Year 13 Physics Curriculum

Unit:	Core knowledge/skill development:	Sequence:	Assessment:	Literacy, numeracy, PSHE, FBV, other links	ACP and VAA development:	Home learning and enrichment
3.6 Further mechanics and thermal physics	The earlier study of mechanics is further advanced through a consideration of circular motion and simple harmonic motion (the harmonic oscillator). A further section allows the thermal properties of materials, the properties and nature of ideal gases, and the molecular kinetic theory to be studied in depth. **Required practical 7:** Investigation into simple harmonic motion using a mass–spring system and a sim ple pendulum. **Required practical 8:** Investigation of Boyle's law (constant temperature) and Charles's law	3.6.1 Periodic motion **3.6.1.1 Circular motion** Motion in a circular path at constant speed implies there is an acceleration and requires a centripetal force. Magnitude of angular speed · = *vr*= 2 · *f* Radian measure of angle. Direction of angular velocity will not be considered. Centripetal acceleration *a* = *v*2 *r* = ·2*r* The derivation of the centripetal acceleration formula will not be examined.	Common to all by topic) Isaac Physics for physics and maths, Exam Questions Block assessment / EOY assessment – exam questions / past papers Practical's: CPAC	MS 0.4 Estimate the acceleration and centripetal force in situations that involve rotation. AT i, k Data loggers can be used to produce *s* − *t*, *v* − *t* and *a* − *t* graphs for SHM. MS 3.6, 3.8, 3.9, 3.12 Sketch relationships between x, v, a and*a*− *t* for simple harmonic oscillators. MS 4.6 / AT b, c Students should recognise the use of the small-angle approximation in	In A level Physics the ACPS in general order of application are: 1. Analysing, 2. Linking, 3. Meta-thinking, 4. Creating and 5. Realising. VAA	(Common to all by topic) Flip learning, revision, homework by Isaac Physics, Exam Questions. School trips. Isaac Physics mentoring. Stretch to pre-University content. Differentiate via topic challenge in question setting

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	(constant pressure) for a gas.	Centripetal force *F* = *mv*2 *r* = *m* ·2*r* 3.6.1.2 Simple harmonic motion (SHM) Analysis of characteristics of simple harmonic motion (SHM). Condition for SHM: *a* ∝ − *x* Defining equation: *a* = − ·2*x* *x* = *A*cos ·*t* and *v* = ± · *A*2 − *x*2 Graphical representations linking the variations of 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		the derivation of the time period for examples of approximate SHM. AT g, i, k Investigation of the factors that determine the resonant frequency of a driven system. MS 1.5 / PS 2.3 / AT a, b, d, f Investigate the factors that affect the change in temperature of a substance using an electrical method or the method of mixtures. Students should be able to identify random and systematic errors in the		

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		from the gradient of the $v - t$ graph. Maximum speed = $\cdot A$ Maximum acceleration = $\cdot 2A$ 3.6.1.3 Simple harmonic systems Study of mass-spring system: $T = 2 \cdot mk$ Study of simple pendulum: $T = 2 \cdot lg$ Questions may involve other harmonic oscillators (eg liquid in U-tube) but full information will be provided in questions where necessary. Variation of E_k, E_p, and total energy with both displacement and time.		experiment and suggest ways to remove them. PS 1.1, 4.1 / AT k Investigate, with a data logger and temperature sensor, the change in temperature with time of a substance undergoing a phase change when energy is supplied at a constant rate. MS 3.3, 3.4, 3.14 / AT a		

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		Effects of damping on oscillations 3.6.1.4 Forced vibrations and resonance Qualitative treatment of free and forced vibrations. Resonance and the effects of damping on the sharpness of resonance. Examples of these effects in mechanical systems and situations involving stationary waves. 3.6.2 Thermal physics 3.6.2.1 Thermal energy transfer Internal energy is the sum of the randomly distributed kinetic energies and potential energies of				

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		the particles in a body. 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. For a change of temperature: $Q = mc\Delta$ · where c is				

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		specific heat capacity. Calculations including continuous flow. For a change of state $Q = ml$ where l is the specific latent heat. 3.6.2.2 Ideal gases Gas laws as experimental relationships between p, V, T and the mass of the gas. Concept of absolute zero of temperature. Ideal gas equation: $pV = nRT$ for n moles and $pV = NkT$ for N molecules. $Work\ done = p\Delta V$ Avogadro constant *NA*, molar gas constant R,				

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		Boltzmann constant k Molar mass and molecular mass. 3.6.2.3 Molecular kinetic theory model Brownian motion as evidence for existence of atoms. Explanation of relationships between p, V and T in terms of a simple molecular model. Students should understand that the gas laws are empirical in nature whereas the kinetic theory model arises from theory. Assumptions leading to pV = 13Nm crms 2 including derivation of the				

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		equation and calculations. A simple algebraic approach involving conservation of momentum is required. Appreciation that for an ideal gas internal energy is kinetic energy of the atoms. Use of *average molecular kinetic energy* = 12*m* crms 2 = 32*kT* = 3*RT* 2*NA* Appreciation of how knowledge and understanding of the behaviour of a gas has changed over time.				
3.7 Fields and their consequences	The concept of field is one of the great unifying ideas in physics. The ideas of gravitation,	3.7.1 Fields Concept of a force field as a region in which a body		MS 0.4 Students can estimate the gravitational		

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	electrostatics and magnetic field theory are developed within the topic to emphasise this unification. Many ideas from mechanics and electricity from earlier in the course support this and are further developed. Practical applications considered include: planetary and satellite orbits, capacitance and capacitors, their charge and discharge through resistors, and electromagnetic induction. These topics have considerable impact on modern society. Required practical 9: Investigation of the charge and discharge of capacitors. Analysis techniques should include log-linear plotting leading to a	experiences a non-contact force. Students should recognise that a force field can be represented as a vector, the direction of which must be determined by inspection. Force fields arise from the interaction of mass, of static charge, and between moving charges. Similarities and differences between gravitational and electrostatic forces: Similarities: Both have inverse-square force laws that have many characteristics in common, eg use of field lines, use of potential concept,		force between a variety of objects. MS 3.8, 3.9 Students use graphical representations to investigate relationships between v, r and g. MS 0.4 Estimate various parameters of planetary orbits, eg kinetic energy of a planet in orbit. MS 3.11 Use logarithmic plots to show relationships between T and r for given data. MS 0.3, 2.3 Students can estimate the		

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	determination of the time constant, RC Required practical 10: Investigate how the force on a wire varies with flux density, current and length of wire using a top pan balance. Required practical 11: Investigate, using a search coil and oscilloscope, the effect on magnetic flux linkage of varying the angle between a search coil and magnetic field direction.	equipotential surfaces etc Differences: masses always attract, but charges may attract or repel 3.7.2 Gravitational fields 3.7.2.1 Newton's law Gravity as a universal attractive force acting between all matter. Magnitude of force between point masses: $F = Gm1m2$ $r2$ where G is the gravitational constant. 3.7.2.2 Gravitational field strength Representation of a gravitational field by gravitational field lines.		magnitude of the electrostatic force between various charge configurations. PS 1.2, 2.2 / AT b Students can investigate the patterns of various field configurations using conducting paper (2D) or electrolytic tank (3D). PS 1.2, 2.2, 4.3 / AT f, g Determine the relative permittivity of a dielectric using a parallel-plate capacitor. Investigate the relationship between C and the dimensions of a parallel-plate		

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		g as force per unit mass as defined by $g = Fm$ Magnitude of g in a radial field given by $g = GM\ r2$ 3.7.2.3 Gravitational potential Understanding of definition of gravitational potential, including zero value at infinity. Understanding of gravitational potential difference. Work done in moving mass m given by $\Delta W = m\Delta V$ Equipotential surfaces. Idea that no work is done when moving along an equipotential surface.		capacitor eg using a capacitance meter MS 4.3 Convert between 2D representations and 3D situations. MS 0.3 / AT b, h Investigate relationships between currents, voltages and numbers of coils in transformers		

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		V in a radial field given by $V = - GMr$ Significance of the negative sign. Graphical representations of variations of g and V with r. V related to g by: $g = - \Delta V \Delta r$ ΔV from area under graph of g against r. 3.7.2.4 Orbits of planets and satellites Orbital period and speed related to radius of circular orbit; derivation of $T2 \propto r3$ Energy considerations for an orbiting satellite. Total energy of an orbiting satellite. Escape velocity.				

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		Synchronous orbits. Use of satellites in low orbits and geostationary orbits, to include plane and radius of geostationary orbit. 3.7.3 Electric fields **3.7.3.1 Coulomb's law** Force between point charges in a vacuum: *F* = 1 4□□0 *Q1Q2 r2* Permittivity of free space, ·0 Appreciation that air can be treated as a vacuum when calculating force between charges. For a charged sphere, charge may be considered to be at the centre.				

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		Comparison of magnitude of gravitational and electrostatic forces between subatomic particles. 3.7.3.2 Electric field strength Representation of electric fields by electric field lines. Electric field strength. E as force per unit charge defined by $E = FQ$ Magnitude of E in a uniform field given by $E = Vd$ Derivation from work done moving charge between plates: $Fd = Q\Delta V$ Trajectory of moving charged particle entering a uniform				

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		electric field initially at right angles. Magnitude of E in a radial field given by *E* = 1 4□□0 *Qr*2 3.7.3.3 Electric potential Understanding of definition of absolute electric potential, including zero value at infinity, and of electric potential difference. Work done in moving charge Q given by $\Delta W = Q\Delta V$ Equipotential surfaces. No work done moving charge along an equipotential surface.				

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		Magnitude of V in a radial field given by $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ Graphical representations of variations of E and V with r. V related to E by $E = \frac{\Delta V}{\Delta r}$ ΔV from the area under graph of E against r. 3.7.4 Capacitance **3.7.4.1 Capacitance** Definition of capacitance: $C = \frac{Q}{V}$ **3.7.4.2 Parallel plate capacitor** Dielectric action in a capacitor $C = \frac{A\varepsilon_0\varepsilon_r}{d}$ Relative permittivity and dielectric constant. Students should be able to describe the				

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		action of a simple polar molecule that rotates in the presence of an electric field. 3.7.4.3 Energy stored by a capacitor Interpretation of the area under a graph of charge against pd. $E = 12QV = 12CV2 = 12\ Q2\ C$ 3.7.4.4 Capacitor charge and discharge Graphical representation of charging and discharging of capacitors through resistors. Corresponding graphs for Q, V and I against time for charging and discharging.				

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		Interpretation of gradients and areas under graphs where appropriate. Time constant RC. Calculation of time constants including their determination from graphical data. Time to halve, $T½ = 0.69RC$ Quantitative treatment of capacitor discharge, $Q = Q0e− t RC$ Use of the corresponding equations for V and I. Quantitative treatment of capacitor charge, $Q = Q0 1 − e− t RC$ 3.7.5 Magnetic fields 3.7.5.1 Magnetic flux density				

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		Force on a current-carrying wire in a magnetic field: $F = BIl$ when field is perpendicular to current. Fleming's left hand rule. Magnetic flux density B and definition of the tesla. 3.7.5.2 Moving charges in a magnetic field Force on charged particles moving in a magnetic field, $F = BQv$ when the field is perpendicular to velocity. Direction of force on positive and negative charged particles. Circular path of particles; application				

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		in devices such as the cyclotron 3.7.5.3 Magnetic flux and flux linkage Magnetic flux defined by $\Phi = BA$ where B is normal to A. Flux linkage as $N\Phi$ where N is the number of turns cutting the flux. Flux and flux linkage passing through a rectangular coil rotated in a magnetic field: flux linkage $N\Phi = BAN\cos\theta$ 3.7.5.4 Electromagnetic induction Simple experimental phenomena. Faraday's and Lenz's laws.				

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		Magnitude of induced emf = rate of change of flux linkage · = *N* Δ · Δ *t* Applications such as a straight conductor moving in a magnetic field. emf induced in a coil rotating uniformly in a magnetic field: · = *BAN* ·sin ·*t* 3.7.5.5 Alternating currents Sinusoidal voltages and currents only; root mean square, peak and peak-to-peak values for sinusoidal waveforms only. *Irms* = *I*02 ; *Vrms* = *V*0 2 Application to the calculation of mains				

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		electricity peak and peak-to-peak voltage values. Use of an oscilloscope as a dc and ac voltmeter, to measure time intervals and frequencies, and to display ac waveforms. No details of the structure of the instrument are required but familiarity with the operation of the controls is expected 3.7.5.6 The operation of a transformer The transformer equation: $\frac{N_s}{N_p} = \frac{V_s}{V_p}$ Transformer efficiency = $\frac{I_S V_S}{I_P V_P}$				

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		Production of eddy currents. Causes of inefficiencies in a transformer. Transmission of electrical power at high voltage including calculations of power loss in transmission lines.				
3.8 Nuclear physics	This section builds on the work of Particles and radiation to link the properties of the nucleus to the production of nuclear power through the characteristics of the nucleus, the properties of unstable nuclei, and the link between energy and mass. Students should become aware of the physics	3.8.1 Radioactivity 3.8.1.1 Rutherford scattering Qualitative study of Rutherford scattering. Appreciation of how knowledge and understanding of the structure of the nucleus has changed over time. 3.8.1.2 α, β and γ radiation		MS 1.3, 3.10, 3.11 / PS 3.1, 3.2 Investigate the decay equation using a variety of approaches (including the use of experimental data, dice simulations etc) and a variety of analytical methods. MS 1.4		

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	that underpins nuclear energy production and also of the impact that it can have on society **Required practical 12:** Investigation of the inverse-square law for gamma radiation.	Their properties and experimental identification using simple absorption experiments; applications eg to relative hazards of exposure to humans. Applications also include thickness measurements of aluminium foil paper and steel. Inverse-square law for γ radiation: $I = k$ $x2$ Experimental verification of inverse-square law. Applications eg to safe handling of radioactive sources. Background radiation; examples of its origins and experimental		Make order of magnitude calculations of the radius of different atomic nuclei		

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		elimination from calculations. Appreciation of balance between risk and benefits in the uses of radiation in medicine. 3.8.1.3 Radioactive decay Random nature of radioactive decay; constant decay probability of a given nucleus; $\Delta N \Delta t = - \cdot N$ $N = N0e- \cdot t$ Use of activity, $A = \cdot N$ Modelling with constant decay probability. Questions may be set which require students to use $A = A0e- \cdot t$				

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		Questions may also involve use of molar mass or the Avogadro constant. Half-life equation: $T½ = \ln 2$ · Determination of half-life from graphical decay data including decay curves and log graphs. Applications eg relevance to storage of radioactive waste, radioactive dating etc. 3.8.1.4 Nuclear instability Graph of N against Z for stable nuclei. Possible decay modes of unstable nuclei including α, β+, β− and electron capture.				

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		Changes in N and Z caused by radioactive decay and representation in simple decay equations. Questions may use nuclear energy level diagrams. Existence of nuclear excited states; γ ray emission; application eg use of technetium-99m as a γ source in medical diagnosis. 3.8.1.5 Nuclear radius Estimate of radius from closest approach of alpha particles and determination of radius from electron diffraction.				

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		Knowledge of typical values for nuclear radius. Students will need to be familiar with the Coulomb equation for the closest approach estimate. Dependence of radius on nucleon number: *R* = *R*0*A*1/3 derived from experimental data. Interpretation of equation as evidence for constant density of nuclear material. Calculation of nuclear density. Students should be familiar with the graph of intensity against angle for				

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		electron diffraction by a nucleus. 3.8.1.6 Mass and energy Appreciation that $E = mc2$ applies to all energy changes, Simple calculations involving mass difference and binding energy. Atomic mass unit, u. Conversion of units; 1 u = 931.5 MeV. Fission and fusion processes. Simple calculations from nuclear masses of energy released in fission and fusion reactions. Graph of average binding energy per nucleon against nucleon number.				

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		Students may be expected to identify, on the plot, the regions where nuclei will release energy when undergoing fission/fusion. Appreciation that knowledge of the physics of nuclear energy allows society to use science to inform decision making. 3.8.1.7 Induced fission Fission induced by thermal neutrons; possibility of a chain reaction; critical mass. The functions of the moderator, control rods, and coolant in a thermal nuclear reactor.				

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		Details of particular reactors are not required. Students should have studied a simple mechanical model of moderation by elastic collisions. Factors affecting the choice of materials for the moderator, control rods and coolant. Examples of materials used for these functions. 3.8.1.8 Safety aspects Fuel used, remote handling of fuel, shielding, emergency shut-down. Production, remote handling, and storage of				

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		radioactive waste materials. Appreciation of balance between risk and benefits in the development of nuclear power.				
3.9 Astrophysics	Fundamental physical principles are applied to the study and interpretation of the Universe. Students gain deeper insight into the behaviour of objects at great distances from Earth and discover the ways in which information from these objects can be gathered. The underlying physical principles of the devices used are covered and some indication is given of the new information gained by the use of radio astronomy. The discovery of					

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	exoplanets is an example of the way in which new information is gained by astronomers					
3.10 Medical physics	Students with an interest in biological and medical topics are offered the opportunity to study some of the applications of physical principles and techniques in medicine. The physics of the eye and ear as sensory organs is discussed. The important and developing field of medical imaging, with both non-ionising and ionising radiations is considered. Further uses of ionising radiation are developed in a section on radiation therapy.					

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3.11 Engineering physics	This option offers opportunities for students to reinforce and extend the work of core units by considering applications in areas of engineering and technology. It extends the student's understanding in areas of rotational dynamics and thermodynamics. The emphasis in this option is on an understanding of the concepts and the application of physics. Questions can be set in novel or unfamiliar contexts, but in such cases the scene is set and any relevant required information is given					
3.12 Turning points in physics	This option is intended to enable key concepts and developments in					

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	physics to be studied in greater depth than in the core content. Students will be able to appreciate, from historical and conceptual viewpoints, the significance of major paradigm shifts for the subject in the perspectives of experimentation and understanding. Many present-day technological industries are the consequence of these key developments and the topics in the option illustrate how unforeseen technologies can develop from new discoveries					
3.13 Electronics	This option is designed for those who wish to learn more about modern electronic					

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	technologies as a development of their core work in electricity. A variety of discrete devices is introduced followed by discussions of both analogue and digital techniques ranging from the operational amplifier to digital signal processing. The option ends with a look at the issues surrounding data communication					