

1.1 Practical skills assessed in a written examination

Planning

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you design experiments, including solving problems set in a practical context? | ☐ | ☐ | ☐ |
| Can you identify the variables to be controlled in an experiment and explain why? | ☐ | ☐ | ☐ |
| Can you evaluate whether an experimental method is appropriate to meet the expected outcomes? | ☐ | ☐ | ☐ |
| Can you choose appropriate techniques and instruments for a given measurement? | ☐ | ☐ | ☐ |

Implementing

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you describe how to use a wide range of practical apparatus and techniques correctly? | ☐ | ☐ | ☐ |
| Can you use appropriate units for measurements? | ☐ | ☐ | ☐ |
| Can you present observations and data in a suitable format, such as tables with headings and units? | ☐ | ☐ | ☐ |

Analysis

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you process, analyse and interpret qualitative and quantitative experimental results? | ☐ | ☐ | ☐ |
| Can you use appropriate mathematical skills to analyse quantitative data? | ☐ | ☐ | ☐ |
| Can you quote results to an appropriate number of significant figures? | ☐ | ☐ | ☐ |
| Can you plot and interpret graphs with suitable labelled axes and scales? | ☐ | ☐ | ☐ |
| Can you measure gradients and intercepts of graphs and explain what they represent? | ☐ | ☐ | ☐ |
| Can you draw valid conclusions from experimental data? | ☐ | ☐ | ☐ |

Evaluation

- | | | | |
|--|-----------------------|-----------------------|-----------------------|
| Can you evaluate results and draw conclusions, identifying anomalies? | ☐ | ☐ | ☐ |
| Can you identify the limitations in an experimental procedure? | ☐ | ☐ | ☐ |
| Can you explain the precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus? | ☐ | ☐ | ☐ |
| Can you suggest and justify improvements to experimental procedures and apparatus? | ☐ | ☐ | ☐ |
| Can you explain how experimental results confirm or refute a hypothesis or prediction? | ☐ | ☐ | ☐ |

Practical skills

Can you apply investigative approaches and methods when using instruments and equipment?	☐ ☐ ☐
Can you use a range of apparatus and materials safely, identifying hazards and ways of reducing risk?	☐ ☐ ☐
Can you follow written instructions accurately?	☐ ☐ ☐
Can you make and record observations and measurements methodically, with appropriate precision?	☐ ☐ ☐
Can you keep appropriate records of experimental activities?	☐ ☐ ☐
Can you present information and data in a scientific way?	☐ ☐ ☐
Can you use appropriate software and tools to process data, carry out research and report findings?	☐ ☐ ☐
Can you use online and offline research skills, including websites, textbooks and other printed sources?	☐ ☐ ☐
Can you correctly cite sources of information?	☐ ☐ ☐
Can you use a wide range of experimental and practical instruments, equipment and techniques appropriate to physics?	☐ ☐ ☐

Use of apparatus and techniques

Can you use analogue apparatus to record length, temperature, pressure, force, angle and volume, interpolating between scale markings?	☐ ☐ ☐
Can you use digital instruments, including multimeters, to obtain values of time, current, potential difference, resistance and mass?	☐ ☐ ☐
Can you use methods to increase accuracy, such as timing over multiple oscillations or using fiducial marks, set squares or plumb lines?	☐ ☐ ☐
Can you use a stopwatch or light gates for timing?	☐ ☐ ☐
Can you use callipers and micrometers to measure small distances?	☐ ☐ ☐
Can you correctly construct circuits from circuit diagrams using DC power supplies, cells and components, including polarity-sensitive ones?	☐ ☐ ☐
Can you design, construct and check circuits using DC power supplies, cells and a range of components?	☐ ☐ ☐
Can you use a signal generator and oscilloscope, including the volts/division and time-base settings?	☐ ☐ ☐
Can you generate and measure waves using a microphone and loudspeaker, ripple tank, vibration transducer or microwave/radio wave source?	☐ ☐ ☐

Can you use a laser or light source to investigate characteristics of light, including interference and diffraction?



Can you use ICT such as computer modelling, data loggers with sensors and data-processing software?



Can you use ionising radiation sources and detectors safely?



Measurement and uncertainty

Can you describe and explain the factors affecting the accuracy and uncertainty of a measurement?



Can you explain why it is important to identify the largest source of uncertainty in a measurement?



Can you use SI units and their prefixes correctly?



Can you use standard form and express angles in both degrees and radians?



Can you correctly use the terms accuracy, precision, resolution, sensitivity, response time, uncertainty and systematic error?

**Presenting data**

Can you use dot-plots to show the distribution of repeated measurements?



Can you estimate the mean or median and the spread of a set of measured values, and identify outliers?



Can you plot and interpret graphs including scatter graphs, pie charts and logarithmic plots?



Can you add uncertainty bars to graphs and use them to judge a line of best fit?

**Calculations and estimates**

Can you calculate the mean, range, spread and percentage uncertainty of a set of measurements?



Can you find the best-fit gradient and intercept of a graph and estimate the uncertainty in each from the steepest and shallowest lines?



Can you combine uncertainties for quantities that are added, subtracted, multiplied, divided or raised to powers?



Can you make sensible order-of-magnitude estimates of everyday physical quantities?



3.1 Communication

Imaging and signalling

Can you explain how a thin converging lens forms a real image by changing the curvature of wavefronts?	☐	☐	☐
Can you describe how an image is stored as an array of numbers (pixels)?	☐	☐	☐
Can you explain how stored image values can be manipulated to change brightness and contrast, reduce noise, detect edges and add false colour?	☐	☐	☐
Can you explain how an analogue signal is digitised, including the effect of noise?	☐	☐	☐
Can you describe the advantages and disadvantages of digital signals compared with analogue signals?	☐	☐	☐
Can you describe evidence that electromagnetic waves can be polarised?	☐	☐	☐
Can you correctly use the terms pixel, bit, byte, focal length, power, magnification and resolution?	☐	☐	☐
Can you correctly use the terms sampling, signal, noise and polarisation?	☐	☐	☐
Can you draw and interpret ray diagrams and wavefront diagrams for light passing through a converging lens?	☐	☐	☐
Can you draw and interpret waveform diagrams?	☐	☐	☐
Can you calculate the amount of information in an image using number of pixels x bits per pixel?	☐	☐	☐
Can you calculate lens power using $P = 1/f$ and relate it to the change in wavefront curvature?	☐	☐	☐
Can you use the thin lens equation $1/v = 1/u + 1/f$ (Cartesian convention) for a thin converging lens forming a real image?	☐	☐	☐
Can you calculate linear magnification using $m = \text{image height} / \text{object height} = v/u$?	☐	☐	☐
Can you use $v = f\lambda$ and $f = 1/T$ for waves?	☐	☐	☐
Can you calculate the number of levels from the number of bits using $N = 2^b$, or $b = \log_2 N$?	☐	☐	☐
Can you explain why the minimum sampling rate must be greater than twice the maximum frequency of the signal, and use this?	☐	☐	☐
Can you calculate a rate of data transmission as samples per second x bits per sample?	☐	☐	☐
Can you represent the digitisation of an analogue signal graphically for a given number of resolution levels?	☐	☐	☐
Can you calculate the maximum useful number of bits per sample from $b = \log_2(V_{\text{total}} / V_{\text{noise}})$?	☐	☐	☐

Can you describe how to determine the power or focal length of a converging lens using the thin lens equation?



Can you describe how to observe polarisation effects using microwaves and light?



Sensing

Can you describe electric current as the flow of charged particles?



Can you explain potential difference as the energy transferred per unit charge?



Can you explain resistance and conductance, including for series and parallel combinations?



Can you explain what is meant by e.m.f. and describe the effect of internal resistance?



Can you describe power dissipation in electric circuits?



Can you state Ohm's law and describe the relationship between potential difference and current for an ohmic resistor?



Can you explain how a potential divider works?



Can you explain the electrical behaviour of metals, semiconductors and insulators in terms of the number density of mobile charge carriers?



Can you explain Kirchhoff's first and second laws as consequences of conservation of charge and energy?



Can you correctly use the terms e.m.f., potential difference, current, charge, resistance and conductance?



Can you correctly use the terms series, parallel, internal resistance, load, resistivity, conductivity and charge carrier number density?



Can you recognise and use standard circuit symbols?



Can you sketch and interpret I-V graphs for ohmic and non-ohmic components?



Can you sketch and interpret graphs of resistance or conductance against temperature, for example for a thermistor?



Can you recall and use $R = V/I$ and $G = 1/R = I/V$?



Can you use $Q = It$ and $W = VQ$?



Can you use $P = W/t = VI = I^2 R = V^2/R$ and $W = VIt$?



Can you use $V = \mathcal{E} - Ir$ to find terminal potential difference, e.m.f. or internal resistance?



Can you combine resistances and conductances in series and in parallel?



Can you calculate resistance using $R = \rho L/A$ and conductance using $G = \sigma A/L$?



Can you calculate the output of a potential divider using $V_{\text{out}} = V_{\text{in}} \times R_2/(R_1 + R_2)$?



Can you use $V_1/V_2 = R_1/R_2$ for resistors in series?



Can you describe how to investigate the I-V characteristics of ohmic and non-ohmic components using voltmeters and ammeters?



Can you describe how to determine the resistivity or conductivity of a metal?



Can you describe how to use potential divider circuits that include sensors such as thermistors and LDRs?



Can you describe how to calibrate a sensor or instrument?



Can you describe how to determine the internal resistance of a chemical cell or other source of e.m.f.?



3.2 Designer materials

Mechanical properties of materials

Can you describe elastic deformation, plastic deformation and fracture?



Can you describe direct evidence for the size and spacing of particles, such as scanning tunnelling microscope images and Rayleigh's oil drop experiment?



Can you describe the structures and behaviour of metals, ceramics and polymers?



Can you explain how the movement of dislocations causes slip and ductility in metals?



Can you explain why brittle materials such as ceramics lack mobile dislocations and fracture by crack propagation?



Can you explain the behaviour of polymers in terms of the entanglement and unravelling of long-chain molecules?



Can you describe one method of measuring the Young modulus and fracture stress of a material?



Can you correctly use the terms stress, strain, Young modulus, tension, compression, fracture stress and yield stress?



Can you correctly use the terms stiff, elastic, plastic, ductile, hard, brittle, tough, strong and dislocation?



Can you sketch and interpret force-extension and stress-strain graphs up to fracture?



Can you use tables and diagrams that compare materials by their properties?



Can you interpret images showing the structures of materials?



Can you use Hooke's law, $F = kx$?



Can you calculate elastic strain energy as $\frac{1}{2} kx^2$, or the area under a force-extension graph for loading?



Can you calculate stress = tension / cross-sectional area and strain = extension / original length?



Can you calculate the Young modulus using $E = \text{stress} / \text{strain}$?



Can you describe how to plot force-extension characteristics for springs, rubber bands and polythene strips?



Can you describe how to determine the Young modulus of a metal wire such as copper or steel?



Superposition and standing waves

Can you explain how standing waves form from two waves travelling in opposite directions, including a graphical treatment?



Can you calculate the wavelength of standing waves (no end corrections)?



Can you correctly use the terms phase, phasor, amplitude, superposition, coherence, path difference and intensity?



Can you describe how to use an oscilloscope to determine frequencies?



Can you describe superposition experiments using vibrating strings, sound, light and microwaves?



Can you describe how to determine the speed of sound in air using standing waves in a resonance tube?

**Refraction, diffraction and interference**

Can you explain refraction at a plane surface in terms of the change in wave speed, using the wave model?



Can you use Snell's law, $n = \sin i / \sin r$, and the term refractive index?



Can you explain diffraction of waves passing through a narrow gap?



Can you explain why waves from two slits interfere and produce a pattern of fringes?



Can you explain diffraction and interference by a diffraction grating?



Can you calculate path differences for double slits and gratings using $n\lambda = d \sin \theta$ for a distant screen, including the small angle approximation?



Can you correctly use the terms interference and diffraction?



Can you describe how to determine the refractive index of a transparent block?



Can you describe how to determine the wavelength of light using a double slit and a diffraction grating?

**Quantum behaviour**

Can you describe evidence that photons transfer energy in discrete quanta, $E = hf$, from LEDs, the photoelectric effect and line spectra?



Can you explain the limitations of the particle and wave models of light?



Can you explain the quantum model: the probability of a quantum arriving is found by combining amplitude and phase (phasors) for all possible paths?



Can you describe evidence from electron diffraction that electrons show quantum behaviour?



Can you correctly use the terms probability, electronvolt, work function and threshold frequency?



Can you calculate photon energies across the electromagnetic spectrum using $E = hf$?



Can you calculate the de Broglie wavelength of a particle using $\lambda = h/p$?



Can you describe how to determine the Planck constant using LEDs of different colours?



4.2 Space and time

Vectors and motion

Can you use vectors to represent displacement, velocity and acceleration?



Can you describe and explain the trajectory of a body moving with constant acceleration in one or two dimensions?



Can you explain why perpendicular components of a force act independently?



Can you describe how displacement, velocity and acceleration can be measured?



Can you correctly use the terms displacement, speed, velocity, acceleration, vector and scalar?



Can you sketch and interpret graphs of accelerated motion, using gradients of s-t and v-t graphs and the area under a v-t graph?



Can you add vectors graphically and show how a vector changes in magnitude and direction?



Can you resolve a vector into two perpendicular components?



Can you add two vectors graphically and add two perpendicular vectors algebraically?



Can you use the equations of motion $v = u + at$, $s = ut + \frac{1}{2}at^2$, $s = ((u + v)/2)t$ and $v^2 = u^2 + 2as$?



Can you model changes in displacement and velocity in small time steps using a computer model or graph, for zero or constant resultant force?



Forces, momentum and Newton's laws

Can you state and apply Newton's three laws of motion?



Can you explain conservation of momentum and Newton's third law as a consequence of it?



Can you correctly use the terms force, mass, momentum and impulse?



Can you use $p = mv$?



Can you use $F = \Delta p / \Delta t$ for constant mass, and recall $F = ma$?



Can you apply conservation of momentum to collisions in one dimension?



Work, energy and power

Can you calculate work done when a force is not parallel to the displacement?



Can you explain and apply the principle of conservation of energy?



Can you describe power as the rate of transfer of energy?



Can you correctly use the terms work, energy and power?



Can you use $W = Fs$ and $W = Fs \cos \theta$?



Can you recall and use kinetic energy $= \frac{1}{2} mv^2$?



Can you recall and use gravitational potential energy $= mgh$?



Can you use $P = \Delta E / t$ and $P = Fv$?



Practical skills in motion

Can you describe how to investigate the motion and collisions of trolleys or air-track gliders using ticker timers, light gates, data loggers or video?



Can you describe how to determine the acceleration of free fall using a trapdoor and electromagnet, light gates or video?



Can you describe how to investigate terminal velocity, for example a ball-bearing in a viscous liquid or paper cones in air?



5.1 Models and rules

Creating models: capacitors and exponential decay

Can you define capacitance as $C = Q/V$?	☐	☐	☐
Can you explain why the energy stored on a capacitor is $E = 1/2 QV$?	☐	☐	☐
Can you explain exponential decay of capacitor charge, where the rate of removal is proportional to the charge left, $dQ/dt = -Q/RC$?	☐	☐	☐
Can you explain radioactive decay as a random process with a fixed probability, giving $dN/dt = -\lambda N$?	☐	☐	☐
Can you correctly use the term time constant, τ ?	☐	☐	☐
Can you correctly use the terms activity, decay constant, half-life, probability and randomness?	☐	☐	☐
Can you express relationships such as $dx/dt = -kx$ in words and move between words, equations and diagrams?	☐	☐	☐
Can you sketch, plot from data and interpret exponential curves on linear and logarithmic scales?	☐	☐	☐
Can you sketch and interpret capacitor charge and discharge curves?	☐	☐	☐
Can you find the energy stored on a capacitor from the area under a Q-V graph?	☐	☐	☐
Can you calculate activity and half-life from data and use $T_{1/2} = \ln 2 / \lambda$?	☐	☐	☐
Can you solve decay equations of the form $N = N_0 e^{-\lambda t}$ using iterative numerical or graphical methods, and know the analytic solution?	☐	☐	☐
Can you calculate the time constant $\tau = RC$ from data and use $Q = Q_0 e^{-t/RC}$?	☐	☐	☐
Can you solve capacitor discharge $Q = Q_0 e^{-t/RC}$ and charging $Q = Q_0(1 - e^{-t/RC})$ equations, and the matching V and I equations, iteratively or graphically?	☐	☐	☐
Can you use $C = Q/V$, $I = \Delta Q/\Delta t$ and $E = 1/2 QV = 1/2 CV^2$?	☐	☐	☐
Can you describe how to investigate charging and discharging a capacitor using meters and data loggers?	☐	☐	☐
Can you describe how to determine the half-life of an isotope such as protactinium?	☐	☐	☐

Creating models: oscillations

Can you explain that simple harmonic motion arises when the restoring force is proportional to displacement, $d^2x/dt^2 = -(k/m)x$?	☐	☐	☐
Can you show that $a = -\omega^2 x$ with $\omega = 2\pi f$ has solutions $x = A \sin \omega t$ and $x = A \cos \omega t$?	☐	☐	☐
Can you describe the changes between kinetic and potential energy during SHM as an example of energy conservation?	☐	☐	☐

Can you describe free and forced oscillations, damping and resonance qualitatively?	☐ ☐ ☐
Can you correctly use the terms SHM, period, frequency, free and forced oscillations, resonance and damping?	☐ ☐ ☐
Can you sketch and interpret x-t, v-t and a-t graphs for SHM, including their relative phases?	☐ ☐ ☐
Can you sketch and interpret graphs of resonator amplitude against driving frequency?	☐ ☐ ☐
Can you use $T = 2\pi\sqrt{m/k}$ and $f = 1/T$ for a mass on a spring?	☐ ☐ ☐
Can you use $T = 2\pi\sqrt{L/g}$ for a simple pendulum?	☐ ☐ ☐
Can you use $F = -kx$ and $E = \frac{1}{2} kx^2$?	☐ ☐ ☐
Can you solve $d^2x/dt^2 = -(k/m)x$ using iterative numerical or graphical methods?	☐ ☐ ☐
Can you use $x = A \sin 2\pi ft$ and $x = A \cos 2\pi ft$?	☐ ☐ ☐
Can you use $E_{\text{total}} = \frac{1}{2} mv^2 + \frac{1}{2} kx^2$ for an oscillator?	☐ ☐ ☐
Can you describe how to measure the period or frequency of SHM for a mass on a spring or a pendulum and relate it to mass or length?	☐ ☐ ☐
Can you make and describe qualitative observations of forced and damped oscillations in a range of systems?	☐ ☐ ☐

Out into space

Can you describe changes of gravitational potential energy and kinetic energy?	☐ ☐ ☐
Can you describe motion in a uniform gravitational field?	☐ ☐ ☐
Can you describe the gravitational field and potential of a point mass, modelling a spherical body as a point mass at its centre?	☐ ☐ ☐
Can you use angular velocity in rad s^{-1} ?	☐ ☐ ☐
Can you explain motion in a horizontal circle and in a circular gravitational orbit?	☐ ☐ ☐
Can you correctly use the terms force, kinetic energy, potential energy, gravitational field, gravitational potential and equipotential surface?	☐ ☐ ☐
Can you find gravitational potential from the area under a field strength-distance graph, and change in potential energy from the area under a force-distance graph?	☐ ☐ ☐
Can you find force from the gradient (tangent) of a potential energy-distance graph and field strength from the gradient of a potential-distance graph?	☐ ☐ ☐
Can you draw and interpret diagrams of gravitational fields and their equipotential surfaces?	☐ ☐ ☐
Can you use $\Delta E = mgh$ for a uniform gravitational field?	☐ ☐ ☐
Can you use $\Delta E = F\Delta s$ and explain why no work is done when moving along an equipotential?	☐ ☐ ☐

Can you use $v = 2\pi r/T = \omega r$ and $F = mv^2/r = mr\omega^2$ for circular motion?



Can you use $F = -GMm/r^2$ and $g = -GM/r^2$ for radial fields?



Can you use gravitational potential energy $E = -GMm/r$?



Can you use gravitational potential $V = -GM/r$?



Our place in the universe

Can you describe radar-type measurements of distances in the solar system, with distance defined in units of time assuming the speed of light is invariant?



Can you explain time dilation using the relativistic factor $\gamma = 1/\sqrt{1 - v^2/c^2}$?



Can you describe how relative velocities can be measured using radar?



Can you describe the evidence for a hot big bang, including cosmological red-shift (Hubble's law) and the cosmic microwave background?



Can you describe how the hot big bang model was developed?



Can you sketch and interpret logarithmic scales for distance, size, mass, energy, power and brightness?



Can you calculate distances and ages of astronomical objects, for example using Hubble's law?



Can you calculate distances and relative velocities from radar-type measurements?



5.2

Matter

Matter: very simple

Can you explain how energy transfer produces a temperature change, using specific thermal capacity?



Can you describe the behaviour of ideal gases?



Can you explain impulse, $F\Delta t = \Delta p$?



Can you state the assumptions of kinetic theory: negligible particle volume, perfectly elastic collisions and no forces except during collisions?



Can you explain that absolute temperature is proportional to the average energy per particle, average energy $= 3/2 kT \approx kT$?



Can you describe the random walk of gas molecules and how distance travelled depends on $\sqrt{N}$ steps?



Can you correctly use the terms ideal gas, root mean square speed, absolute temperature and internal energy?



Can you correctly use the terms Avogadro constant, Boltzmann constant, gas constant and mole?



Can you sketch and interpret graphs of the relationships between p , V , N and T for an ideal gas?



Can you find impulse from the area under a force-time graph?



Can you use $\Delta E = mc\Delta\theta$?



Can you use $pV = NkT$, with $N = nN_A$ and $Nk = nR$?



Can you use $pV = \frac{1}{3} Nm(c_{rms})^2$ from kinetic theory?



Can you describe how to determine the specific thermal capacity of a metal block or a liquid by an electrical method?



Can you describe how to investigate the gas laws, including estimating absolute zero?



Can you describe how to investigate the relationship between pressure and volume using a pressure gauge or differential pressure sensor and data logger?



Matter: hot or cold

Can you explain ratios of numbers of particles in quantum states of different energy at different temperatures (classical approximation)?



Can you describe the effect of temperature on processes with an activation energy, such as changes of state, thermionic emission, ionisation, conduction in semiconductors and viscous flow?



Can you sketch and interpret graphs of the Boltzmann factor against energy and against temperature?



Can you calculate ratios of characteristic energies to kT and judge whether a process will happen?



Can you use the Boltzmann factor $e^{-E/kT}$?



6.1 Fields

Electromagnetism

Can you explain how a transformer works, with flux produced by a coil and induced e.m.f. equal to the rate of change of flux linkage?	☐	☐	☐
Can you explain how a dynamo works through relative motion changing the flux linked by a conductor?	☐	☐	☐
Can you explain electromagnetic forces qualitatively using the tendency of flux lines to contract or induced poles?	☐	☐	☐
Can you describe simple linked electric and magnetic circuits, including flux produced by current-turns, the need for large conductance and permeance, the effect of scaling up machines and the effect of iron and air gaps?	☐	☐	☐
Can you correctly use the terms B-field, magnetic field, flux, flux linkage, induced e.m.f. and eddy currents?	☐	☐	☐
Can you sketch and interpret graphs of how current, flux and induced e.m.f. vary with time?	☐	☐	☐
Can you sketch and interpret flux-line diagrams of magnetic circuits, showing continuity of flux?	☐	☐	☐
Can you use Faraday's and Lenz's laws, induced e.m.f. = $-N \frac{d\Phi}{dt}$?	☐	☐	☐
Can you use $F = BIL$ for a current perpendicular to a uniform magnetic field?	☐	☐	☐
Can you recall and use $V_s/V_p = N_s/N_p$ for an ideal transformer?	☐	☐	☐
Can you recall and use $I_s/I_p = N_p/N_s$ for an ideal transformer?	☐	☐	☐
Can you describe how to observe induced e.m.f.s, for example by dropping a magnet through a coil connected to a data logger or oscilloscope?	☐	☐	☐
Can you describe how to determine the magnetic flux density between magnet poles using a rigid current-carrying wire and a digital balance?	☐	☐	☐
Can you describe how to investigate transformers?	☐	☐	☐

Charge and field

Can you describe a uniform electric field and use $E = V/d$?	☐	☐	☐
Can you describe the electric field of a charged object and the force on a charge in it, including the inverse square law for a point charge?	☐	☐	☐
Can you explain why a spherically symmetric charged conductor can be treated as a point charge at its centre?	☐	☐	☐
Can you describe the electrical potential energy and potential of a point charge, showing the $1/r$ relationship?	☐	☐	☐

Can you describe evidence that charge is discrete, such as Millikan's oil drop experiment?



Can you describe the force on a moving charged particle in a uniform magnetic field?



Can you compare the similarities and differences between electric and gravitational fields?



Can you correctly use the terms charge, electric field, electric potential, equipotential surface and electronvolt?



Can you find electric potential from the area under a field-distance graph and change in potential energy from the area under a force-distance graph?



Can you find force from the gradient of a potential energy-distance graph and field strength from the gradient of a potential-distance graph?



Can you draw and interpret diagrams of electric fields and their equipotential surfaces?



Can you use $F = kqQ/r^2$ and $E = F/q = kQ/r^2$, where $k = 1/(4\pi\epsilon_0)$?



Can you use $E = -dV/dr$, and $E = V/d$ for a uniform field?



Can you use electrical potential energy $= kQq/r$ and potential $V = kQ/r$?



Can you use $F = qvB$ for a charge moving in a magnetic field?



6.2 Fundamental particles

Probing deep into matter

Can you describe how particle accelerators produce high-energy beams for scattering experiments?



Can you describe scattering evidence for a small massive nucleus and how the nuclear model of the atom developed?



Can you describe evidence for discrete energy levels in atoms, such as electron collisions and line spectra?



Can you explain a simple model of the atom based on standing waves of electrons confined in a box?



Can you describe the quark structure of protons and neutrons?



Can you balance nuclear equations using conservation of mass-energy, charge and lepton number?



Can you explain why relativistic calculations are needed for very fast particles, for example in accelerators and cosmic rays?



Can you correctly use the terms energy level, scattering, nucleus, proton, neutron, nucleon, electron and positron?



Can you correctly use the terms quark, gluon, neutrino, hadron, lepton, antiparticle and lepton number?



Can you sketch the paths of scattered particles?	☐ ☐ ☐
Can you sketch electron standing waves in simple models of the atom?	☐ ☐ ☐
Can you use $F = qvB$ to analyse the circular motion of a charged particle in a magnetic field?	☐ ☐ ☐
Can you calculate the kinetic and potential energy of a charged particle being scattered, for example the distance of closest approach?	☐ ☐ ☐
Can you use rest energy $E = mc^2$ and the relativistic factor γ ?	☐ ☐ ☐
Can you use total energy = γ x rest energy?	☐ ☐ ☐

Ionising radiation and risk

Can you describe the nature of alpha, beta and gamma radiation and their different ionising and penetrating powers?	☐ ☐ ☐
Can you describe the effects of ionising radiation on living tissue?	☐ ☐ ☐
Can you explain nuclear stability and decay in terms of binding energy, including how a nucleus changes when it emits radiation?	☐ ☐ ☐
Can you explain how binding energy per nucleon varies with proton and neutron number (the nuclear valley)?	☐ ☐ ☐
Can you explain nuclear fission, chain reactions and nuclear fusion?	☐ ☐ ☐
Can you describe how nuclear power is generated and weigh up its benefits and the concerns about it?	☐ ☐ ☐
Can you correctly use the terms nucleon number, proton number, isotope, binding energy and atomic mass unit?	☐ ☐ ☐
Can you correctly use the terms absorbed dose, effective dose and risk?	☐ ☐ ☐
Can you sketch and interpret a graph of binding energy per nucleon against nucleon number?	☐ ☐ ☐
Can you calculate the activity of a radioactive sample using its half-life or decay constant?	☐ ☐ ☐
Can you calculate absorbed dose in grays as energy deposited per unit mass?	☐ ☐ ☐
Can you calculate effective dose in sieverts as absorbed dose x quality factor?	☐ ☐ ☐
Can you calculate energy changes in nuclear transformations using $E = mc^2$?	☐ ☐ ☐
Can you describe how to study the absorption of alpha particles, beta particles and gamma rays by suitable materials?	☐ ☐ ☐
Can you describe how to determine the half-life of an isotope such as protactinium?	☐ ☐ ☐

Practical activity groups

PAG1 Can you investigate motion, including collisions, the acceleration of free fall and terminal velocity?



PAG2 Can you investigate the properties of materials, including force-extension graphs and the Young modulus of a wire?



PAG3 Can you investigate electrical properties, including I-V characteristics, resistivity, calibrating a sensor and internal resistance?



PAG4 Can you investigate electrical circuits, including potential dividers with thermistors and LDRs?



PAG5 Can you investigate waves, including oscilloscope frequency measurement, superposition, the wavelength of light and the speed of sound in a resonance tube?



PAG6 Can you investigate optics and quantum effects, including lens focal length, polarisation, refractive index and the Planck constant using LEDs?



PAG7 Can you investigate ionising radiation, including the half-life of protactinium?



PAG8 Can you investigate gases, including the gas laws, absolute zero and the pressure-volume relationship?



PAG9 Can you investigate capacitors, including charging and discharging with meters or data loggers?



PAG10 Can you investigate simple harmonic motion, including the period of a mass-spring system or pendulum and damped and forced oscillations?



PAG11 Can you investigate thermal properties, including the specific thermal capacity of a metal block or liquid by an electrical method?



PAG12 Can you use research skills to investigate a physics topic, using and correctly citing online and offline sources?

