Physics (0625)

IGCSE • Extended • CAIE

Compact Cheat Sheet

The Practice Book
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1 Electricity and magnetism

KEY FORMULAS

Electric current

$$I = \frac{Q}{t}$$

Current is the rate of flow of charge, in amperes (1 A = 1 C/s). Use to link a current I flowing for a time t to the charge Q that passes, rearranging to $Q = It$.

Electrical power

$$P = IV$$

Power is the energy transferred per second, in watts (W). Use for the power dissipated by a component carrying current I across a potential difference V.

Potential difference and e.m.f.

$$V = \frac{E}{Q}$$

Voltage is the energy transferred per unit charge, in volts (1 V = 1 J/C). Use to find the energy E given to or delivered by a charge Q moving through a voltage V.

Resistance and Ohm's law

$$V = IR$$

Defines resistance $R = V/I$, in ohms (Ω). Use to find any one of voltage, current or resistance for a component when the other two are known.

Resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

The combined resistance of resistors in parallel is found by adding the reciprocals. The result is always *smaller* than the smallest branch. Use when components are on separate branches sharing the same voltage.

Resistors in series

$$R = R_1 + R_2 + \dots$$

The combined resistance of resistors in series is the sum of the separate resistances. Use when components share a single loop, so the same current flows through each.

Transformer turns ratio

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

For a transformer the ratio of primary to secondary voltage equals the ratio of the numbers of turns on the two coils. Use to find an unknown voltage or number of turns; more turns means a higher voltage on that side.

KEY CONCEPTS

- **Connecting an ammeter and a voltmeter**: An *ammeter* measures current and is connected in *series*, in the same loop as the component, so the same current passes through both. A *voltmeter* measures potential difference and is connected in *parallel*, across the component. An ideal ammeter has zero resistance and an ideal voltmeter has infinite resistance.
- **Electric charge and charging by friction**: There are two kinds of charge, positive and negative; like charges repel and unlike charges attract. Charging an insulator by friction transfers *electrons*: the object that gains electrons becomes negative and the one that loses them becomes positive. Protons never move, so charging is always about where the electrons go.
- **Inducing an e.m.f.**: Moving a magnet near a coil, or moving a wire so that it cuts magnetic field lines, *induces* an e.m.f. across the conductor; if the circuit is complete a current flows. The induced e.m.f. is larger when the motion is faster, the magnet is stronger, or the coil has more turns.
- **Live, neutral and earth wires**: A mains plug carries three wires: the *live* (brown) carries the alternating supply, the *neutral* (blue) completes the circuit, and the *earth* (green and yellow) is a safety path to ground. A *fuse* and a switch are always placed in the live wire so the appliance is isolated from the supply when they break the circuit.
- **Magnetic field and field lines**: A magnetic field is the region where a magnet exerts a force on another magnet or on a magnetic material. It is drawn with *field lines* that run from the *north* pole to the *south* pole outside the magnet. Where the lines are close together the field is strong; where they are spread apart it is weak. Like poles repel and unlike poles attract.
- **Magnetic field of a current**: An electric current produces a magnetic field around itself. Around a straight wire the field is a set of concentric circles whose direction is given by the *right-hand grip rule* (thumb along the conventional current, fingers curl the field). Winding the wire into a *solenoid* gives a field like a bar magnet's, strong and uniform inside.
- **The a.c. generator**: Rotating a coil in a magnetic field makes the field through the coil change continuously, inducing an *alternating* e.m.f. The coil connects to the external circuit through *slip rings* and brushes. The output is a sine curve, with one complete cycle per revolution of the coil.
- **The d.c. motor**: In a d.c. motor a current-carrying coil in a magnetic field feels opposite forces on its two sides, one pushed up and one pushed down, which turn the coil. A *split-ring commutator* reverses the current in the coil every half turn, so the forces always drive the rotation the same way and the coil spins continuously.
- **The motor effect and Fleming's left-hand rule**: A current-carrying conductor placed in a magnetic field experiences a force, the *motor effect*, because the two fields interact. *Fleming's left-hand rule* gives the direction: the thumb is the force (motion), the first finger is the field (north to south), and the second finger is the current. The force reverses if either the current or the field is reversed.

2 Motion, forces and energy

KEY FORMULAS

Acceleration

$$a = \frac{\Delta v}{\Delta t}$$

Acceleration is the change in velocity per unit time. Use for uniformly changing motion; on a speed-time graph it equals the gradient of the line.

Density

$$\rho = \frac{m}{V}$$

Mass per unit volume of a substance. Use to decide floating (an object floats on a fluid of greater density) and to identify materials; water has a density of 1000 kg/m³.

Kinetic energy

$$E_k = \frac{1}{2}mv^2$$

The energy a body has because of its motion. Use whenever a mass changes speed; it depends on the *square* of the speed, so doubling the speed quadruples the kinetic energy.

Moment of a force

$$M = Fd$$

The turning effect of a force about a pivot, where d is the perpendicular distance from the pivot to the line of action of the force. Measured in newton metres (N·m).

Momentum

$$p = mv$$

Momentum is mass times velocity, a vector measured in kg·m/s. Use it in collision and explosion problems, where the total momentum of a system is conserved.

Newton's second law

$$F = ma$$

The resultant force on a body equals its mass times its acceleration. Always find the *resultant* force first, then divide by the mass to get the acceleration.

Power

$$P = \frac{E}{t}$$

Power is the rate of transferring energy or doing work, measured in watts (1 W = 1 J/s). Equivalently $P = W/t$ for work W done in time t.

Pressure

$$p = \frac{F}{A}$$

Pressure is the force acting normally per unit area, measured in pascals (1 Pa = 1 N/m²). The same force on a smaller area gives a greater pressure.

Resultant of two perpendicular forces

$$R = \sqrt{F_1^2 + F_2^2}$$

Combines two forces acting at right angles into a single resultant. Use when two perpendicular forces (or any perpendicular vectors) act at a point; for other angles use a scale drawing.

Weight

$$W = mg$$

The gravitational force on a mass m in a field of strength g. Use to convert between mass in kilograms and weight in newtons; on Earth $g \approx 9.8$ N/kg.

Work done

$$W = Fd$$

Work is the energy transferred when a force moves its point of application a distance d in the direction of the force. Measured in joules; no movement means no work is done.

KEY CONCEPTS

- **Centre of gravity and stability**: The *centre of gravity* is the single point at which the whole weight of an object appears to act. An object is more stable when its centre of gravity is low and its base is wide, and it topples only when the line of action of its weight falls outside the base.
- **Renewable and non-renewable resources**: A *renewable* resource is replaced as fast as it is used (solar, wind, hydroelectric, geothermal, tidal and biomass). A *non-renewable* resource is used far faster than it forms (coal, oil, gas and nuclear fuel). Comparisons weigh reliability, cost and pollution against each other.

3 Nuclear physics

KEY FORMULAS

Alpha decay equation

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\mathrm{He}$$

Use for alpha decay. The nucleus loses an alpha particle, so the nucleon number A falls by 4 and the proton number Z falls by 2. Balance the top row and the bottom row separately.

Beta-minus decay equation

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\mathrm{e}$$

Use for beta-minus decay. A neutron becomes a proton and emits a fast electron, so Z rises by 1 while A stays the same.

Corrected count rate

$$\text{corrected count rate} = \text{measured count rate} - \text{background count rate}$$

Use whenever a source's count rate is measured. Background radiation is always present, so subtract the background rate (measured with no source) before quoting the activity of a source.

Fraction remaining after n half-lives

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n, \qquad n = \frac{t}{T_{1/2}}$$

Use to find how much of a sample is left. n is the number of half-lives in the time elapsed t. The same factor applies to the number of nuclei, the mass, the activity or the corrected count rate.

Neutron number from nuclide notation

$${}^{A}_{Z}X, \qquad \text{neutrons} = A - Z$$

Use to read a nuclide. Z is the proton number (which fixes the element) and A is the nucleon number (protons plus neutrons), so the neutron count is $A - Z$.

KEY CONCEPTS

- **Isotopes**: Isotopes are atoms of the same element (same proton number Z) with different numbers of neutrons (different nucleon number A). They have identical chemical behaviour because they have the same electron arrangement, but they differ in nuclear mass and stability.
- **Nature of alpha, beta and gamma radiation**: Alpha (α) is a helium nucleus ${}^{4}_{2}\mathrm{He}$: most ionising, stopped by paper. Beta-minus (β^-) is a fast electron ${}^{0}_{-1}\mathrm{e}$: medium ionising, stopped by a few mm of aluminium. Gamma (γ) is a high-energy electromagnetic wave: least ionising, only reduced by thick lead or concrete.
- **Nuclear model of the atom**: An atom is a tiny, dense, positively charged *nucleus* of protons and neutrons surrounded by *electrons* in mostly empty space. The nucleus holds almost all the mass. A neutral atom has equal protons and electrons; losing an electron makes a positive *ion* and gaining one makes a negative ion.
- **Reducing radiation dose (time, distance, shielding)**: Ionising radiation damages living cells, so handlers reduce their *dose* with three levers: less *time* near the source, more *distance* from it

(intensity falls steeply with distance), and *shielding* such as lead or concrete between source and body. Sources are stored in lead-lined boxes and handled with tongs.

4 Space physics

KEY FORMULAS

Hubble's law

$$v = H_0 d$$

Recession speed of a galaxy equals the Hubble constant H_0 times its distance d. Use to find how fast a distant galaxy is moving away, or, rearranged, to find its distance. With d in metres and H_0 in s^{-1} the speed is in m/s.

Orbital speed

$$v = \frac{2\pi r}{T}$$

Speed of any body in a circular orbit: one lap covers the circumference $2\pi r$ in the orbital period T. Use for the Moon, a planet or a satellite. Keep r in metres and T in seconds for a speed in m/s.

KEY CONCEPTS

- **Elliptical orbits and changing speed**: Orbits are *ellipses* (slightly squashed circles), not perfect circles, with the Sun at one focus. Because the distance to the Sun changes around the orbit, the speed changes too: a body moves *fastest at its closest point* to the Sun and slowest at its farthest. A comet on a long stretched orbit shows this most dramatically.
- **Redshift and the expanding Universe**: Light from distant galaxies is shifted to longer (redder) wavelengths: *redshift*. The further away a galaxy is, the greater its redshift, so the faster it is receding. This is evidence that the whole Universe is *expanding* from an initial hot, dense state, the Big Bang.
- **Spin versus orbit**: The Earth *spins* on its axis once every 24 hours, which gives day and night. Separately it *orbits* the Sun once a year, and because its axis is tilted this gives the seasons. The Moon orbits the Earth about once a month, and the changing fraction of its sunlit half that faces us gives the *phases*.
- **Structure of the Solar System**: The Solar System is one star, the Sun, plus eight planets with their moons, together with dwarf planets, asteroids and comets, all held in orbit by the Sun's gravity. The four inner planets are small and rocky; the four outer planets are large gas and ice giants.
- **The Sun and nuclear fusion**: The Sun is an average star powered by *nuclear fusion* of hydrogen into helium in its core, releasing the energy that lights and warms the Solar System. Stars are gathered by gravity into *galaxies*; our galaxy is the Milky Way.

5 Thermal physics

KEY FORMULAS

Boyle's Law (pressure and volume)

$$p_1V_1 = p_2V_2$$

For a fixed mass of gas at constant temperature, pressure is inversely proportional to volume. Use when a gas is compressed or expanded without any change in temperature.

Kelvin temperature conversion

$$T_K = \theta_C + 273$$

Converts a Celsius temperature θ_C to the absolute (Kelvin) scale. Always convert to kelvin before substituting a temperature into a gas-law ratio.

Specific heat capacity equation

$$\Delta E = mc\Delta\theta$$

Energy to change the temperature of mass m by $\Delta\theta$ with no change of state. Here c is the specific heat capacity in J/(kg·°C).

Specific latent heat equation

$$E = mL$$

Energy to change the state of mass m at constant temperature. L is the specific latent heat (of fusion for melting and freezing, of vaporisation for boiling and condensing).

KEY CONCEPTS

- **Conduction**: Conduction is the transfer of thermal energy through a material without the material itself moving. Particles at the hot end vibrate more and pass energy to their neighbours through collisions. Metals also conduct through a sea of *free electrons*, which makes them the best conductors.
- **Convection**: Convection is the transfer of thermal energy through a *fluid* (a liquid or a gas) by the bulk movement of the fluid. Warmer fluid expands, becomes less dense and rises, while cooler, denser fluid sinks to replace it. Convection cannot occur in a solid or a vacuum.
- **Particle model of matter**: All matter is made of particles in constant motion. In a *solid* the particles vibrate about fixed positions in a regular lattice; in a *liquid* they are still close together but free to move past one another; in a *gas* they are far apart and move rapidly in all directions, filling the container.
- **Thermal radiation**: Thermal radiation is the transfer of thermal energy as *infrared* electromagnetic waves. It needs no medium, so it can travel through a vacuum, which is how energy from the Sun reaches the Earth. Every object above absolute zero emits thermal radiation.

6 Waves

KEY FORMULAS

Critical angle

$$\sin c = \frac{1}{n}$$

Gives the critical angle c for a ray inside a medium of refractive index n. At an angle of incidence greater than c the ray is totally internally reflected.

Refractive index

$$n = \frac{\sin i}{\sin r}$$

Refractive index of a medium from the angle of incidence i in air and the angle of refraction r in the medium. A larger n means light slows more and bends more.

Wave equation

$$v = f\lambda$$

Wave speed equals frequency times wavelength. Use for any wave to find one quantity from the other two; v in m/s, f in Hz, λ in m.

KEY CONCEPTS

- **Converging and diverging lenses**: A *converging* (convex) lens bends parallel rays inward to meet at the *principal focus*, a distance equal to the focal length f from the lens. A *diverging* (concave) lens spreads parallel rays apart so they appear to come from a focus on the same side.
- **Law of reflection and the plane-mirror image**: The angle of incidence equals the angle of reflection, both measured from the *normal*. The image in a plane mirror is the same size as the object, as far behind the mirror as the object is in front, upright, laterally inverted and *virtual*.
- **Order of the electromagnetic spectrum**: In order of increasing frequency and decreasing wavelength the regions are radio, microwave, infrared, visible, ultraviolet, X-rays and gamma. All electromagnetic waves are transverse and travel through a vacuum at the same speed, 3.0×10^8 m/s.
- **Sound as a longitudinal wave**: Sound is a *longitudinal* wave of compressions and rarefactions produced by a vibrating source. It needs a medium, so it cannot travel through a vacuum, and it travels fastest in solids, slower in liquids and slowest in gases.
- **Transverse and longitudinal waves**: A wave transfers *energy* from place to place without transferring matter. In a *transverse* wave the vibration is at right angles to the direction of travel, as in light and water ripples; in a *longitudinal* wave the vibration is along the direction of travel, as in sound.

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