3.3.1.1 – Progressive waves	Revised it
To be able to define the terms amplitude, frequency, period, wavelength, phase and phase difference.	
To explain what is meant by phase and phase difference.	
To use the equation $c = f\lambda$	

3.3.1.2 – Longitudinal and Transverse waves	Revised it
To be able to describe the nature of longitudinal and transverse waves.	
To recognise that electromagnetic waves as examples of transverse waves.	
To know the speed of electromagnetic waves.	
To be able to describe the polarisation of transverse waves	
To be able to describe applications of polarisers.	

3.3.1.3 – Superposition of waves and Stationary waves	Revised it
To explain what is meant by a stationary wave.	
To define the terms node and antinode.	
To be able to calculate the frequency of the first harmonic produced by a stationary wave on a string.	
To describe the formation of a stationary wave by two waves of the same frequency travelling in opposite directions.	
To be able to use graphs to demonstrate the formation of standing waves.	
To be able to give examples of stationary waves including those formed on strings and those produced using sound waves or microwaves.	

3.3.2.1 – Interference	Revised it
To explain the meaning of path difference and coherence	
To describe the Young's double slit experiment and calculate fringe spacing using data from the experiment.	
To be able to use the equation for fringe spacing: $w = \frac{\lambda D}{s}$	
To distinguish between the fringe patterns produced by monochromatic and white light.	
To be able to analyse different examples of the double slit experiment using both electromagnetic and sound waves.	

To explain how knowledge and understanding of the nature of electromagnetic radiation has changed over time.	

3.3.2.2 – Diffraction	*Revised it*
To describe the diffraction patterns produced using a single slit with monochromatic light and contrast this with the pattern produced by white light.	
To describe the effect on the width of the central maximum when the slit width is varied.	
To describe using a plane diffraction grating with light at normal incidence.	
To use the grating equation in calculations.	
To know the derivation of the grating equation: $dsin\theta = n\lambda$	
To describe uses of the diffraction grating	

3.3.2.3 – Refraction at a plane surface	*Revised it*
To define refractive index in terms wave speed in different media.	
To recall that the refractive index of air is approximately 1.	
Use Snell's law to calculate angles when light crosses a boundary between two media $$n_1 \sin\theta_1 = n_2 \sin\theta_2$$	
To describe total internal reflection and distinguish this from partial reflection.	
Calculate critical angles using refractive indices. $$\sin\theta_c = \frac{n_1}{n_2}$$	
To be able to Describe the step index optic fibre.	
To understand the principles and consequences of pulse broadening and absorption.	

Bulk Modulus of Solids	*Revised it*
Density	
Hooke's Law, elastic Limit, F = kΔl, k = as stiffness and spring constant.	
Tensile strain and tensile stress. Elastic strain energy and braking stress. Energy stored = 1/2FΔL = area under the force – extension graph.	
Description of plastic behaviour, fracture and brittle Behaviour linked to force–extension graphs.	
Quantitative and qualitative application of energy conservation to examples involving elastic strain energy and energy to deform.	
Spring energy transformed to kinetic and gravitational potential energy.	
Interpretation of simple stress–strain curves.	
Appreciation of energy conservation issues in the context of ethical transport design.	
The Young Modulus	
Young modulus, tensile stress and tensile strain.	
Use of stress–strain graphs to find the Young modulus.	

Scalars and Vectors	*Revised it*
Nature of scalars and vectors. Examples should include: velocity/speed, mass, force/weight, acceleration, displacement/distance.	
Addition of vectors by calculation or scale drawing. Scale drawings may involve vectors at angles other than 90°.	
Resolution of vectors into two components at right angles to each other.	
Conditions for equilibrium for two or three coplanar forces acting at a point. Appreciation of the meaning of equilibrium in the context of an object at rest or moving with constant velocity.	
Moments	
Moment of a force about a point. Moment defined as *force × perpendicular distance from the point to the line of action of the force*.	

Couple as a pair of equal and opposite coplanar forces. Moment of couple defined as *force × perpendicular distance between the lines of action of the forces*.	
Principle of moments.	
Centre of mass. Knowledge that the position of the centre of mass of uniform regular solid is at its centre.	
Motion Along a Straight Line	
Displacement, speed, velocity, acceleration. Calculations may include average and instantaneous speeds and velocities.	
Representation by graphical methods of uniform and nonuniform acceleration.	
Significance of areas of velocity–time and acceleration–time	
Graphs and gradients of displacement–time and velocity–time	
Graphs for uniform and non-uniform acceleration eg graphs for motion of bouncing ball.	
Equations for uniform acceleration: SUVAT	
Acceleration due to gravity, g.	
Projective Motion	
Qualitative treatment of lift and drag forces. Terminal speed.	
Knowledge that air resistance increases with speed. Qualitative understanding of the effect of air resistance on the trajectory of a projectile and on the factors that affect the maximum speed of a vehicle.	

Newton's Laws of Motion	*Revised it*
Knowledge and application of the three laws of motion in appropriate situations.	
$F = ma$ for situations where the mass is constant.	
Momentum	
momentum = *mass* × *velocity* Conservation of linear momentum.	
Force as the rate of change of momentum,	
Impulse = change in momentum $F\Delta t = \Delta mv$, where F is constant.	

Significance of the area under a force–time graph.	
Elastic and inelastic collisions; explosions.	
Appreciation of momentum conservation issues in the context of ethical transport design.	
Work, Energy and Power	
Energy transferred, $W = Fs\cos\theta$ *rate of doing work = rate of energy transfer,*	
Significance of the area under a force–displacement graph.	
efficiency = useful output power/input power Efficiency can be expressed as a percentage.	
Conservation of Energy	
Principle of conservation of energy. GPE & KE	
Quantitative and qualitative application of energy conservation to examples involving gravitational potential energy, kinetic energy, and work done against resistive forces.	

Basics of Electricity	*Revised it*
Electric current as the rate of flow of charge; potential difference as work done per unit charge.	
Resistance defined as R=V/I	
Current Voltage Characteristics	
For an ohmic conductor, semiconductor diode, and filament lamp. Ohm's law as a special case where $I \propto V$ under constant physical conditions.	
Unless specifically stated in questions, ammeters and voltmeters should be treated as ideal (having zero and infinite resistance respectively).	
Resistivity	
Resistivity, $\rho = RA/L$	
Description of the qualitative effect of temperature on the resistance of metal conductors and thermistors.	
Applications of thermistors to include temperature sensors and resistance–temperature graphs.	
Superconductivity as a property of certain materials which have zero resistivity at and below a critical temperature which depends on the material.	

Applications of superconductors to include the production of strong magnetic fields and the reduction of energy loss in transmission of electric power.	
Circuits	
Resistors in series and parallel	
Energy and Power Equations	
The relationships between currents, voltages and resistances in series and parallel circuits, including cells in series and identical cells in parallel. Conservation of charge and conservation of energy in dc circuits.	
Potential Divider	
The potential divider used to supply constant or variable potential difference from a power supply.	
Examples should include the use of variable resistors, thermistors, and light dependent resistors (LDR) in the potential divider.	
EMF & IR	
EMF = E/Q EMF = $I R$ + Ir Terminal pd; emf	

3.2.1.1 Constituents of the atom	*Revised it*
Understand the simple model of the atom, including the proton, neutron and electron.	
Know the charge and mass of the proton, neutron and electron in SI units and relative units.	
Know about the atomic mass unit (amu) (which is included in the A-level Nuclear physics section).	
Understand and be able to calculate the specific charge of the proton and the electron, and of nuclei and ions.	
Understand and be able to calculate the number of particles in the atom using the *ZXA* notation.	
Understand the meaning of isotopes and the use of isotopic data.	
3.2.1.2 Stable and unstable nuclei	
Understand the Strong Nuclear Force; its role in keeping the nucleus stable; short-range attraction up to approximately 3 fm, very-short range repulsion closer than approximately 0.5 fm.	
Understand why some nuclei are unstable.	

Explain alpha decay including the decay equations.	
Explain beta decay including the decay equations.	
Understand the need for the neutrino in beta decay; its existence was hypothesised to account for conservation of energy in beta decay.	
3.2.1.3 Particles, antiparticles and photons	
Account for conservation of energy in beta decay.	
Know that for every type of particle, there is a corresponding antiparticle.	
Be able to compare the particle and antiparticle masses, charge and rest energy in MeV.	
Know that the positron, antiproton, antineutron and antineutrino are the antiparticles of the electron, proton, neutron and neutrino respectively.	
Understand the photon model of electromagnetic radiation, the Planck constant. $E = hf = \frac{hc}{\lambda}$	
Define and explain annihilation and the energies involved. Understand that two photons are produced to conserve momentum.	
Define and explain pair production and the energies involved.	
3.2.1.4 Particle interactions	
Know and explain the four fundamental interactions: gravity, electromagnetic, weak nuclear, strong nuclear.	
Understand the concept of exchange particles to explain forces between elementary particles.	
Know the exchange particles for the four forces.	
Describe the weak interactions including the Feynman diagrams for: Beta minus, beta plus, electron capture and electron proton collision.	
3.2.1.5 Classification of Particles	
Hadrons are subject to the strong interaction.	
The two classes of hadrons: • baryons (proton, neutron) and antibaryons (antiproton and antineutron) • mesons (pion, kaon).	
Know that interactions are conserved following the baryon quantum number.	
Know that the proton is the only stable baryon into which other baryons eventually decay.	
Know that the pion as the exchange particle of the strong nuclear force.	

Know that the kaon as a particle that can decay into pions.	
Know the main leptons: electron, muon, neutrino (electron and muon types only) and their antiparticles.	
Know that interactions are conserved following the lepton quantum number.	
Know the muon as a particle that decays into an electron.	
Know strange particles as particles that are produced through the strong interaction and decay through the weak interaction (eg kaons).	
Know strangeness (symbol s) as a quantum number to reflect the fact that strange particles are always created in pairs.	
Know that strangeness is only conserved in strong interactions.	
Know that strangeness can have the values of -3, -2, -1, +1, +2, +3 and that strangeness can change by 0, +1 or -1 in weak interactions.	
Appreciation that particle physics relies on the collaborative efforts of large teams of scientists and engineers to validate new knowledge.	
3.2.1.6 Quarks and antiquarks	
Properties of quarks and antiquarks: charge, baryon number and strangeness.	
Know the properties of quarks and antiquarks: charge, baryon number and strangeness.	
Know the quark combination for the proton, neutron, antiproton and antineutron, pion and kaon.	
Be able to describe beta plus and beta minus decay in terms of quarks.	
3.2.1.7 Applications of conservation laws	
Application of the conservation laws for charge, baryon number, lepton number and strangeness to particle interactions.	
Recognise that energy and momentum are conserved in interactions.	

3.2.2.1 The photoelectric effect	
Know how to convert from Joules to eV.	
Define and explain threshold frequency including photon explanation of threshold frequency.	
Define and explain work function.	
Define and explain stopping potential.	

Explain the photoelectric effect equation $hf = \varphi + E_{kmax}$	
Define and explain E_{kmax}	
3.2.2.3 Energy levels and photon emission	
Define excitation of an atomic electron.	
Define ionisation of an atomic electron.	
Know the two ways an electron may be excited to a higher level; by absorption of a photon of the exact energy difference or by collision with a free electron.	
Be able to describe how line spectra (eg of atomic hydrogen) may be used as evidence for transitions between discrete energy levels in atoms.	
3.2.2.4 Wave-particle duality	
Know that electron diffraction suggests that particles possess wave properties and the photoelectric effect suggests that electromagnetic waves have a particulate nature.	
Know the de Broglie wavelength may be calculated by $\lambda = \frac{h}{mv}$	
Explain how and why the amount of diffraction changes when the momentum of the particle is changed.	
Appreciation of how knowledge and understanding of the nature of matter changes over time.	
Appreciation that such changes need to be evaluated through peer review and validated by the scientific community.	

3.6.2.1 Thermal energy transfer	
Understand internal energy is the sum of the randomly distributed kinetic energies and potential energies of the particles in a body.	
Understand the internal energy of a system is increased when energy is transferred to it by heating or when work is done on it (and vice versa), eg a qualitative treatment of the first law of thermodynamics.	
Appreciation that during a change of state the potential energies of the particle ensemble are changing but not the kinetic energies. Calculations involving transfer of energy.	
Perform calculations for a change of temperature: $Q = mc\,\Delta\,\theta$ where c is specific heat capacity.	
Perform calculations including continuous flow.	
Perform calculations for a change of state $Q = ml$ where l is the specific latent heat.	
3.6.2.2 Ideal gases	
Understand the gas laws as experimental relationships between p, V, T and the mass of the gas.	
Understand the concept of absolute zero of temperature.	
Perform calculations using the ideal gas equation: $pV = nRT$ for n moles and $pV = NkT$, for N molecules.	
Understand *Work done* $= p\Delta V$	
Know Avogadro constant *N*A, molar gas constant R, Boltzmann constant k	
Know and be able to use molar mass and molecular mass.	
3.6.2.3 Molecular kinetic theory model	
Understand Brownian motion as evidence for existence of atoms.	
Be able to explain the relationships between p, V and T in terms of a simple molecular model.	
Know and list the assumptions leading to $pV = \frac{1}{3}Nm\,(c_{rms})^2$ including derivation of the equation and calculations.	
Appreciation that for an ideal gas internal energy is kinetic energy of the atoms.	
Perform calculations using *average molecular kinetic energy:* $\frac{1}{2}m\,(c_{rms})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$	
Appreciation of how knowledge and understanding of the behaviour of a gas has changed over time.	

	Revised It
3.6.1.1 Circular Motion	
1. Understand that motion in a circular path at constant speed implies there is an acceleration and requires a centripetal force.	
2. Understand motion in a circular path at constant speed implies there is an acceleration and requires a centripetal force.	
3. Perform calculations of angular speed $\omega = \frac{v}{r} = 2\pi f$	
4. Understand and use radian measure of angle	
5. Understand and perform calculations involving centripetal acceleration, $a = \frac{v^2}{r} = \omega^2 r$	
6. Understand and perform calculations involving centripetal force, $F = \frac{mv^2}{r} = m\omega^2 r$	
3.6.1.2 Simple Harmonic Motion	
1. Analysis of characteristics of simple harmonic motion (SHM).	
2. Understand and explain characteristics of simple harmonic motion (SHM).	
3. Know and explain the conditions for SHM: $a \propto -x$	
4. Understand and perform calculations involving: $a = -\omega^2 x$ $x = A\cos\omega t$ $v = \pm\omega\sqrt{(A^2 - x^2)}$	
5. Be able to draw the graphs relating x, v and a with time. Appreciation that the $v - t$ graph is derived from the gradient of the $x - t$ graph and that the $a - t$ graph is derived from the gradient of the $v - t$ graph.	
6. Know maximum speed equals ωA.	
7. Know maximum acceleration equals $\omega^2 A$	

3.6.1.3 Simple Harmonic Systems	
1. Understand the mass-spring system and perform calculations using: $T = 2\pi\sqrt{\frac{m}{k}}$	
2. Understand the simple pendulum and perform calculations using: $T = 2\pi\sqrt{\frac{l}{g}}$	
3. Understand the variation of *E*k, *E*p, and total energy with both displacement and time.	
4. Understand and explain the effects of damping on oscillations.	
3.6.1.4 Forced Vibrations and Resonance	
1. Know and explain free and forced vibrations.	
2. Understand and explain resonance and the effects of damping on the sharpness of resonance.	
3. Be able to describe examples of resonance effects in mechanical systems and situations involving stationary waves.	