

1.1 Basic physics

Units and dimensions

Can you state the six base SI units (kg, m, s, A, mol, K)?



Can you express derived units in terms of base SI units and use standard prefixes (e.g. p, n, μ , m, k, M, G)?



Can you use base units to check an equation for homogeneity?



Scalars and vectors

Can you distinguish between scalar and vector quantities and give examples of each?



Can you add and subtract coplanar vectors, calculating the resultant of two perpendicular vectors?



Can you resolve a vector into two perpendicular components?



Density

Can you define density and use density = mass / volume to calculate mass, density or volume?



Moments and equilibrium

Can you explain the turning effect of a force and calculate its moment?



Can you state and use the principle of moments?



Can you define centre of gravity and state its position in a uniform cylinder, sphere and cuboid (beam)?



Can you state the conditions for equilibrium (zero resultant force and zero resultant moment) and use them in simple calculations?



1.2 Kinematics

Describing motion

Can you define displacement, mean and instantaneous speed, velocity and acceleration?



Can you represent displacement, speed, velocity and acceleration graphically?



Can you use the gradient of a displacement-time graph and the gradient and area of a velocity-time graph?



Can you interpret speed-time and displacement-time graphs for non-uniform acceleration?



Uniform acceleration

Can you derive and use the equations for uniformly accelerated motion in a straight line ($v = u + at$, $x = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2ax$, $x = \frac{1}{2}(u + v)t$)?



Can you describe the motion of bodies falling in a gravitational field with and without air resistance, including terminal velocity?



Projectiles

Can you explain the independence of vertical and horizontal motion of a body moving freely under gravity?



Can you analyse motion combining uniform velocity in one direction and uniform acceleration in a perpendicular direction, with simple projectile calculations?



1.3 Dynamics

Forces and Newton's laws

Can you explain the concept of force and state Newton's third law, identifying third-law pairs?



Can you draw and use free body diagrams to represent the forces on a particle or body?



Can you use $F = ma$ in situations where mass is constant?



Momentum

Can you define linear momentum as mass x velocity?



Can you state that force is the rate of change of momentum and apply this where mass is constant?



Can you apply the principle of conservation of momentum in one dimension to elastic and inelastic collisions?



Can you distinguish elastic and inelastic collisions in terms of kinetic energy?



1.4 Energy concepts

Work and energy

Can you define work done as force x distance moved in the direction of a constant force?



Can you calculate work done when the force is not along the line of motion using $W = Fx \cos \theta$?



Can you apply the principle of conservation of energy, including gravitational potential energy, elastic potential energy and kinetic energy?



Can you use the work-energy relationship, $Fx = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$?



Power and efficiency

Can you define power as the rate of energy transfer and calculate it?



Can you explain how dissipative forces such as friction and drag reduce the efficiency of a system?



Can you calculate efficiency as useful energy output / total energy input x 100%?



1.5 Solids under stress

Hooke's law and Young modulus

Can you state Hooke's law, $F = kx$, and define the spring constant as force per unit extension?



Can you define tensile stress, tensile strain and the Young modulus, and state when Hooke's law applies?



Can you calculate work done in deforming a solid as the area under a force-extension graph, equal to $\frac{1}{2}Fx$ when Hooke's law is obeyed?



Types of solid

Can you classify solids as crystalline, amorphous (including glasses and ceramics) or polymeric?



Behaviour of materials

Can you describe the force-extension features of a ductile metal such as copper, including elastic and plastic strain?



Can you explain plastic deformation in metals in terms of dislocations, and how metals can be strengthened by pinning dislocations?



Can you describe necking and ductile fracture in a metal?



Can you describe the force-extension behaviour of a brittle material such as glass, which obeys Hooke's law up to fracture?



Can you explain brittle fracture by crack propagation, the effect of surface imperfections, and how glass is strengthened by putting the surface under compression?



Can you describe the force-extension behaviour of rubber, including approximate Hooke's law at small strains and a low Young modulus?



Can you explain the large extension of rubber in terms of straightening of chain molecules, and explain hysteresis in rubber?



1.6 Using radiation to investigate stars

Stellar spectra and black bodies

Can you explain that a stellar spectrum is a continuous emission spectrum from the dense surface with a line absorption spectrum from the tenuous atmosphere?



Can you describe a black body as a perfect absorber and explain why stars approximate black bodies?



Can you sketch the shape of the black body spectrum and state that peak wavelength is inversely proportional to absolute temperature?



Can you convert between Celsius and kelvin using $T(K) = \theta(^{\circ}C) + 273.15$?



Laws applied to stars

Can you use Wien's displacement law, $\lambda_{\max} = W/T$, to find the temperature of a star?



Can you use Stefan's law, $P = A\sigma T^4$, to relate luminosity, size and temperature of a star?



Can you use the inverse square law for intensity, $I = P/(4\pi d^2)$, to relate luminosity and distance of a star?



Can you explain the meaning and value of multiwavelength astronomy?



1.7 Particles and nuclear structure

Quarks, leptons and hadrons

Can you state that matter is made of quarks and leptons, which form three generations (first generation only for questions)?



Can you recall the first-generation leptons (electron, electron neutrino) and quarks (up, down) and their charges?



Can you explain that antiparticles have the same properties as their particles apart from opposite charge, and that particle and antiparticle annihilate when they meet?



Can you use the symbols for the positron, antiquarks and hadrons?



Can you explain that quarks are never observed in isolation but combine as baryons (3 quarks), antibaryons (3 antiquarks) and mesons (quark-antiquark pairs)?



Can you give the quark compositions of the proton (uud) and neutron (udd)?



Can you use data to suggest the quark make-up of less well-known first-generation baryons and of the charged pions?



Interactions and conservation laws

Can you describe the four interactions (gravitational, weak, electromagnetic, strong), their relative strengths and ranges, and which particles experience each?



Can you apply conservation of charge, lepton number and baryon (quark) number to decide whether simple reactions are possible?



Can you state that neutrino involvement and changes of quark flavour happen only in weak interactions, and identify weak interactions such as beta decay?



2.1 Conduction of electricity

Charge and current

Can you state that the coulomb is the unit of charge and that the electron charge is a very small fraction of a coulomb?



Can you explain that charge can flow through conductors?



Can you define electric current as the rate of flow of charge and use $I = Q/t$, with $1 \text{ A} = 1 \text{ C s}^{-1}$?



Can you describe conduction in metals as the drift of free electrons?



Can you derive and use $I = nAve$ for free electrons?



2.2 Resistance

Potential difference and Ohm's law

Can you define potential difference as energy transferred per unit charge, with $1 \text{ V} = 1 \text{ J C}^{-1}$?



Can you sketch and explain the I-V characteristics of a filament lamp and of a metal wire at constant temperature?



Can you state Ohm's law, define resistance using $V = IR$, and state that $1 \Omega = 1 \text{ V A}^{-1}$?



Can you use $P = IV = I^2R = V^2/R$?



Resistivity and temperature

Can you explain resistance in terms of collisions between electrons and lattice ions, and why resistance increases with temperature?



Can you use $R = \rho l/A$?



Can you state that the resistance of a metal varies almost linearly with temperature over a wide range?



Can you explain that collisions increase the vibrational energy of the ions, so the metal's temperature rises?



Superconductivity

Can you explain superconductivity and the superconducting transition temperature?



Can you state that most metals become superconducting a few kelvin above absolute zero?



Can you state that high-temperature superconductors have transition temperatures above the boiling point of nitrogen ($-196\text{ }^{\circ}\text{C}$)?



Can you describe uses of superconductors, such as MRI scanners and particle accelerators?



2.3 D.C. circuits

Series and parallel circuits

Can you explain that the current from a source equals the sum of the currents in parallel branches, as a consequence of conservation of charge?



Can you explain that potential differences round a series circuit add to the supply p.d., as a consequence of conservation of energy?



Can you state that p.d.s across components in parallel are equal?



Can you calculate combined resistance of resistors in series and in parallel?



Can you use potential divider circuits, including those with LDRs and thermistors as sensors?



Emf and internal resistance

Can you define emf and state that it is measured in volts?



Can you explain internal resistance and use $V = E - Ir$?



Can you calculate the current and terminal p.d. for a circuit with one cell or several cells in series?



2.4 The nature of waves

Wave basics

Can you state that a progressive wave transfers energy without transferring matter?



Can you distinguish between transverse and longitudinal waves?



Can you explain polarisation and why only transverse waves can be polarised?



Can you explain what is meant by oscillations being in phase and in antiphase?



Can you define displacement, amplitude, wavelength, frequency, period and wave velocity?



Can you draw and interpret displacement-time and displacement-position graphs for transverse waves?



Can you use the wave equation $c = f\lambda$?



Can you explain that points on a wavefront oscillate in phase and that rays are at right angles to wavefronts?



2.5 Wave properties

Diffraction

Can you describe diffraction of waves at slits and obstacles?



Can you explain that there is little diffraction when the wavelength is much smaller than the slit or obstacle?



Can you describe how waves spread out as semicircular wavefronts when wavelength is equal to or greater than the slit width, and through less than 180° when it is smaller?



Interference and superposition

Can you explain how two-source interference occurs?



Can you explain the historical importance of Young's double-slit experiment as evidence for the wave nature of light?



Can you state the principle of superposition and draw sketch graphs to illustrate it?



Can you state the path difference conditions for constructive ($n\lambda$) and destructive ($(n + 1/2)\lambda$) interference from in-phase sources?



Can you use the double-slit equation $\lambda = ay/D$?



Can you derive and use $d \sin \theta = n\lambda$ for a diffraction grating?



Can you explain that a small slit spacing spreads the orders further apart and that many slits make the beams sharper?



Coherence

Can you state that coherent sources are monochromatic with continuous wavefronts and a constant phase relationship?



Can you give examples of coherent and incoherent sources?



Can you state that observable two-source interference needs a zero or constant phase difference and oscillations in the same direction?



Stationary waves

Can you state the differences between stationary and progressive waves?



Can you explain the formation of a stationary wave as the superposition of two progressive waves of equal amplitude and frequency travelling in opposite directions, with internodal distance $\lambda/2$?



2.6 Refraction of light

Refraction

Can you define refractive index as $n = c/v$?



Can you use $n_1 v_1 = n_2 v_2$ and Snell's law, $n_1 \sin \theta_1 = n_2 \sin \theta_2$?



Can you relate Snell's law to the wave model, drawing plane waves refracting at a boundary?



Total internal reflection and optical fibres

Can you state the conditions for total internal reflection?



Can you derive and use $\sin C = n_2/n_1$ for the critical angle?



Can you apply total internal reflection to multimode optical fibres?



Can you explain how multimode dispersion limits data transfer rate and transmission distance?



Can you explain why monomode fibres allow much greater transmission rates and distances?



2.7 Photons

Photoelectric effect

Can you state that light is made of discrete packets of energy called photons, with $E = hf$?



Can you describe a demonstration of the photoelectric effect?



Can you describe how a vacuum photocell is used to measure $E_{k \text{ max}}$ in eV and J?



Can you sketch and interpret a graph of $E_{k \text{ max}}$ against frequency?



Can you use Einstein's equation $E_{k \text{ max}} = hf - \phi$ and relate it to the gradient and intercepts of the graph?



Electromagnetic spectrum

Can you state that the visible spectrum runs from about 700 nm (red) to 400 nm (violet) and give orders of magnitude of wavelength for other regions of the EM spectrum?



Can you give typical photon energies for the different EM radiations?

**Atomic spectra and energy levels**

Can you explain how line emission and line absorption spectra are produced by atoms?



Can you describe how these spectra appear when viewed with a diffraction grating?



Can you use simple atomic energy level diagrams with the photon hypothesis to explain line spectra?



Can you determine ionisation energies from energy level diagrams?

**Wave-particle duality**

Can you explain how electron diffraction shows the wave-like nature of particles?



Can you use $p = h/\lambda$ for both particles and photons?



Can you calculate the radiation pressure on a surface that absorbs or reflects photons?

**2.8 Lasers****Laser principles**

Can you explain stimulated emission and how it produces coherent light?



Can you explain why a population inversion ($N_2 > N_1$) is needed for a laser?



Can you explain why a population inversion is usually not possible in a 2-level system?



Can you explain how a population inversion is achieved in 3-level and 4-level systems?



Can you explain what pumping is and why it is needed?



Can you describe the structure of a typical laser: an amplifying medium between two mirrors, one partially transmitting?



Can you give the advantages of semiconductor lasers (small, cheap, efficient) and their uses, such as CDs, DVDs and telecommunications?



3.1 Circular motion**A-LEVEL ONLY****Circular motion**

Can you define period of rotation and frequency?	☐	☐	☐
Can you define the radian and use it as a measure of angle?	☐	☐	☐
Can you define angular velocity ω for circular motion and simple harmonic motion?	☐	☐	☐
Can you explain that centripetal force is the resultant force on a body moving at constant speed in a circle?	☐	☐	☐
Can you state that centripetal force and acceleration are directed towards the centre of the circle?	☐	☐	☐
Can you use $v = \omega r$, $a = v^2/r = \omega^2 r$ and $F = mv^2/r = m\omega^2 r$?	☐	☐	☐

3.2 Vibrations**A-LEVEL ONLY****Simple harmonic motion**

Can you define simple harmonic motion in words?	☐	☐	☐
Can you state and use the defining equation $a = -\omega^2 x$?	☐	☐	☐
Can you sketch and interpret the acceleration-displacement graph for SHM?	☐	☐	☐
Can you use $x = A \cos(\omega t + \phi)$ as a solution to $a = -\omega^2 x$?	☐	☐	☐
Can you define frequency, period, amplitude and phase for SHM?	☐	☐	☐
Can you use $T = 1/f$ and $T = 2\pi/\omega$?	☐	☐	☐
Can you use $v = -A\omega \sin(\omega t + \phi)$ and find the maximum speed $A\omega$?	☐	☐	☐
Can you sketch and interpret displacement-time and velocity-time graphs for SHM?	☐	☐	☐
Can you use $T = 2\pi\sqrt{m/k}$ for a mass on a spring, with k the stiffness?	☐	☐	☐
Can you use $T = 2\pi\sqrt{l/g}$ for a simple pendulum?	☐	☐	☐
Can you describe the interchange of kinetic and potential energy in undamped SHM, sketch energy graphs and do energy calculations?	☐	☐	☐

Damping and resonance

Can you describe free oscillations and the effect of damping in real systems?	☐	☐	☐
Can you give practical examples of damped oscillations?	☐	☐	☐

Can you explain critical damping and its importance, for example in car suspension systems?



Can you describe forced oscillations and resonance, with practical examples?



Can you sketch how the amplitude of a forced oscillation varies with driving frequency and show how increased damping broadens and lowers the resonance curve?



Can you give examples where resonance is useful (e.g. circuit tuning, microwave cooking) and where it must be avoided (e.g. bridge design)?



3.3 Kinetic theory

A-LEVEL ONLY

Ideal gases

Can you use the equation of state for an ideal gas, $pV = nRT$ and $pV = NkT$?



Can you state the assumptions of the kinetic theory of gases, including random distribution of energy among molecules?



Can you explain how molecular movement causes gas pressure and use $p = \frac{1}{3} (N/V) m \langle c^2 \rangle$?



Can you define the Avogadro constant and the mole?



Can you relate molar mass M to relative molecular mass M_r and use $n = \text{total mass} / \text{molar mass}$?



Can you derive the total translational kinetic energy of a mole of monatomic gas as $\frac{3}{2} RT$ and the mean kinetic energy per molecule as $\frac{3}{2} kT$?



Can you explain that absolute temperature is proportional to the mean kinetic energy of the molecules?



3.4 Thermal physics

A-LEVEL ONLY

Internal energy

Can you define internal energy as the sum of the potential and kinetic energies of the molecules?



Can you explain absolute zero as the temperature at which internal energy is a minimum?



Can you use $U = \frac{3}{2} nRT$ for an ideal monatomic gas?



Heat and work

Can you explain that heat is energy in transit across a boundary due to a temperature difference?



Can you explain thermal equilibrium: no net heat flow between bodies in contact, so they are at the same temperature?



Can you explain that work is also energy in transit?



Can you use $W = p\Delta V$ for a gas at constant pressure?



Can you find work done as the area under a p-V graph when pressure changes?



First law and specific heat capacity

Can you state and apply the first law of thermodynamics, $\Delta U = Q - W$, interpreting negative values?



Can you explain why W is usually negligible for solids and liquids, so $Q = \Delta U$?



Can you use $Q = mc\Delta\theta$ as the defining equation for specific heat capacity?



3.5 Nuclear decay

A-LEVEL ONLY

Radiation

Can you explain the spontaneous nature of radioactive decay and describe alpha, beta and gamma radiation?



Can you write nuclear equations for decays using $A/Z X$ notation?



Can you describe methods to distinguish alpha, beta and gamma radiation and link their nature to penetrating power and range?



Can you allow for background radiation in measurements?



Decay law

Can you define half-life, $T_{1/2}$?



Can you define activity and the becquerel?



Can you define the decay constant λ and use $A = \lambda N$?



Can you use the exponential decay law $N = N_0 e^{-\lambda t}$ and $A = A_0 e^{-\lambda t}$, in graphical and algebraic form, including non-integer numbers of half-lives?



Can you derive and use $T_{1/2} = \ln 2 / \lambda$?



Mass-energy and binding energy

Can you use $E = mc^2$ to relate mass and energy?



Can you define the binding energy of a nucleus and binding energy per nucleon, using the unified atomic mass unit where needed?



Can you calculate binding energy and binding energy per nucleon from given nuclear masses?



Can you apply conservation of mass-energy to particle interactions such as fission and fusion?



Can you use the binding energy per nucleon against nucleon number curve to explain why energy is released in fission and fusion?



4.1 Capacitance

A-LEVEL ONLY

Capacitors

Can you describe a simple parallel-plate capacitor as two equal parallel metal plates separated by a vacuum or air?



Can you explain that a capacitor stores energy by transferring charge from one plate to the other, giving equal and opposite charges and zero net charge?



Can you define capacitance as $C = Q/V$?



Can you use $C = \epsilon_0 A/d$ for a parallel-plate capacitor with no dielectric?



Can you explain that a dielectric increases capacitance compared with vacuum spacing?



Can you explain that the field between parallel plates is uniform and use $E = V/d$?



Can you use $U = 1/2 QV$ (and equivalent forms) for the energy stored in a capacitor?



Can you calculate the combined capacitance of capacitors in series and in parallel?



Charging and discharging

Can you describe the charging and discharging of a capacitor through a resistor?



Can you use $Q = Q_0 e^{-t/RC}$ and $Q = Q_0(1 - e^{-t/RC})$ and explain the time constant RC ?



4.2 Electrostatic and gravitational fields

A-LEVEL ONLY

Field strength and force laws

Can you define electric field strength as force per unit positive charge and gravitational field strength as force per unit mass?



Can you use Coulomb's law, $F = Q_1 Q_2 / (4\pi\epsilon_0 r^2)$, and Newton's law of gravitation, $F = GM_1 M_2 / r^2$, as inverse square laws?



Can you explain that electric forces can attract or repel but gravitational forces always attract?



Can you use $E = Q/(4\pi\epsilon_0 r^2)$ and $g = GM/r^2$ for point sources?



Can you explain that the gravitational field outside a spherical body is as if all its mass were at the centre?



Can you use field lines to show field direction?



Potential and potential energy

Can you define electric and gravitational potential as work done per unit charge or mass brought from infinity, and use $V = Q/(4\pi\epsilon_0 r)$ and $V = -GM/r$?



Can you use $U = Q_1 Q_2 / (4\pi\epsilon_0 r)$ and $U = -GM_1 M_2 / r$ for the potential energy of two point sources?



Can you use $\Delta U = q\Delta V$ and $\Delta U = m\Delta V$ for a moving charge or mass?



Can you find field strength as minus the gradient of a potential-distance graph?



Can you describe equipotential surfaces, including spherical ones around a point charge or mass?



Can you calculate net potential and resultant field strength due to more than one point charge or mass?



Can you use $\Delta U_p = mg\Delta h$ where g is effectively constant?

**4.3 Orbits and the wider universe****A-LEVEL ONLY****Planetary orbits**

Can you state Kepler's three laws of planetary motion?



Can you use Newton's law of gravitation for planets and satellites in circular orbits?



Can you derive Kepler's third law for circular orbits?



Can you use orbital data to find the mass of the central body?

**Dark matter**

Can you use orbital speeds of stars in spiral galaxies as evidence for dark matter?



Can you outline the suggested link between the Higgs boson and dark matter?

**Binary systems and exoplanets**

Can you find the centre of mass of two spherical bodies and their common orbital period?



Can you use the Doppler relationship $\Delta\lambda/\lambda = v/c$?



Can you determine radial velocity from Doppler shifts in spectra?



Can you use radial velocity data to find masses in a double system such as a star and exoplanet?



Cosmology

Can you use Hubble's law, $v = H_0 D$?



Can you explain why $1/H_0$ gives an approximate age of the universe?



Can you derive the critical density of a flat universe, $\rho_c = 3H_0^2/(8\pi G)$, using energy conservation?

**4.4 Magnetic fields****A-LEVEL ONLY****Forces in magnetic fields**

Can you determine the direction of the force on a current-carrying conductor in a magnetic field?



Can you define B using $F = BIl \sin \theta$ and calculate the force?



Can you use $F = Bqv \sin \theta$ for a moving charge?



Can you explain how a Hall voltage is produced and that V_H is proportional to B for constant current?

**Fields of currents**

Can you sketch the magnetic field shapes of a long straight wire and a long solenoid?



Can you use $B = \mu_0 I / (2\pi a)$ and $B = \mu_0 nI$?



Can you explain the effect of an iron core on the field of a solenoid?



Can you explain the forces between current-carrying conductors and their directions?

**Charged particle beams**

Can you explain the deflection of ion beams in uniform electric and magnetic fields?



Can you describe the motion of charged particles in linear accelerators, cyclotrons and synchrotrons?

**4.5 Electromagnetic induction****A-LEVEL ONLY****Induction**

Can you define magnetic flux, $\Phi = BA \cos \theta$, and flux linkage, $N\Phi$?



Can you state Faraday's law and Lenz's law?



Can you apply the laws: induced emf = -rate of change of flux linkage?



Can you calculate the emf induced in a linear conductor moving at right angles to a uniform field?



Can you describe qualitatively how the instantaneous emf in a rotating coil depends on its position, flux density, area and angular velocity?



OptA

Alternating currents

OPTION

Generating a.c.

Can you apply Faraday's law to a coil rotating in a magnetic field?



Can you use $\Phi = BAN \cos \omega t$ for the flux linkage of a rotating flat coil?



Can you use $V = \omega BAN \sin \omega t$ for the induced emf?



Can you define frequency, period, peak value and rms value of an alternating signal?



Can you relate rms value to energy dissipated per cycle and use $I_0 = \sqrt{2} I_{\text{rms}}$ and $V_0 = \sqrt{2} V_{\text{rms}}$?



Can you calculate mean power in a resistor using rms values in $P = IV = I^2 R = V^2/R$?



Can you use an oscilloscope to measure a.c. and d.c. voltages, currents and frequencies?



Reactance and impedance

Can you explain the 90° phase lag of current behind p.d. in an inductor and use $X_L = \omega L$?



Can you explain the 90° phase lead of current ahead of p.d. in a capacitor and use $X_C = 1/(\omega C)$?



Can you explain why the mean power dissipated in a pure inductor or capacitor is zero?



Can you use phasors to add p.d.s across series RC, RL and RLC combinations?



Can you calculate phase angle and impedance, $Z = V_{\text{rms}}/I_{\text{rms}}$?



Resonance in RLC circuits

Can you derive and use the resonance frequency of a series RLC circuit, $f_0 = 1/(2\pi\sqrt{LC})$?



Can you define and calculate the Q factor of an RLC circuit at resonance?



Can you explain how the Q factor determines the sharpness of the resonance curve?



X-rays

Can you describe the nature and properties of X-rays?



Can you explain how an X-ray spectrum is produced and how beam intensity and photon energy are controlled?



Can you explain why high-energy X-rays are used for therapy and low-energy X-rays for diagnosis?



Can you use the attenuation equation $I = I_0 e^{-\mu x}$?



Can you describe X-ray imaging of soft tissue and fluoroscopy using image intensifiers?



Can you describe radiography techniques, including digital image receptors?



Can you describe the rotating-beam X-ray CT scanner?

**Ultrasound**

Can you describe how ultrasound is generated and detected using piezoelectric transducers?



Can you describe A-scans and B-scans in ultrasound imaging?



Can you use acoustic impedance $Z = \rho c$ to explain reflection and transmission at tissue boundaries and the need for coupling media?



Can you use the Doppler equation to measure blood flow with ultrasound?

**MRI and comparing imaging**

Can you explain magnetic resonance in terms of precession, resonance and relaxation time, and use the Larmor frequency $f = 42.6 \times 10^6 \text{ B}$?



Can you describe how MRI gives diagnostic information about internal structures?



Can you compare the advantages and disadvantages of ultrasound, X-ray and MRI imaging?

**Radiation dosimetry**

Can you describe the effects of alpha, beta and gamma radiation on living matter?



Can you define the gray as the unit of absorbed dose and the sievert as the unit of equivalent and effective dose?



Can you use $H = D \times WR$ for equivalent dose and $E = H \times WT$ for effective dose?



Nuclear medicine

Can you explain the use of radionuclides as tracers, with reference to technetium-99m?



Can you describe the gamma camera, including the collimator, scintillation counter and photomultiplier or CCD?



Can you describe PET scanning and its use in detecting tumours?

**OptC****The physics of sports****OPTION****Forces and collisions**

Can you apply centre of gravity to stability and toppling in sporting contexts?



Can you use the principle of moments for forces in muscle systems and other contexts such as sailing?



Can you use Newton's second law in impulse form, $Ft = mv - mu$?



Can you define the coefficient of restitution e and use $h/H = e^2$ for a bouncing ball?

**Rotational motion**

Can you explain the meaning of moment of inertia?



Can you use $I = \frac{2}{5} mr^2$ for a solid sphere and $I = \frac{2}{3} mr^2$ for a thin spherical shell?



Can you use angular acceleration $\alpha = (\omega_2 - \omega_1)/t$?



Can you use torque $\tau = I\alpha$?



Can you use angular momentum $L = I\omega$?



Can you apply conservation of angular momentum to sporting problems such as spinning skaters and divers?



Can you use rotational kinetic energy $= \frac{1}{2} I\omega^2$?



Can you apply conservation of energy including linear, rotational, gravitational and elastic energy?

**Projectiles and fluids**

Can you solve projectile motion problems in sporting contexts?



Can you apply Bernoulli's equation in sporting contexts, such as spinning balls?



Can you use the drag equation $F = \frac{1}{2} \rho AC D v^2$?



Earth's temperature

Can you explain thermal equilibrium of the Earth and the effect of increasing CO₂ levels on its temperature?



Can you describe the origin and transmission of solar energy, the Sun's spectrum and absorption by the atmosphere?



Can you apply Wien's law and the Stefan-Boltzmann law to solar power?



Can you use density and Archimedes' principle to explain rising sea levels, including melting floating and land ice?

**Energy sources**

Can you compare renewable and non-renewable energy sources in the UK and internationally?



Can you describe solar power, including the proton-proton chain, intensity and the inverse square law, and photovoltaic efficiency?



Can you use $P = \frac{1}{2} \rho A v^3$ for the power in a flowing fluid and explain factors affecting wind turbine efficiency?



Can you describe energy conversions in tidal, hydroelectric and pumped storage schemes and compare them with wind power?



Can you describe nuclear fission and fusion, including enrichment and breeding, the difficulties of sustained fusion and the triple product?

**Fuel cells and heat transfer**

Can you describe how a fuel cell operates and its benefits for greenhouse gas emissions?



Can you use the thermal conduction equation, $\Delta Q/\Delta t = -AK \Delta\theta/\Delta x$?



Can you calculate heat loss through parallel surfaces using $P = UA\Delta T$ and explain the role of insulation?



5.1 Practical skills**A-LEVEL ONLY****Independent thinking**

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you solve problems set in practical contexts? | ☐ | ☐ | ☐ |
| Can you apply scientific knowledge to practical contexts? | ☐ | ☐ | ☐ |
| Can you apply investigative approaches and methods to practical work? | ☐ | ☐ | ☐ |

Scientific methods and practices

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you use equipment, techniques and materials safely and correctly? | ☐ | ☐ | ☐ |
| Can you identify variables, including those that must be controlled? | ☐ | ☐ | ☐ |
| Can you follow written instructions and make and record observations? | ☐ | ☐ | ☐ |
| Can you keep appropriate records and present information and data in a scientific way? | ☐ | ☐ | ☐ |
| Can you use software and tools to process data and report findings? | ☐ | ☐ | ☐ |
| Can you evaluate results and draw conclusions with reference to measurement uncertainties and errors? | ☐ | ☐ | ☐ |
| Can you comment on experimental design and evaluate scientific methods? | ☐ | ☐ | ☐ |

Numeracy and data analysis

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you plot and interpret graphs, including finding gradients and intercepts? | ☐ | ☐ | ☐ |
| Can you process and analyse data using appropriate mathematical skills? | ☐ | ☐ | ☐ |
| Can you consider margins of error, accuracy and precision of data, including combining uncertainties? | ☐ | ☐ | ☐ |

Research and referencing

- | | | | |
|--|-----------------------|-----------------------|-----------------------|
| Can you use online and offline research sources and cite them correctly? | ☐ | ☐ | ☐ |
|--|-----------------------|-----------------------|-----------------------|

5.2 Practical techniques**A-LEVEL ONLY****Measuring**

- | | | | |
|---|-----------------------|-----------------------|-----------------------|
| Can you use analogue apparatus to record length, temperature, pressure, force, angles and volume, interpolating between scale markings? | ☐ | ☐ | ☐ |
| Can you use digital instruments, including multimeters, to measure time, current, voltage, resistance and mass? | ☐ | ☐ | ☐ |

Can you improve accuracy using methods such as timing multiple oscillations, a fiducial marker, set square or plumb line?



Can you use a stopwatch or light gates for timing?



Can you use callipers and micrometers with digital or vernier scales for small distances?



Circuits and waves

Can you correctly construct circuits from diagrams using d.c. supplies, cells and components, including polarity-sensitive ones?



Can you design, construct and check circuits using d.c. supplies, cells and components?



Can you use a signal generator and oscilloscope, including volts/division and time-base settings?



Can you generate and measure waves using a microphone and loudspeaker, ripple tank, vibration transducer or microwave/radio source?



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



ICT and radiation

Can you use ICT such as computer modelling or data loggers with sensors to collect and process data?



Can you use ionising radiation and detectors safely?



Specified practical work

1 Can you measure the density of solids?	☐	☐	☐
2 Can you determine unknown masses using the principle of moments?	☐	☐	☐
3 Can you measure g by freefall?	☐	☐	☐
4 Can you investigate Newton's 2nd law?	☐	☐	☐
5 Can you determine the Young modulus of a metal wire?	☐	☐	☐
6 Can you investigate the force-extension relationship for rubber?	☐	☐	☐
7 Can you investigate the I-V characteristics of a filament lamp and a metal wire at constant temperature?	☐	☐	☐
8 Can you determine the resistivity of a metal?	☐	☐	☐
9 Can you investigate the variation of resistance with temperature for a metal wire?	☐	☐	☐
10 Can you determine the internal resistance of a cell?	☐	☐	☐
11 Can you measure intensity variations for polarisation?	☐	☐	☐
12 Can you determine wavelength using Young's double slits?	☐	☐	☐
13 Can you determine wavelength using a diffraction grating?	☐	☐	☐
14 Can you determine the speed of sound using stationary waves?	☐	☐	☐
15 Can you measure the refractive index of a material?	☐	☐	☐
16 Can you determine the Planck constant h using LEDs?	☐	☐	☐
17 Can you measure g with a pendulum?	☐	☐	☐
18 Can you investigate the damping of a spring?	☐	☐	☐
19 Can you estimate absolute zero using the gas laws?	☐	☐	☐
20 Can you measure the specific heat capacity of a solid?	☐	☐	☐
21 Can you investigate radioactive decay using a dice analogy?	☐	☐	☐
22 Can you investigate the variation of intensity of gamma radiation with distance?	☐	☐	☐
23 Can you investigate the charging and discharging of a capacitor to determine the time constant?	☐	☐	☐
24 Can you investigate the energy stored in a capacitor?	☐	☐	☐
25 Can you investigate the force on a current in a magnetic field?	☐	☐	☐
26 Can you investigate magnetic flux density using a Hall probe?	☐	☐	☐