

1.1 Physical quantities**Physical quantities**

Can you explain that every physical quantity consists of a numerical magnitude and a unit?



Can you make reasonable estimates of physical quantities included in the syllabus?

**1.2 SI units****SI units**

Can you recall the SI base quantities and units: mass (kg), length (m), time (s), current (A) and temperature (K)?



Can you express derived units as products or quotients of the SI base units?



Can you use SI base units to check the homogeneity of physical equations?



Can you recall and use the prefixes and their symbols from pico (p) to tera (T)?

**1.3 Errors and uncertainties****Errors and uncertainties**

Can you explain systematic errors (including zero errors) and random errors in measurements?



Can you distinguish between precision and accuracy?



Can you assess the uncertainty in a derived quantity by simple addition of absolute or percentage uncertainties?

**1.4 Scalars and vectors****Scalars and vectors**

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



Can you add and subtract coplanar vectors?



Can you represent a vector as two perpendicular components?



2.1 Equations of motion

Describing motion

Can you define and use distance, displacement, speed, velocity and acceleration?



Can you use graphs to represent distance, displacement, speed, velocity and acceleration?



Can you determine displacement from the area under a velocity-time graph?



Can you determine velocity using the gradient of a displacement-time graph?



Can you determine acceleration using the gradient of a velocity-time graph?



Uniform acceleration

Can you derive the equations of motion for constant acceleration in a straight line from the definitions of velocity and acceleration?



Can you solve problems using the equations of motion for uniform acceleration, including free fall in a uniform gravitational field without air resistance?



Can you describe an experiment to determine the acceleration of free fall g using a falling object?



Can you describe and explain motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction (projectile motion)?



3.1 Momentum and Newton's laws of motion

Momentum and Newton's laws of motion

Can you explain that mass is the property of an object that resists change in motion?	☐	☐	☐
Can you recall and use $F = ma$ and explain that acceleration and resultant force are always in the same direction?	☐	☐	☐
Can you define and use linear momentum as the product of mass and velocity?	☐	☐	☐
Can you define and use force as rate of change of momentum?	☐	☐	☐
Can you state and apply each of Newton's three laws of motion?	☐	☐	☐
Can you describe weight as the effect of a gravitational field on a mass and recall that weight is proportional to mass ($W = mg$)?	☐	☐	☐

3.2 Non-uniform motion

Non-uniform motion

Can you show a qualitative understanding of frictional forces and drag forces, including air resistance, with drag increasing as speed increases?	☐	☐	☐
Can you describe and explain qualitatively the motion of objects in a uniform gravitational field with air resistance?	☐	☐	☐
Can you explain how an object moving against a resistive force may reach a terminal (constant) velocity?	☐	☐	☐

3.3 Linear momentum and its conservation

Linear momentum and its conservation

Can you state the principle of conservation of momentum?	☐	☐	☐
Can you apply the principle of conservation of momentum to simple problems, including elastic and inelastic interactions between objects in one dimension?	☐	☐	☐
Can you apply the principle of conservation of momentum to problems involving interactions in two dimensions?	☐	☐	☐
Can you recall that, for a perfectly elastic collision, total kinetic energy is conserved and the relative speed of approach equals the relative speed of separation?	☐	☐	☐
Can you explain that, while momentum of a system is always conserved, total kinetic energy may change in an interaction?	☐	☐	☐

4.1 Turning effects of forces

Turning effects of forces

Can you explain that the weight of an object may be taken as acting at a single point called its centre of gravity?



Can you define and apply the moment of a force?



Can you explain that a couple is a pair of forces that acts to produce rotation only?



Can you define and apply the torque of a couple?



4.2 Equilibrium of forces

Equilibrium of forces

Can you state and apply the principle of moments?



Can you explain that, for an object in equilibrium, there is no resultant force and no resultant torque?



Can you use a vector triangle to represent coplanar forces in equilibrium?



4.3 Density and pressure

Density and pressure

Can you define and use density?



Can you define and use pressure?



Can you derive $\Delta p = \rho g \Delta h$ from the definitions of pressure and density?



Can you use $\Delta p = \rho g \Delta h$ to calculate the pressure difference in a fluid?



Upthrust

Can you explain the origin of the upthrust acting on an object in a fluid as a difference in hydrostatic pressure?



Can you calculate the upthrust on an object in a fluid using $F = \rho g V$ (Archimedes' principle)?



5.1 Energy conservation

Work and energy

Can you explain that work done is the product of force and displacement in the direction of the force?



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



Can you define efficiency as the ratio of useful energy output to total energy input?



Can you use efficiency to solve problems?



Power

Can you define power as work done per unit time?



Can you solve problems using $P = W/t$?



Can you derive $P = Fv$ and use it to solve problems?



5.2 Gravitational potential energy and kinetic energy

Gravitational potential energy and kinetic energy

Can you derive $\Delta E_p = mg\Delta h$ from the definition of work done ($W = Fs$) for an object in a uniform gravitational field?



Can you recall and use $\Delta E_p = mg\Delta h$ for gravitational potential energy changes in a uniform field?



Can you derive $E_k = \frac{1}{2}mv^2$ from the equations of motion?



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



6.1 Stress and strain

Stress and strain

Can you explain that deformation is caused by tensile or compressive forces (in one dimension only)?



Can you understand and use the terms load, extension, compression and limit of proportionality?



Can you recall and use Hooke's law?



Can you recall and use the formula for the spring constant, $k = F/x$?



Can you define and use the terms stress, strain and the Young modulus?



Can you describe an experiment to determine the Young modulus of a metal in the form of a wire?



6.2 Elastic and plastic behaviour

Elastic and plastic behaviour

Can you understand and use the terms elastic deformation, plastic deformation and elastic limit?



Can you explain that the area under a force-extension graph represents the work done?



Can you determine the elastic potential energy of a material deformed within its limit of proportionality from the area under the force-extension graph?



Can you recall and use $E_p = \frac{1}{2}Fx = \frac{1}{2}kx^2$ for a material deformed within its limit of proportionality?



7.1 Progressive waves

Describing waves

- | | |
|--|---|
| Can you describe the motion of a progressive wave using examples such as waves on a rope, a spring and in a ripple tank? | ☐ ☐ ☐ |
| Can you understand and use the terms displacement, amplitude, phase difference, period, frequency, wavelength and speed? | ☐ ☐ ☐ |
| Can you use the time-base and y-gain of a cathode-ray oscilloscope (CRO) to determine frequency and amplitude? | ☐ ☐ ☐ |
| Can you derive $v = f\lambda$ from the definitions of speed, frequency and wavelength? | ☐ ☐ ☐ |
| Can you recall and use $v = f\lambda$? | ☐ ☐ ☐ |

Energy and intensity

- | | |
|--|---|
| Can you explain that energy is transferred by a progressive wave? | ☐ ☐ ☐ |
| Can you recall and use $\text{intensity} = \text{power}/\text{area}$ and $\text{intensity} \propto (\text{amplitude})^2$ for a progressive wave? | ☐ ☐ ☐ |

7.2 Transverse and longitudinal waves

Transverse and longitudinal waves

- | | |
|---|---|
| Can you compare transverse and longitudinal waves? | ☐ ☐ ☐ |
| Can you analyse and interpret graphical representations of transverse and longitudinal waves? | ☐ ☐ ☐ |

7.3 Doppler effect for sound waves

Doppler effect for sound waves

- | | |
|--|---|
| Can you explain that when a source of sound waves moves relative to a stationary observer, the observed frequency differs from the source frequency? | ☐ ☐ ☐ |
| Can you use $f_o = f_s v/(v \pm v_s)$ for the observed frequency when a source moves relative to a stationary observer? | ☐ ☐ ☐ |

7.4

Electromagnetic spectrum

Electromagnetic spectrum

Can you state that all electromagnetic waves are transverse waves that travel with the same speed c in free space?



Can you recall the approximate range of wavelengths in free space of the principal regions of the electromagnetic spectrum, from radio waves to γ -rays?



Can you recall that wavelengths in the range 400-700 nm in free space are visible to the human eye?



7.5

Polarisation

Polarisation

Can you explain that polarisation is a phenomenon associated with transverse waves only?



Can you recall and use Malus's law ($I = I_0 \cos^2 \theta$) to calculate the intensity of plane-polarised light transmitted through a polarising filter or a series of filters?



8.1 Stationary waves

Stationary waves

Can you explain and use the principle of superposition?



Can you describe experiments that demonstrate stationary waves using microwaves, stretched strings and air columns (ignoring end corrections)?



Can you explain the formation of a stationary wave using a graphical method and identify nodes and antinodes?



Can you determine the wavelength of a stationary wave from the separation of nodes or antinodes?



8.2 Diffraction

Diffraction

Can you explain the meaning of the term diffraction?



Can you describe diffraction experiments, such as water waves in a ripple tank, showing the effect of gap width relative to wavelength?



8.3 Interference

Interference

Can you understand the terms interference and coherence?



Can you describe experiments demonstrating two-source interference using water waves in a ripple tank, sound, light and microwaves?



Can you state the conditions required for two-source interference fringes to be observed?



Can you recall and use $\lambda = ax/D$ for double-slit interference using light?



8.4 The diffraction grating

The diffraction grating

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



Can you describe the use of a diffraction grating to determine the wavelength of light?



9.1 Electric current

Electric current

- | | |
|--|---|
| Can you explain that electric current is a flow of charge carriers? | ☐ ☐ ☐ |
| Can you explain that the charge on charge carriers is quantised? | ☐ ☐ ☐ |
| Can you recall and use $Q = It$? | ☐ ☐ ☐ |
| Can you use $I = Anvq$ for a current-carrying conductor, where n is the number density of charge carriers? | ☐ ☐ ☐ |

9.2 Potential difference and power

Potential difference and power

- | | |
|---|---|
| Can you define the potential difference across a component as the energy transferred per unit charge? | ☐ ☐ ☐ |
| Can you recall and use $V = W/Q$? | ☐ ☐ ☐ |
| Can you recall and use $P = VI$, $P = I^2 R$ and $P = V^2/R$? | ☐ ☐ ☐ |

9.3 Resistance and resistivity

Resistance and I-V characteristics

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|--|---|
| Can you define resistance? | ☐ ☐ ☐ |
| Can you recall and use $V = IR$? | ☐ ☐ ☐ |
| Can you sketch the I-V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp? | ☐ ☐ ☐ |
| Can you explain that the resistance of a filament lamp increases as current increases because its temperature increases? | ☐ ☐ ☐ |
| Can you state Ohm's law? | ☐ ☐ ☐ |

Resistivity and sensors

- | | |
|---|---|
| Can you recall and use $R = \rho L/A$? | ☐ ☐ ☐ |
| Can you explain that the resistance of a light-dependent resistor (LDR) decreases as the light intensity increases? | ☐ ☐ ☐ |

Can you explain that the resistance of a thermistor (negative temperature coefficient) decreases as the temperature increases?



10.1

Practical circuits

Practical circuits

Can you recall and use the circuit symbols listed in the syllabus?	☐	☐	☐
Can you draw and interpret circuit diagrams containing the syllabus circuit symbols?	☐	☐	☐
Can you define electromotive force (e.m.f.) as the energy transferred per unit charge in driving charge around a complete circuit?	☐	☐	☐
Can you distinguish between e.m.f. and potential difference (p.d.) in terms of energy considerations?	☐	☐	☐
Can you explain the effects of the internal resistance of a source of e.m.f. on the terminal potential difference?	☐	☐	☐

10.2

Kirchhoff's laws

Kirchhoff's laws

Can you recall Kirchhoff's first law and explain that it is a consequence of conservation of charge?	☐	☐	☐
Can you recall Kirchhoff's second law and explain that it is a consequence of conservation of energy?	☐	☐	☐
Can you derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series?	☐	☐	☐
Can you use the formula for the combined resistance of two or more resistors in series?	☐	☐	☐
Can you derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel?	☐	☐	☐
Can you use the formula for the combined resistance of two or more resistors in parallel?	☐	☐	☐
Can you use Kirchhoff's laws to solve simple circuit problems?	☐	☐	☐

10.3

Potential dividers

Potential dividers

Can you explain the principle of a potential divider circuit?	☐	☐	☐
Can you recall and use the principle of the potentiometer as a means of comparing potential differences?	☐	☐	☐
Can you explain the use of a galvanometer in null methods?	☐	☐	☐

Can you explain the use of thermistors and light-dependent resistors in potential dividers to provide a p.d. that depends on temperature or light intensity?



11.1 Atoms, nuclei and radiation

The nuclear atom

- Can you infer from the results of the α -particle scattering experiment the existence and small size of the nucleus? ☐ ☐ ☐
- Can you describe a simple model for the nuclear atom with protons and neutrons in the nucleus and orbital electrons? ☐ ☐ ☐
- Can you distinguish between nucleon number and proton number? ☐ ☐ ☐
- Can you explain that isotopes are forms of the same element with different numbers of neutrons in their nuclei? ☐ ☐ ☐
- Can you understand and use the notation $A/Z X$ for the representation of nuclides? ☐ ☐ ☐
- Can you explain that nucleon number and charge are conserved in nuclear processes? ☐ ☐ ☐

Radiation and decay

- Can you describe the composition, mass and charge of α , β^- and β^+ particles and γ radiation? ☐ ☐ ☐
- Can you explain that an antiparticle has the same mass but opposite charge to the corresponding particle, and that a positron is the antiparticle of an electron? ☐ ☐ ☐
- Can you state that electron antineutrinos are produced in β^- decay and electron neutrinos are produced in β^+ decay? ☐ ☐ ☐
- Can you explain that α -particles have discrete energies but β -particles have a continuous range of energies because (anti)neutrinos are emitted in β decay? ☐ ☐ ☐
- Can you represent α and β decay by radioactive decay equations, e.g. ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^4_2\alpha$? ☐ ☐ ☐
- Can you use the unified atomic mass unit (u) as a unit of mass? ☐ ☐ ☐

11.2 Fundamental particles

Fundamental particles

- Can you explain that quarks are fundamental particles and that there are six flavours: up, down, strange, charm, top and bottom? ☐ ☐ ☐
- Can you recall and use the charge of each flavour of quark and explain that each quark has a corresponding antiquark with opposite charge? ☐ ☐ ☐
- Can you recall that protons and neutrons are not fundamental particles and describe them in terms of their quark composition? ☐ ☐ ☐

Can you explain that a hadron may be a baryon (three quarks) or a meson (one quark and one antiquark)?



Can you describe the changes to quark composition that take place during β^- and β^+ decay?



Can you recall that electrons and neutrinos are fundamental particles called leptons?



12.1

Kinematics of uniform circular motion

A-LEVEL ONLY

Kinematics of uniform circular motion

Can you define the radian and express angular displacement in radians?



Can you understand and use the concept of angular speed?

Can you recall and use $\omega = 2\pi/T$ and $v = r\omega$?

12.2

Centripetal acceleration

A-LEVEL ONLY

Centripetal acceleration

Can you explain that a force of constant magnitude that is always perpendicular to the direction of motion causes centripetal acceleration?



Can you explain that centripetal acceleration causes circular motion with a constant angular speed?

Can you recall and use $a = r\omega^2$ and $a = v^2/r$?Can you recall and use $F = mr\omega^2$ and $F = mv^2/r$?

13.1 Gravitational field

A-LEVEL ONLY

Gravitational field

Can you explain that a gravitational field is an example of a field of force and define gravitational field strength as force per unit mass?



Can you represent a gravitational field by means of field lines?



13.2

Gravitational force between point masses

A-LEVEL ONLY

Gravitational force between point masses

Can you explain that, for a point outside a uniform sphere, the mass of the sphere may be considered to be a point mass at its centre?



Can you recall and use Newton's law of gravitation $F = Gm_1m_2/r^2$ for the force between two point masses?



Can you analyse circular orbits in gravitational fields by relating the gravitational force to the centripetal acceleration it causes?



Can you explain that a satellite in a geostationary orbit remains at the same point above the Earth's surface, with a period of 24 hours, orbiting from west to east directly above the Equator?



13.3

Gravitational field of a point mass

A-LEVEL ONLY

Gravitational field of a point mass

Can you derive $g = GM/r^2$ from Newton's law of gravitation and the definition of gravitational field strength?



Can you recall and use $g = GM/r^2$ for the gravitational field strength due to a point mass?



Can you explain why g is approximately constant for small changes in height near the Earth's surface?



13.4

Gravitational potential

A-LEVEL ONLY

Gravitational potential

Can you define gravitational potential at a point as the work done per unit mass in bringing a small test mass from infinity to that point?



Can you use $\phi = -GM/r$ for the gravitational potential in the field due to a point mass?



Can you explain how the concept of gravitational potential leads to the gravitational potential energy of two point masses, $E_p = -GMm/r$, and use this equation?



14.1

Thermal equilibrium

A-LEVEL ONLY

Thermal equilibrium

Can you explain that thermal energy is transferred from a region of higher temperature to a region of lower temperature?



Can you explain that regions of equal temperature are in thermal equilibrium?



14.2

Temperature scales

A-LEVEL ONLY

Temperature scales

Can you explain that a physical property that varies with temperature (e.g. density of a liquid, volume of a gas at constant pressure, resistance of a metal, e.m.f. of a thermocouple) may be used for temperature measurement?



Can you explain that the thermodynamic (kelvin) scale of temperature does not depend on the property of any particular substance?



Can you convert temperatures between kelvin and degrees Celsius using $T/K = \theta/^{\circ}\text{C} + 273.15$?



Can you explain that the lowest possible temperature is zero kelvin on the thermodynamic temperature scale, known as absolute zero?



14.3

Specific heat capacity and specific latent heat

A-LEVEL ONLY

Specific heat capacity and specific latent heat

Can you define and use specific heat capacity?



Can you define and use specific latent heat and distinguish between specific latent heat of fusion and specific latent heat of vaporisation?



15.1 The mole**A-LEVEL ONLY****The mole**

Can you explain that amount of substance is an SI base quantity with the base unit mol?



Can you use molar quantities, where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant N_A ?

**15.2 Equation of state****A-LEVEL ONLY****Equation of state**

Can you explain that a gas obeying $pV \propto T$, where T is the thermodynamic temperature, is known as an ideal gas?



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



Can you recall that the Boltzmann constant k is given by $k = R/N_A$?

**15.3 Kinetic theory of gases****A-LEVEL ONLY****Kinetic theory of gases**

Can you state the basic assumptions of the kinetic theory of gases?



Can you explain how molecular movement causes the pressure exerted by a gas, and derive and use $pV = \frac{1}{3}Nm\langle c^2 \rangle$?



Can you explain that the root-mean-square speed c_{rms} is given by $\sqrt{\langle c^2 \rangle}$?



Can you compare $pV = \frac{1}{3}Nm\langle c^2 \rangle$ with $pV = NkT$ to deduce that the average translational kinetic energy of a molecule is $(3/2)kT$, and use this expression?



16.1

Internal energy

A-LEVEL ONLY

Internal energy

Can you explain that internal energy is determined by the state of the system and is the sum of a random distribution of kinetic and potential energies of the molecules?



Can you relate a rise in temperature of an object to an increase in its internal energy?



16.2

The first law of thermodynamics

A-LEVEL ONLY

The first law of thermodynamics

Can you recall and use $W = p\Delta V$ for the work done when the volume of a gas changes at constant pressure, and distinguish between work done by the gas and work done on the gas?



Can you recall and use the first law of thermodynamics in the form $\Delta U = q + W$, explaining the meaning of each sign?



17.1

Simple harmonic oscillations

A-LEVEL ONLY

Simple harmonic oscillations

Can you understand and use the terms displacement, amplitude, period, frequency, angular frequency and phase difference, and express period in terms of frequency and angular frequency?



Can you explain that simple harmonic motion occurs when acceleration is proportional to displacement from a fixed point and in the opposite direction?



Can you use $a = -\omega^2 x$ and recall and use $x = x_0 \sin \omega t$ as a solution to this equation?



Can you use $v = v_0 \cos \omega t$ and $v = \pm \omega \sqrt{(x_0^2 - x^2)}$?



Can you analyse and interpret graphical representations of the variations of displacement, velocity and acceleration with time for simple harmonic motion?



17.2

Energy in simple harmonic motion

A-LEVEL ONLY

Energy in simple harmonic motion

Can you describe the interchange between kinetic and potential energy during simple harmonic motion?



Can you recall and use $E = \frac{1}{2}m\omega^2 x_0^2$ for the total energy of a system undergoing simple harmonic motion?



17.3

Damped and forced oscillations, resonance

A-LEVEL ONLY

Damped and forced oscillations, resonance

Can you explain that a resistive force acting on an oscillating system causes damping?



Can you understand and use the terms light, critical and heavy damping, and sketch displacement-time graphs illustrating each?



Can you explain that resonance involves a maximum amplitude of oscillations and that this occurs when an oscillating system is forced to oscillate at its natural frequency?



18.1

Electric fields and field lines

A-LEVEL ONLY

Electric fields and field lines

Can you explain that an electric field is an example of a field of force and define electric field strength as force per unit positive charge?



Can you recall and use $F = qE$ for the force on a charge in an electric field?



Can you represent an electric field by means of field lines?



18.2

Uniform electric fields

A-LEVEL ONLY

Uniform electric fields

Can you recall and use $E = \Delta V / \Delta d$ to calculate the field strength of the uniform field between charged parallel plates?



Can you describe the effect of a uniform electric field on the motion of charged particles?



18.3

Electric force between point charges

A-LEVEL ONLY

Electric force between point charges

Can you explain that, for a point outside a spherical conductor, the charge on the sphere may be considered to be a point charge at its centre?



Can you recall and use Coulomb's law $F = Q_1 Q_2 / (4\pi\epsilon_0 r^2)$ for the force between two point charges in free space?



18.4

Electric field of a point charge

A-LEVEL ONLY

Electric field of a point charge

Can you recall and use $E = Q / (4\pi\epsilon_0 r^2)$ for the electric field strength due to a point charge in free space?



Electric potential

Can you define electric potential at a point as the work done per unit positive charge in bringing a small test charge from infinity to that point?



Can you explain that the electric field strength at a point is equal to the negative of the potential gradient at that point?



Can you use $V = Q/(4\pi\epsilon_0 r)$ for the electric potential in the field due to a point charge?



Can you explain how the concept of electric potential leads to the electric potential energy of two point charges, and use $E_p = Qq/(4\pi\epsilon_0 r)$?



19.1 Capacitors and capacitance

A-LEVEL ONLY

Capacitors and capacitance

Can you define capacitance, as applied to both isolated spherical conductors and to parallel plate capacitors?



Can you recall and use $C = Q/V$?



Can you derive, using $C = Q/V$, formulae for the combined capacitance of capacitors in series and in parallel?



Can you use the capacitance formulae for capacitors in series and in parallel?



19.2 Energy stored in a capacitor

A-LEVEL ONLY

Energy stored in a capacitor

Can you determine the electric potential energy stored in a capacitor from the area under the potential-charge graph?



Can you recall and use $W = \frac{1}{2}QV = \frac{1}{2}CV^2$?



19.3 Discharging a capacitor

A-LEVEL ONLY

Discharging a capacitor

Can you analyse graphs of the variation with time of potential difference, charge and current for a capacitor discharging through a resistor?



Can you recall and use $\tau = RC$ for the time constant for a capacitor discharging through a resistor?



Can you use equations of the form $x = x_0 e^{-t/RC}$, where x could represent current, charge or potential difference, for a capacitor discharging through a resistor?



20.1 Concept of a magnetic field**A-LEVEL ONLY****Concept of a magnetic field**

Can you explain that a magnetic field is an example of a field of force produced either by moving charges or by permanent magnets?



Can you represent a magnetic field by field lines?

**20.2 Force on a current-carrying conductor****A-LEVEL ONLY****Force on a current-carrying conductor**

Can you explain that a force might act on a current-carrying conductor placed in a magnetic field?



Can you recall and use $F = BIL \sin \theta$, with directions as interpreted by Fleming's left-hand rule?



Can you define magnetic flux density as the force acting per unit current per unit length on a wire placed at right angles to the magnetic field?

**20.3 Force on a moving charge****A-LEVEL ONLY****Force on a moving charge**

Can you determine the direction of the force on a charge moving in a magnetic field?



Can you recall and use $F = BQv \sin \theta$?



Can you explain the origin of the Hall voltage and derive and use $V_H = BI/(ntq)$, where t is the thickness?



Can you explain the use of a Hall probe to measure magnetic flux density?

**Charged particles in fields**

Can you describe the motion of a charged particle moving in a uniform magnetic field perpendicular to the direction of motion of the particle?



Can you explain how electric and magnetic fields can be used in velocity selection?



Magnetic fields due to currents

Can you sketch magnetic field patterns due to the currents in a long straight wire, a flat circular coil and a long solenoid?



Can you explain that the magnetic field due to the current in a solenoid is increased by a ferrous core?



Can you explain the origin of the forces between current-carrying conductors and determine the direction of the forces?



Magnetic flux

Can you define magnetic flux as the product of the magnetic flux density and the cross-sectional area perpendicular to the direction of the magnetic flux density?



Can you recall and use $\Phi = BA$?



Can you understand and use the concept of magnetic flux linkage?



Induced e.m.f.

Can you understand and explain experiments that demonstrate that a changing magnetic flux can induce an e.m.f. in a circuit?



Can you explain that the direction of an induced e.m.f. opposes the change producing it?



Can you describe the factors affecting the magnitude of an induced e.m.f.?



Can you recall and use Faraday's and Lenz's laws of electromagnetic induction?



21.1

Characteristics of alternating currents

A-LEVEL ONLY

Characteristics of alternating currents

Can you understand and use the terms period, frequency and peak value as applied to an alternating current or voltage?



Can you use equations of the form $x = x_0 \sin \omega t$ representing a sinusoidally alternating current or voltage?



Can you recall and use the fact that the mean power in a resistive load is half the maximum power for a sinusoidal alternating current?



Can you distinguish between root-mean-square (r.m.s.) and peak values, and recall and use $I_{\text{rms}} = I_0/\sqrt{2}$ and $V_{\text{rms}} = V_0/\sqrt{2}$ for a sinusoidal alternating current?



21.2

Rectification and smoothing

A-LEVEL ONLY

Rectification and smoothing

Can you distinguish graphically between half-wave and full-wave rectification?



Can you explain the use of a single diode for the half-wave rectification of an alternating current?



Can you explain the use of four diodes (bridge rectifier) for the full-wave rectification of an alternating current?



Can you analyse the effect of a single capacitor in smoothing, including the effect of the values of capacitance and the load resistance?



22.1

Energy and momentum of a photon

A-LEVEL ONLY

Energy and momentum of a photon

Can you explain that electromagnetic radiation has a particulate nature?



Can you explain that a photon is a quantum of electromagnetic energy?

Can you recall and use $E = hf$?

Can you use the electronvolt (eV) as a unit of energy?

Can you explain that a photon has momentum and that the momentum is given by $p = E/c$?

22.2

Photoelectric effect

A-LEVEL ONLY

Photoelectric effect

Can you explain that photoelectrons may be emitted from a metal surface when it is illuminated by electromagnetic radiation?



Can you understand and use the terms threshold frequency and threshold wavelength?



Can you explain photoelectric emission in terms of photon energy and work function energy?

Can you recall and use $hf = \Phi + \frac{1}{2}mv_{\text{max}}^2$?

Can you explain why the maximum kinetic energy of photoelectrons is independent of intensity, whereas the photoelectric current is proportional to intensity?



22.3

Wave-particle duality

A-LEVEL ONLY

Wave-particle duality

Can you explain that the photoelectric effect provides evidence for a particulate nature of electromagnetic radiation, while phenomena such as interference and diffraction provide evidence for a wave nature?



Can you describe and interpret qualitatively the evidence provided by electron diffraction for the wave nature of particles?



Can you explain the de Broglie wavelength as the wavelength associated with a moving particle?

Can you recall and use $\lambda = h/p$?

Energy levels in atoms and line spectra

Can you explain that there are discrete electron energy levels in isolated atoms (e.g. atomic hydrogen)?



Can you explain the appearance and formation of emission and absorption line spectra?



Can you recall and use $hf = E_1 - E_2$?



23.1

Mass defect and nuclear binding energy

A-LEVEL ONLY

Mass defect and binding energy

Can you explain the equivalence between energy and mass as represented by $E = mc^2$, and recall and use this equation?



Can you represent simple nuclear reactions by nuclear equations of the form ${}^{14}_7\text{N} + {}^4_2\text{He} \rightarrow {}^{17}_8\text{O} + {}^1_1\text{H}$?



Can you define and use the terms mass defect and binding energy?



Can you sketch the variation of binding energy per nucleon with nucleon number?



Fission and fusion

Can you explain what is meant by nuclear fusion and nuclear fission?



Can you explain the relevance of binding energy per nucleon to nuclear reactions, including nuclear fusion and nuclear fission?



Can you calculate the energy released in nuclear reactions using $\Delta E = \Delta mc^2$?



23.2

Radioactive decay

A-LEVEL ONLY

Radioactive decay

Can you explain that fluctuations in count rate provide evidence for the random nature of radioactive decay?



Can you explain that radioactive decay is both spontaneous and random?



Can you define activity and decay constant, and recall and use $A = \lambda N$?



Can you define half-life?



Can you use $\lambda = 0.693/t_{1/2}$?



Can you explain the exponential nature of radioactive decay, and sketch and use $x = x_0 e^{-\lambda t}$, where x could represent activity, number of undecayed nuclei or received count rate?



24.1 Production and use of ultrasound**A-LEVEL ONLY****Producing and detecting ultrasound**

Can you explain that a piezoelectric crystal changes shape when a p.d. is applied across it, and that the crystal generates an e.m.f. when its shape changes?



Can you explain how ultrasound waves are generated and detected by a piezoelectric transducer?



Can you explain how the reflection of pulses of ultrasound at boundaries between tissues can be used to obtain diagnostic information about internal structures?

**Acoustic impedance and attenuation**

Can you define the specific acoustic impedance of a medium as $Z = \rho c$, where c is the speed of sound in the medium?



Can you use $I_R/I_0 = (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ for the intensity reflection coefficient of a boundary between two media?



Can you recall and use $I = I_0 e^{-\mu x}$ for the attenuation of ultrasound in matter?

**24.2 Production and use of X-rays****A-LEVEL ONLY****Production and use of X-rays**

Can you explain that X-rays are produced by electron bombardment of a metal target, and calculate the minimum wavelength of X-rays produced from the accelerating p.d.?



Can you explain the use of X-rays in imaging internal body structures, including an understanding of the term contrast in X-ray imaging?



Can you recall and use $I = I_0 e^{-\mu x}$ for the attenuation of X-rays in matter?



Can you explain that computed tomography (CT) scanning produces a 3D image of an internal structure by combining multiple X-ray images taken in the same section from different angles to build up 2D images of slices?

**24.3 PET scanning****A-LEVEL ONLY****PET scanning**

Can you explain that a tracer is a substance containing radioactive nuclei that can be introduced into the body and is then absorbed by the tissue being studied?



Can you recall that a tracer that decays by β^+ decay is used in positron emission tomography (PET scanning)?



Can you explain annihilation, in which mass-energy and momentum are conserved?



Can you explain that, in PET scanning, positrons emitted by the tracer annihilate with electrons in the tissue, producing a pair of gamma-ray photons travelling in opposite directions?



Can you calculate the energy of the gamma-ray photons emitted during the annihilation of an electron-positron pair?



Can you explain that the gamma-ray photons from an annihilation event travel outside the body and can be detected, and that the arrival times are processed to produce an image of the tracer concentration?



25.1

Standard candles

A-LEVEL ONLY

Standard candles

Can you define luminosity as the total power of radiation emitted by a star?

Can you recall and use the inverse square law for radiant flux intensity F in terms of luminosity L , $F = L/(4\pi d^2)$?

Can you explain that a standard candle is an astronomical object of known luminosity?



Can you explain how standard candles can be used to determine distances to galaxies?



25.2

Stellar radii

A-LEVEL ONLY

Stellar radii

Can you recall and use Wien's displacement law $\lambda_{\text{max}} \propto 1/T$ to estimate the peak surface temperature of a star?Can you use the Stefan-Boltzmann law $L = 4\pi\sigma r^2 T^4$?

Can you use Wien's displacement law and the Stefan-Boltzmann law to estimate the radius of a star?



25.3

Hubble's law and the Big Bang theory

A-LEVEL ONLY

Hubble's law and the Big Bang theory

Can you explain that the lines in the emission spectra from distant objects show an increase in wavelength from their known values (redshift)?

Can you use $\Delta\lambda/\lambda \approx \Delta f/f \approx v/c$ for the redshift of electromagnetic radiation from a source moving relative to an observer?

Can you explain why redshift leads to the idea that the universe is expanding?

Can you recall and use Hubble's law $v \approx H_0 d$ and explain how this leads to the Big Bang theory (only SI units required)?