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A-Level Physics

Synoptic Links · Topic Map

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How A-Level Physics topics connect - the synoptic threads examiners reward across the whole course.

Threads across the course

Conservation of energy	The single thread that runs through almost every topic. A falling mass swaps gravitational potential for kinetic energy; a charging capacitor stores energy that a resistor later dissipates as heat; a photon delivers its whole energy to one electron in the photoelectric effect; a fusing nucleus releases the binding-energy difference. Whenever you can write energy in equals energy out, you have a route to an answer even when no single named equation fits.
Conservation of momentum	Total momentum before equals total momentum after in any closed system, and this links collisions in mechanics, recoil of a gun or a rocket, alpha decay where the daughter nucleus recoils against the alpha particle, and pair production where momentum must balance as well as energy. Pairing it with conservation of energy distinguishes elastic from inelastic collisions and lets you solve two-body problems fully.
Force = rate of change of momentum	Newton's second law in its full form, $F = \Delta p \div \Delta t$, ties together steady forces in mechanics, the thrust of a rocket or a jet ejecting mass each second, the pressure a gas exerts as molecules rebound off the walls in kinetic theory, and the impulse delivered in a collision as the area under a force-time graph. It is the deeper statement that $F = ma$ is only a special case of.
Graphs: gradient and area	Reading a gradient and an area is a portable skill the examiners reuse everywhere. Gradient gives velocity from a displacement-time graph, acceleration from velocity-time, force from a potential-energy curve, and the decay constant from a log-linear activity plot; area gives displacement under velocity-time, impulse under force-time, work under force-distance, and charge under current-time. Spotting which one a question wants is often half the marks.
Exponential change	The same mathematical shape appears in a discharging capacitor, a decaying radioactive sample, the absorption of radiation through matter, and the cooling of a body. In every case a quantity falls by the same fraction in equal time intervals, the rate of change is proportional to what is left, and a graph of the natural log against time is a straight line whose gradient is the constant. Recognising the pattern lets you carry the method from one topic straight into another.
Fields as a unifying idea	Gravitational, electric and magnetic fields are all described with the same toolkit - a field line picture, a field strength as force per unit of something, a potential, and the link between them. Mastering field strength, potential, equipotentials and the work done moving through a field once means you can transfer the whole structure between gravity, electrostatics and magnetism rather than learning three separate topics from scratch.
Models and assumptions	Physics progresses by simplifying: a point mass, an ideal gas, a perfectly elastic collision, a resistance-free wire, a uniform field. Knowing which assumption a model rests on, and when it breaks down, is a synoptic habit examiners reward - explaining why real gases deviate at high pressure, why a real cell has internal resistance, or why air resistance changes a projectile path shows you understand the model rather than just its equation.

Mechanics and fields

Circular motion to simple harmonic motion to fields	A mass moving in a circle needs a centripetal force directed to the centre; the same maths of ω and angular frequency reappears in simple harmonic motion, where the restoring force points back to equilibrium. Orbits then unite both with gravity: a satellite is in circular motion held by a gravitational field, and equating the field force to the centripetal requirement gives orbital speed and period directly.
Gravitational and electric fields as analogues	Place Newton's law of gravitation beside Coulomb's law and the parallels are exact in form: both have an inverse-square force, a field strength, a potential that falls to zero at infinity, and equipotential surfaces at right angles to the field lines. The one decisive difference - gravity only attracts while charge can repel - is itself a favourite synoptic discussion point that tests whether you understand the analogy rather than just memorising it.
Work done as the area in any field	Moving a mass through a gravitational field, a charge through an electric field, or stretching a spring all share one idea: work done is the area under the force-distance graph, and it equals the change in potential energy. This connects gravitational potential energy, electrical potential energy and elastic strain energy under a single method, and explains why potential is defined as work done per unit mass or per unit charge.
Capacitors and gravity store energy the same way	The energy in a charged capacitor is the area under its charge-voltage graph, exactly as the strain energy in a spring is the area under its force-extension graph and the work to lift a mass is the area under its force-height graph. The factor of one half in each formula comes from the same triangular area, so seeing one derivation makes the others immediate rather than three separate results to recall.
Electromagnetic induction joins fields and circuits	A changing magnetic flux induces an electromotive force, linking the magnetic-field topic to circuits, energy and mechanics in one stroke. Lenz's law is conservation of energy in disguise - the induced current always opposes the change that made it, so you must do work to keep a generator turning - and the same flux-linkage idea explains transformers, dynamos and the back-electromotive force in a motor.
Forces on charges and on currents	A single moving charge in a magnetic field feels a force perpendicular to its motion, and a current is just many such charges, so the force on a current-carrying wire is the same physics scaled up. This connects particle accelerators and mass spectrometers, where charges curve in fields, with motors and the motor effect in circuits, and the circular path of a charge mirrors the centripetal motion met in mechanics.
Projectiles and independence of perpendicular motions	Splitting motion into horizontal and vertical components, which are independent, is the key to projectiles, but the same vector resolution unlocks forces on an inclined plane, the components of a field, and the resolved parts of a velocity entering a magnetic field. Treating perpendicular directions separately and recombining them is a method that travels far beyond the projectile question where it is first met.

Waves, quantum and nuclear

Waves everywhere	One set of ideas - wavelength λ, frequency, speed, amplitude, phase - describes sound, light, water ripples, waves on strings, and the de Broglie waves of matter. Reflection, refraction, diffraction, interference and standing waves recur in each context, so a stationary wave on a string, a standing wave in an air column, and the resonance of an electron in an atom are versions of the same behaviour seen through different topics.
Wave-particle duality	Light shows interference and diffraction like a wave yet ejects electrons one quantum at a time like a particle, while electrons that we picture as particles diffract through a crystal like waves. This duality bridges the waves topic and the quantum topic, and it is why the photon energy $E = hf$ and the de Broglie wavelength sit at the heart of explaining the photoelectric effect, atomic line spectra and electron diffraction together.

Photon energy and the electronvolt	The photon idea links the colour of light to an energy through E = hf, and the electronvolt links that energy to a charge accelerated through a voltage. This thread runs from the photoelectric effect, to the discrete energy levels that produce emission and absorption line spectra, to the minimum wavelength of X-rays from an accelerating tube, all tied by the same small packet of energy measured in the same convenient unit.
Energy levels and spectra	Electrons in an atom occupy discrete energy levels, and a photon is emitted or absorbed only when its energy exactly matches the gap between two levels. This single rule explains the bright lines of an emission spectrum, the dark lines of an absorption spectrum, the fluorescence in a lamp, and why each element has a unique fingerprint - connecting quantum theory directly to the observable colours analysed in spectroscopy.
Exponential decay in capacitors and radioactivity	A radioactive sample and a discharging capacitor obey the identical mathematics: the rate of decrease is proportional to the amount remaining, so both follow a falling exponential with a characteristic constant - half-life for the nucleus, time constant for the capacitor. The same log-linear graph straightens both, and the same reasoning about constant fractional change in equal times answers questions in either topic.
Mass-energy equivalence	Einstein's $E = mc^2$ turns the small mass difference in a nuclear reaction into a large energy release, and this binds the nuclear topic to conservation of energy across the whole course. The binding energy per nucleon curve explains why fusion of light nuclei and fission of heavy ones both release energy, why iron sits at the most stable point, and where the Sun's output and a reactor's heat ultimately come from.
Conservation laws in particle reactions	Every particle interaction must conserve charge, energy, momentum and other quantities at once, so the bookkeeping skills from mechanics reappear at the subatomic scale. Pair production needs a photon with at least the combined rest energy of the particles created, annihilation reverses it, and beta decay's missing energy and momentum revealed the neutrino - each a synoptic blend of the conservation threads applied to the smallest building blocks.

Maths skills in physics

Straight-line graphs and y = mx + c	Rearranging a physical relationship into the form of a straight line lets you read a constant from a gradient and another from an intercept. Plotting period squared against length for a pendulum, force against extension for a spring, or the photoelectric stopping voltage against frequency to find Planck's constant all rely on this same move - choosing what to plot so that the theory predicts a line.
Logarithms to straighten exponentials and powers	Taking the natural log of an exponential decay turns a curve into a straight line whose gradient is the decay or time constant, used identically for radioactivity and capacitor discharge. Taking logs of both sides of a power law lets you find an unknown exponent from the gradient of a log-log plot, a technique that recovers hidden relationships in many practical investigations.
Vectors, components and resolving	Splitting a quantity into perpendicular components, and adding vectors tip to tail, underpins projectiles, forces in equilibrium, fields at an angle, and momentum in two dimensions. The same resolving step that finds the weight along a slope finds the horizontal launch speed of a projectile and the velocity component of a charge across a field, so the skill is reused constantly rather than belonging to one topic.
Areas and gradients beyond the graph	The calculus ideas of gradient as a rate of change and area as an accumulated total appear without ever needing formal integration. The gradient of any tangent gives an instantaneous rate, the area under any rate gives a total, and naming the quantities - velocity and displacement, force and impulse, power and energy - turns an abstract graph into a physical answer in whichever topic the axes come from.

Uncertainties and significant figures	Combining uncertainties by adding percentages for products and quotients, and judging how many significant figures an answer deserves, applies to every practical and every calculation in the course. Carrying an uncertainty through to a final result, then quoting the answer to a matching precision, is a synoptic discipline that separates a measurement you can trust from a number with no honest meaning.
Standard form and orders of magnitude	Physics spans the mass of an electron to the mass of a star, so writing quantities in standard form and converting prefixes - nano, micro, kilo, mega, giga - is essential everywhere. A quick order-of-magnitude check, asking whether an answer of 10^{-9} or 10^{9} even makes sense, catches the powers-of-ten slips that otherwise quietly destroy an answer in any topic.
Angles, radians and the small-angle world	Measuring angles in radians links arc length, angular velocity ω in circular motion, and the phase of an oscillation or wave on the same footing. The small-angle approximation that makes a pendulum simple harmonic, the radian measure behind diffraction-grating angles, and the geometry of a wavefront all depend on handling angles consistently rather than switching between degrees and radians by accident.