voltage) is the energy transferred per unit charge passed and hence that the volt is a joule per coulomb**

2.6 *Investigate the relationship between potential difference (voltage), current and resistance*

2.7 Explain how changing the resistance in a circuit changes the current and how this can be achieved using a variable resistor

2.8 Use the equation:

potential difference (volt, V) = current (ampere, A) × resistance (ohm, Ω)

$V = I \times R$

2.9 Demonstrate an understanding of how current varies with potential difference for the following devices:

a filament lamps

b diodes

c fixed resistors

2.10 Demonstrate an understanding of how the resistance of a light-dependent resistor (LDR) changes with light intensity

2.11 Demonstrate an understanding of how the resistance of a thermistor changes with change of temperature (negative temperature coefficient thermistors only)

2.12 Explain why, when there is an electric current in a resistor, there is an energy transfer which heats the resistor

2.13 **Explain the energy transfer (in 2.12 above) as the result of collisions between electrons and the ions in the lattice**

2.14 Distinguish between the advantages and disadvantages of the heating effect of an electric current

2.15 Use the equation:

electrical power (watt, W) = current (ampere, A) × potential difference (volt, V)

$P = I \times V$

2.16 Use the equation:

energy transferred (joule, J) = current (ampere, A) × potential difference (volt, V) × time (second, s)
$E = I \times V \times t$

Topic 3

Motion and forces

3.1 Demonstrate an understanding of the following as vector quantities:

a displacement

b velocity

c acceleration

d force

3.2 Interpret distance/time graphs including determination of speed from the gradient

3.3 Recall that velocity is speed in a stated direction

3.4 Use the equation:

speed (m/s) = distance (m) / time (s)

3.5 Use the equation:

acceleration (metre per second squared, m/s^2) = change in velocity (metre per second, m/s) / time taken (second, s)

$$a = \frac{(v - u)}{t}$$

3.6 Interpret velocity/time graphs to:

a compare acceleration from gradients qualitatively

b calculate the acceleration from the gradient (for uniform acceleration only)

c **determine the distance travelled using the area between the graph line and the time axis (for uniform acceleration only**

3.7 Draw and interpret a free-body force diagram

3.8 Demonstrate an understanding that when two bodies interact, the forces they exert on each other are equal in size and opposite in direction and that these are known as action and reaction forces

3.9 Calculate a resultant force using a range of forces (limited to the resultant of forces acting along a line) including resistive forces

3.10 Demonstrate an understanding that if the resultant force acting on a body is zero, it will remain at rest or continue to move at the same velocity

3.11 Demonstrate an understanding that if the resultant force acting on a body is not zero, it will accelerate in the direction of the resultant force

3.12 Demonstrate an understanding that a resultant force acting on an object produces an acceleration which depends on:

a the size of the resultant force

b the mass of the object

3.13 Use the equation:

force (newton, N) = mass (kilogram, kg) × acceleration (metre per second squared, m/s^2)
$F = m \times a$

3.14 Use the equation:

weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg)
$W = m \times g$

3.15 *Investigate the relationship between force, mass and acceleration*

3.16 Recall that in a vacuum all falling bodies accelerate at the same rate

3.17 Demonstrate an understanding that:

a when an object falls through an atmosphere air resistance increases with increasing speed

b air resistance increases until it is equal in size to the weight of the falling object

c when the two forces are balanced, acceleration is zero and terminal velocity is reached

Topic 4

Momentum, energy, work and power

4.1 Recall that the stopping distance of a vehicle is made up of the sum of the thinking distance and the braking distance

4.2 Demonstrate an understanding of the factors affecting the stopping distance of a vehicle, including:

a the mass of the vehicle

b the speed of the vehicle

c the driver's reaction time

d the state of the vehicle's brakes

e the state of the road

f the amount of friction between the tyre and the road surface

4.3 *Investigate the forces required to slide blocks along different surfaces, with differing amounts of friction*

4.4 Use the equation:

momentum (kilogram metre per second, kg m/s) = mass (kilogram, kg) × velocity (metre per second, m/s)

to calculate the momentum of a moving object

4.5 Demonstrate an understanding of momentum as a vector quantity

4.6 Demonstrate an understanding of the idea of linear momentum conservation

4.7 Demonstrate an understanding of the idea of rate of change of momentum to explain protective features including bubble wraps, seat belts, crumple zones and air bags

4.8 *Investigate how crumple zones can be used to reduce the forces in collisions*

4.9 **Use the equation:**

force (newton, N) = change in momentum (kilogram metre per second, kg m/s) / time (second, s)

$$\boldsymbol{F = \frac{(mv - mu)}{t}}$$

to calculate the change in momentum of a system, as in 4.6

4.10 Use the equation:

work done (joule, J) = force (newton, N) × distance moved in the direction of the force (metre, m)

$E = F \times d$

4.11 Demonstrate an understanding that energy transferred (joule, J) is equal to work done (joule, J)

4.12 Recall that power is the rate of doing work and is measured in watts, W

4.13 Use the equation:

power (watt, W) = work done (joule, J) / time taken (second, s)

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

4.14 Recall that one watt is equal to one joule per second, J/s

4.15 Use the equation:

gravitational potential energy (joule, J) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) × vertical height (metre, m)

GPE = $m \times g \times h$

4.16 Use the equation:

kinetic energy (joule, J) = $\frac{1}{2}$ × mass (kilogram, kg) × velocity^2 ((metre/second)^2 (m/s)^2)

KE = $\frac{1}{2} \times m \times v^2$

4.17 Demonstrate an understanding of the idea of conservation of energy in various energy transfers

4.18 **Carry out calculations on work done to show the dependence of braking distance for a vehicle on initial velocity squared (work done to bring a vehicle to rest equals its initial kinetic energy)**

Topic 5

Nuclear fission and nuclear fusion

5.1 Describe the structure of nuclei of isotopes using the terms atomic (proton) number and mass (nucleon) number and using symbols in the format $^{14}_{6}C$

5.2 Explain how atoms may gain or lose electrons to form ions

5.3 Recall that alpha and beta particles and gamma rays are ionising radiations emitted from unstable nuclei in a random process

5.4 Recall that an alpha particle is equivalent to a helium nucleus, a beta particle is an electron emitted from the nucleus and a gamma ray is electromagnetic radiation

5.5 Compare alpha, beta and gamma radiations in terms of their abilities to penetrate and ionise

5.6 Demonstrate an understanding that nuclear reactions can be a source of energy, including fission, fusion and radioactive decay

5.7 Explain how the fission of U-235 produces two daughter nuclei and two or more neutrons, accompanied by a release of energy

5.8 Explain the principle of a controlled nuclear chain reaction

5.9 Explain how the chain reaction is controlled in a nuclear reactor including the action of moderators and control rods

5.10 Describe how thermal (heat) energy from the chain reaction is converted into electrical energy in a nuclear power station

5.11 Recall that the products of nuclear fission are radioactive

5.12 Describe nuclear fusion as the creation of larger nuclei from smaller nuclei, accompanied by a release of energy and recognise fusion as the energy source for stars

5.13 Explain the difference between nuclear fusion and nuclear fission

5.14 **Explain why nuclear fusion does not happen at low temperatures and pressures, due to electrostatic repulsion of protons**

5.15 **Relate the conditions for fusion to the difficulty of making a practical and economic form of power station**

5.16 Demonstrate an understanding that new scientific theories, such as ‘cold fusion’, are not accepted until they have been validated by the scientific community

Topic 6

Advantages and disadvantages of using radioactive materials

6.1 Explain what is meant by background radiation, including how regional variations within the UK are caused in particular by radon gas

6.2 Recall the origins of background radiation from Earth and space

6.3 Describe uses of radioactivity, including:

- a household fire (smoke) alarms
- b irradiating food
- c sterilisation of equipment
- d tracing and gauging thicknesses
- e diagnosis and treatment of cancer

6.4 Describe how the activity of a radioactive source decreases over a period of time

6.5 Recall that the unit of activity of a radioactive isotope is the Becquerel, Bq

6.6 Recall that the half-life of a radioactive isotope is the time taken for half the undecayed nuclei to decay

6.7 Use the concept of half-life to carry out simple calculations on the decay of a radioactive isotope, including graphical representations

6.8 *Investigate models which simulate radioactive decay*

6.9 Demonstrate an understanding of the dangers of ionising radiation in terms of tissue damage and possible mutations and relate this to the precautions needed

6.10 Describe how scientists have changed their ideas of radioactivity over time, including:

- a the awareness of the hazards associated with radioactive sources
- b why the scientific ideas change over time

6.11 Discuss the long-term possibilities for storage and disposal of nuclear waste

6.12 Evaluate the advantages and disadvantages of nuclear power for generating electricity, including the lack of carbon dioxide emissions, risks, public perception, waste disposal and safety issues

Unit P3: Applications of physics

Overview

Content and How Science Works overview

This highly engaging unit builds on the knowledge gained in units P1 and P2 by introducing students to medical physics. Students will learn how physics principles are vital in modern medicine in the way in which they are applied to diagnosis, treatment and storage of medicines.

Practical work in this unit will give students opportunities to plan practical ways to answer scientific questions; devise appropriate methods for the collection of numerical and other data; assess and manage risks when carrying out practical work; collect, process, analyse and interpret primary and secondary data; draw evidence-based conclusions; and evaluate methods of data collection and the quality of the resulting data.

Students will explain ideas and processes using models while studying radiation, radioactive decay, subatomic structure, momentum and kinetic theory. Work on the intensity of radiation, lenses, momentum, kinetic energy, frequency and gases will provide students with opportunities to work quantitatively. They will have opportunities to communicate scientific information using scientific and mathematical conventions and symbols during work on ray diagrams and vision, and when constructing nuclear equations.

Students will consider the role that physics and physicists play in our lives through the study of laser and other treatments for correcting vision, the use of X-rays in medicine, ECGs and pacemakers, and the uses of radioactive materials. They will consider advantages, disadvantages and risks of using radioactive materials, and consider how decisions about their use are made. They will look at how international collaboration is necessary for the building of particle accelerators and how these can lead to new discoveries about the world around us.

In Topic 1 students will learn about the use of radiation and other waves in medical treatment and diagnosis. Students will apply their understanding of lenses to treatments for long and short sightedness.

In Topic 2 students will learn about the production of X-rays and then discuss the risks and advantages of using X-rays for treatment and diagnosis. A brief study of the use of an electrocardiogram (ECG) will enable students to develop a simple understanding of the use of a pacemaker to regulate heart action.

In Topic 3 students will discuss the ethical and social issues relating to the use of radioactive techniques in medical physics. Students will learn in detail about the decay of radio isotopes and the use of beta decay. They will relate their knowledge to medical treatments and diagnosis and the dangers of using radiation.

In Topic 4 students will investigate circular motion, momentum and conservation of energy. Students will develop an understanding of particle accelerators and their use in medical physics and wider research.

In Topic 5 students will learn simple kinetic theory and the gas laws. They will learn the general gas equation and how to apply this equation to, for example, bottled gases in medicine.

Assessment overview

This unit is externally assessed, through a one hour, 60 mark, tiered written examination, containing six questions.

The examination will contain a mixture of question styles, including objective questions, short answer questions and extended writing questions.

Practical investigations in this unit

Within this unit, students will develop understanding of the process of scientific investigations, including that investigations:

- use hypotheses which are tested
- require assessment and management of risks
- require the collection, presentation, analysis and interpretation of primary and secondary evidence including the use of appropriate technology
- should include review of methodology to assess fitness for purpose
- should include a review of hypotheses in the light of outcomes.

The following specification points are practical investigations that exemplify the scientific process and may appear in the written examination for this unit:

1.8 *Investigate variations of image characteristics with objects at different distances from a converging lens*

1.18 *Investigate the critical angle for perspex/air or glass/air or water/air boundaries*

1.19 *Investigate TIR between different media*

4.12 *Investigate factors affecting the height of rebound of bouncing balls*

5.7 *Investigate the temperature and volume relationship for a gas*

5.9 *Investigate the volume and pressure relationship for a gas*

The following are further suggestions for practical work within this unit:

- *Investigate the relationship between the intensity of radiation and the distance from the source*
- *Investigate the absorption of light by translucent materials in order to simulate X-rays' absorption*

- *Investigate conservation of energy and momentum during collisions using models to represent particles*
- *Investigate inelastic collisions with the two objects remaining together after the collision and also 'near' elastic collisions*
- *Investigate the temperature and pressure relationship for a gas*

The controlled assessment task (CAT) for the GCSE in Physics will be taken from any of these practical investigations (specification points and further suggested practical investigations). This task will change every year, so future CATs will be chosen from this list.

Detailed unit content

In this specification bold text refers to higher tier only content. Italic text refers to practical investigations, which students are required to demonstrate an understanding of.

Throughout the unit

0.1 Use equations given in this unit, or in a given alternate form

0.2 **Use and rearrange equations given in this unit**

0.3 Demonstrate an understanding of which units are required in equations

Topic 1

Radiation in treatment and medicine

1.1 Demonstrate an understanding of the methods that medical physicists can employ to help doctors solve medical problems, including:

- a CAT scans
- b ultrasounds
- c endoscopes
- d ionising and non-ionising radiation

1.2 Use the word 'radiation' to describe any form of energy originating from a source, including both waves and particles

1.3 Demonstrate an understanding that the intensity of radiation will decrease with distance from a source and according to the nature of the medium through which it is travelling

1.4 **Use the equation:**

intensity = power of incident radiation / area

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

1.5 Describe the refraction of light by converging and diverging lenses

1.6 Relate the power of a lens to its shape

1.7 Use the equation:

power of lens (dioptre, D) = 1/focal length (metre, m)

1.8 *Investigate variations of image characteristics with objects at different distances from a converging lens*

1.9 **Use the lens equation:**

$$\boldsymbol{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$$

(f = focal length (m), u = object distance (m), v = image distance (m))

The use of the real is positive sign convention is preferred and will be used in the exam

1.10 Identify the following features in a diagram of the eye – cornea, iris, pupil, lens, retina, ciliary muscles

1.11 Demonstrate an understanding that light is focused on the retina by the action of the lens and cornea

1.12 Recall that the average adult human eye has a near point at about 25 cm and a far point at infinity

1.13 Explain the symptoms and causes of short sight and long sight (students will not be expected to draw scaled ray diagrams, but may be expected to interpret them)

1.14 Compare and contrast treatments for short sight and long sight, including the use of:

a simple lenses

b contact lenses

c **laser correction**

(combined lens equation is not required; students will not be expected to draw scaled ray diagrams, but may be expected to interpret them)

1.15 Explain, with the aid of ray diagrams, reflection, refraction and total internal reflection (TIR), including the law of reflection and critical angle

1.16 **Calculate critical angle using Snell's Law**

1.17 Explain refraction in terms of change of speed of radiation

1.18 *Investigate the critical angle for perspex/air or glass/air or water/air boundaries*

1.19 *Investigate TIR between different media*

1.20 Explain how TIR is used in optical fibres

1.21 Explain uses of optical fibres in endoscopes

1.22 Explain uses of ultrasound in diagnosis and treatment

Topic 2

X-rays and ECGs

2.1 Relate the ionisation by X-rays to their frequency and energy qualitatively ($E = hf$ is not required)

2.2 Explain the key features of passing a current through an evacuated tube, including:

a thermionic emission of electrons from a heated filament

b potential difference between the cathode (filament) and the anode (metal target)

c why the vacuum is necessary

d possible production of X-rays by collision with a metal target

2.3 Explain why a beam of charged particles is equivalent to an electric current

2.4 **Use the equation:**

current (ampere, A) = number of particles per second (1/second, 1/s) × charge on each particle (coulomb, C)
$\boldsymbol{I = N \times q}$

2.5 **Use the equation:**

kinetic energy (joule, J) = electronic charge (coulomb, C) × accelerating potential difference (volt, V)

$\mathbf{KE} = \frac{1}{2}mv^2 = e \times V$

2.6 Demonstrate an understanding of the inverse square law for electromagnetic radiation

2.7 Relate the absorption of X-rays to the thickness of the material through which they are travelling, quantitatively

2.8 Describe how X-rays are used in CAT scans and fluoroscopes

2.9 Demonstrate an understanding of the comparison of the risks and advantages of using X-rays for treatment and diagnosis

2.10 Explain how action potentials can be measured with an electrocardiogram (ECG) to monitor heart action

2.11 Relate the characteristic shape of a normal ECG to heart action

2.12 Use the equation:

frequency (hertz, Hz) = 1/time period (second, s)

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

2.13 Describe the use of a pacemaker to regulate the heart action

2.14 Describe the principles and use of pulse oximetry

Topic 3

Production, uses and risks of ionising radiation from radioactive sources

3.1 Evaluate the social and ethical issues relating to the use of radioactive techniques in medical physics

3.2 Describe the properties of alpha, beta, gamma, positron and neutron radiation

3.3 Recall the relative masses and relative electric charges of protons, neutrons, electrons and positrons

3.4 Recall that in an atom the number of protons equals the number of electrons

3.5 Describe the process of $\beta-$ decay (a neutron becomes a proton plus an electron)

3.6 **Describe the process of $\beta+$ decay (a proton becomes a neutron plus a positron)**

3.7 Explain the effects on the atomic (proton) number and mass (nucleon) number of radioactive decays (α, β and γ decay)

3.8 **Use given data to balance nuclear equations**

3.9 **Describe the features of the *N-Z* curve for stable isotopes**

3.10 **Identify isotopes as radioactive from their position relative to the stability curve**

3.11 **Recall that nuclei with high values of *Z* (above 82) usually undergo alpha decay**

3.12 **Recall that an isotope above the curve has too many neutrons to be stable and will undergo β− decay**

3.13 **Recall that an isotope below the curve has too many protons to be stable and will undergo β+ decay**

3.14 **Recall that the proton and neutron each contain three particles called quarks**

3.15 **Describe the arrangement of up and down quarks in protons and neutrons**

3.16 **Use given data to explain the arrangement of up and down quarks in protons and neutrons in terms of charge and mass**

3.17 **Explain β− decay as a process that involves a down quark changing into an up quark (a neutron becomes a proton and an electron)**

3.18 **Explain β+ decay as a process that involves an up quark changing into a down quark (a proton becomes a neutron and a positron)**

3.19 Recall that nuclei that have undergone radioactive decay often undergo nuclear rearrangement with a loss of energy as gamma radiation

3.20 Describe the dangers of ionising radiation in terms of tissue damage and possible mutations

3.21 Explain the precautions taken to ensure the safety of people exposed to radiation, including limiting the dose for patients and the risks to medical personnel

3.22 Compare and contrast the treatment of tumours using radiation applied internally or externally

3.23 Describe palliative care including the use of radiation in some instances

3.24 Explain some of the uses of radioactive substances in diagnosis of medical conditions, including PET scanners and tracers

3.25 Explain why isotopes used in PET scanners have to be produced nearby

Topic 4

Motion of particles

4.1 Discuss how instruments, including particle accelerators, can help scientists develop better explanations about the physical world

4.2 Discuss reasons for collaborative, international research into big scientific questions, including particle physics

4.3 Explain how for motion in a circle there must be a resultant force known as a centripetal force that acts towards the centre of the circle

4.4 Explain how particle accelerators called cyclotrons cause charged particles to move in a circular or spiral path, due to a magnetic field

4.5 Demonstrate an understanding that certain stable elements can be bombarded with proton radiation to change them into radioactive isotopes

4.6 Describe the use of particle accelerators (cyclotrons) to produce radioactive isotopes for medical purposes

4.7 Demonstrate an understanding that for inelastic collisions momentum is conserved but kinetic energy is not conserved

4.8 Demonstrate an understanding that for elastic collisions both momentum and kinetic energy are conserved

4.9 Analyse collisions in one dimension in terms of momentum and kinetic energy

4.10 **Carry out calculations using momentum conservation for a two-body collision (in one dimension only)**

4.11 **Carry out calculations using conservation of kinetic energy for a two-body elastic collision (in one dimension only)**

4.12 *Investigate factors affecting the height of rebound of bouncing balls*

4.13 Recall that gamma rays can be produced by the annihilation of an electron and a positron

4.14 Apply conservation of momentum and charge to positron electron annihilation

4.15 Apply the idea of conservation of mass energy for positron electron annihilation

a in a qualitative way (calculations involving $E = mc^2$ will not be required)

b **in a quantitive way using the equation $E = mc^2$**

4.16 Explain the use of radio isotopes in PET scanners to produce gamma rays

Topic 5

Kinetic theory and gases

5.1 Use a simple kinetic theory model to describe movement of particles in the three states of matter

5.2 Explain the pressure of a gas in terms of the motion of its particles

5.3 Describe the effect of changing the temperature of a gas on the speed of its particles

5.4 Describe the term absolute zero, −273°C, in terms of the lack of movement of particles

5.5 Convert between the Kelvin and Celsius scales

5.6 Recall that the average kinetic energy of the particles in a gas is directly proportional to the Kelvin temperature of the gas

5.7 *Investigate the temperature and volume relationship for a gas*

5.8 Use the relationship:

$$V_1 = \frac{V_2 T_1}{T_2}$$

to calculate volume for gases of fixed mass at constant pressure (rearranging not required)

5.9 *Investigate the volume and pressure relationship for a gas*

5.10 Use the relationship:

$$V_1 P_1 = V_2 P_2$$

to calculate volume or pressure for gases of fixed mass at constant temperature

5.11 **Use the equation:**

initial pressure (pascal, Pa) × initial volume (metre^3, m^3) / initial temperature (kelvin, K) = final pressure (pascal, Pa) × final volume (metre^3, m^3) / final temperature (kelvin, K)

$$\boldsymbol{\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}}$$

5.12 Apply an understanding of the equation in 5.11 to the use of bottled gases in medicine, including the need for a pressure above atmospheric and the calculation of the volume of gas released at atmospheric pressure