GCE PHYSICS

TERMS, DEFINITIONS & UNITS

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This document is issued by WJEC to assist teachers with the preparation of candidates for the GCE examination in PHYSICS. It consists of the definitions of terms from the current AS/A specification.

The definitions were produced by the Principal Examining team. It is acknowledged that there will always be disagreement on precise definitions, but the aim has been to produce wording which is accessible to students while preserving a fair level of rigour.

The rationale for the production of this document is to help learners towards an understanding of the basic vocabulary of Physics, without which clear explanations are impossible. It will also of course aid the learners in revision, as knowledge of terms, definitions and units is examined in every paper.

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AS Unit 1

Section	Item	Definition
1.1 (a)	Quantity	In S.I. a quantity is represented by a number × a unit, (e.g. m = 3.0 kg).
1.1 (d)	Scalar	A scalar is a quantity that has magnitude only.
	Vector	A vector is a quantity that has magnitude and direction.
1.1 (f)	Resolving a vector into components in particular directions	This means finding vectors (the so-called *components*) in these directions, which add together vectorially to make the original vector, and so, together, are equivalent to this vector.
1.1 (g)	Density of a material, ρ	$\text{density} = \dfrac{\text{mass}}{\text{volume}}$ **Unit: kg m^{-3}** or **g cm^{-3}** in which mass and volume apply to any sample of the material.
1.1 (h)	Moment (or torque) of a force	The moment (or torque) of a force about a point is defined as the force × the perpendicular distance from the point to the line of action of the force, i.e. moment = $F \times d$ **Unit: N m** [N.B. the unit is not J]
1.1 (i)	The principle of moments	For a system to be in equilibrium, $\sum$ anticlockwise moments about a point = $\sum$ clockwise moments about the same point.
1.1 (j)	Centre of gravity	The centre of gravity is the single point within a body at which the entire weight of the body may be considered to act.
1.2 (a)	Displacement	The displacement of a point B from a point A is the shortest distance from A to B, together with the direction. **Unit: m**
	Mean speed	$\text{Mean speed} = \dfrac{\text{total distance travelled}}{\text{total time taken}} = \dfrac{\Delta x}{\Delta t}$ **Unit: m s^{-1}**
	Instantaneous speed	Instantaneous speed = rate of change of distance **Unit: m s^{-1}**
	Mean velocity	$\text{Mean velocity} = \dfrac{\text{total displacement}}{\text{total time taken}}$ **Unit: m s^{-1}**
	Instantaneous velocity	The velocity of a body is the rate of change of displacement. **Unit: m s^{-1}**
	Mean acceleration	$\text{Mean acceleration} = \dfrac{\text{change in velocity}}{\text{time taken}} = \dfrac{\Delta v}{\Delta t}$ **Unit: m s^{-2}**
	Instantaneous acceleration	The instantaneous acceleration of a body is its rate of change of velocity. **Unit: m s^{-2}**
1.2 (e)	Terminal velocity	The terminal velocity is the constant, maximum velocity of an object when the resistive forces on it are equal and opposite to the 'accelerating' force (e.g. pull of gravity).
1.3 (a)	Force, F	A force on a body is a push or a pull acting on the body from some external body. **Unit: N**
	Newton's 3rd law	If a body **A** exerts a force on a body **B**, then **B** exerts an equal and opposite force on **A**.
1.3 (c)	$\Sigma F = m a$	The mass of a body × its acceleration is equal to the vector sum of the forces acting on the body. This vector sum is called the *resultant force*.

1.3 (d)	Momentum	The momentum of an object is its mass multiplied by its velocity. ($p = mv$). It is a vector. **UNIT: kg m s^{-1}** or **Ns**
1.3 (e)	Newton's 2nd law	The rate of change of momentum of an object is proportional to the resultant force acting on it, and takes place in the direction of that force.
1.3 (f)	The principle of conservation of momentum	The vector sum of the momenta of bodies in a system stays constant even if forces act between the bodies, provided there is no external resultant force.
	Elastic collision	A collision in which there is no change in total kinetic energy.
	Inelastic collision	A collision in which kinetic energy is lost.
1.4 (a)	Work, W	Work done by a force is the product of the magnitude of the force and the distance moved in the direction of the force.(W.D. = $Fx\cos\theta$) **Unit: J**
1.4 (c)	Principle of conservation of energy	Energy cannot be created or destroyed, only transferred from one form to another. Energy is a scalar.
	Potential energy, E_p	This is energy possessed by an object by virtue of its position. $E_p = mgh$ **Unit: J**
	Kinetic energy, E_k	This is energy possessed by an object by virtue of its motion. $E_k = ½mv^2$ **Unit: J**
	Elastic potential energy	This is the energy possessed by an object when it has been deformed due to forces acting on it. $E_{elastic} = ½ F_x$ or $½ kx^2$ **Unit: J**
1.4 (d)	Energy	The energy of a body or system is the amount of work it can do. **Unit: J**
1.4 (e)	Power, P	This is the work done per second, or energy transferred per second. **Unit: W [= J s^{-1}]**
1.5 (a)	Hooke's law	The tension in a spring or wire is proportional to its extension from its natural length, provided the extension is not too great.
	Spring constant, k	The spring constant is the force per unit extension. **Unit: N m^{-1}**
1.5 (b)	Stress, σ	Stress is the force per unit cross-sectional area when equal opposing forces act on a body. **Unit Pa** or **N m^{-2}**
	Strain, ε	Strain is defined as the extension per unit length due to an applied stress. **Unit: none**
	Young modulus, E	Young modulus $E = \dfrac{\text{tensilestress}}{\text{tensilestrain}}$ Unless otherwise indicated this is defined for the Hooke's law region. **Unit: Pa or N m^{-2}**
1.5 (d)	Crystal	Solid in which atoms are arranged in a regular array. There is a long range order within crystal structures.
	Crystalline solid	Solid consisting of a crystal, or of many crystals, usually arranged randomly. The latter is strictly a *poly*crystalline solid. Metals are polycrystalline.
	Amorphous solid	A truly amorphous solid would have atoms arranged quite randomly. Examples are rare. In practice we include solids such as glass or brick in which there is no long range order in the way atoms are arranged, though there may be ordered clusters of atoms.
	Polymeric solid	A solid which is made up of chain-like molecules.

1.5 (e)	Ductile material	A material which can be drawn out into a wire. This implies that plastic strain occurs under enough stress.
	Elastic strain	This is strain that disappears when the stress is removed, that is the specimen returns to its original size and shape.
	Plastic (or inelastic) strain	This is strain that decreases only slightly when the stress is removed. In a metal it arises from the movement of dislocations within the crystal structure.
	Elastic limit	This is the point at which deformation ceases to be elastic. For a specimen it is usually measured by the maximum force, and for a material, by the maximum stress, before the strain ceases to be elastic.
	Dislocations in crystals	Certain faults in crystals which (if there are not too many) reduce the stress needed for planes of atoms to slide. The easiest dislocation to picture is an *edge* dislocation: the edge of an intrusive, incomplete plane of atoms.
	Grain boundaries	The boundaries between crystals (grains) in a polycrystalline material.
	Ductile fracture (necking)	The characteristic fracture process in a ductile material. The fracture of a rod or wire is preceded by local thinning which increases the stress.
1.5 (f)	Brittle material	Material with no region of plastic flow, which, under tension, fails by brittle fracture.
	Brittle fracture	This is the fracture under tension of brittle materials by means of crack propagation.
1.5 (g)	Elastic hysteresis	When a material such as rubber is put under stress and the stress is then relaxed, the stress-strain graphs for increasing and decreasing stress do not coincide, but form a loop. This is hysteresis.
1.6 (b)	Black body	A black body is a body (or surface) which absorbs all the electromagnetic radiation that falls upon it. No body is a better *emitter* of radiation at any wavelength than a black body at the same temperature.
1.6 (d)	Wien's displacement law	The wavelength of peak emission from a black body is inversely proportional to the absolute (kelvin) temperature of the body. $\lambda_{\max} = \frac{W}{T}$ [W = the Wien constant = 2.90×10^{-3} m K]
	Absolute or kelvin temperature	The temperature, T in kelvin (K) is related to the temperature, θ, in celsius (°C) by: T / K= θ / °C + 273.15 At 0 K (-273.15°C) the energy of particles in a body is the lowest it can possibly be.
	Stefan's law [The Stefan-Boltzmann law]	The total electromagnetic radiation energy emitted per unit time by a black body is given by *power* = $A\,\sigma T^4$ in which A is the body's surface area and σ is a constant called *the Stefan constant*. [σ = 5.67×10^{-8} W m^{-2} K^{-4}]
	Luminosity of a star	The luminosity of a star is the total energy it emits per unit time in the form of electromagnetic radiation. **UNIT: W** [Thus we could have written *luminosity* instead of *power* in Stefan's law (above).]

	Intensity	The intensity of radiation at a distance R from a source is given by $I = \frac{P}{4\pi R^2}$ **UNIT: W m^{-2}**
1.7 (c)	Lepton	Leptons are electrons and electron-neutrinos [and analogous pairs of particles of the so-called *second and third generations*].
1.7 (f)	Hadron	Hadrons are particles consisting of quarks or antiquarks bound together. Only hadrons (and quarks or antiquarks themselves) can 'feel' the *strong* force.
	Baryon	A baryon is a hadron consisting of 3 quarks or 3 antiquarks. The best known baryons are the *nucleons*, i.e. protons and neutrons.
	Meson	A meson is a hadron consisting of a quark-antiquark pair.

AS Unit 2

Section	Item	Definition
2.1 (a)	Electric current, I	This is the rate of flow of electric charge. $I = \frac{\Delta Q}{\Delta t}$ **Unit: A**
2.1 (d)	Efficiency of a system	$\% \text{ Efficiency} = 100 \times \frac{\text{usefulwork (or energy) out}}{\text{work (or energy) put in}}$ **Unit: none**
2.2 (a)	Potential difference (pd), V	The pd between two points is the energy converted from electrical potential energy to some other form per coulomb of charge flowing from one point to the other. **Unit: V [= J C^{-1}]**
2.2 (d)	Ohm's law	The current in a metal wire at constant temperature is proportional to the pd across it.
2.2 (e)	Electrical resistance, R	The resistance of a conductor is the pd (V) placed across it divided by the resulting current (I) through it. $R = \frac{V}{I}$ **Unit: Ω [= V A^{-1}]**
2.2 (h)	Resistivity, ρ	The resistance, R, of a metal wire of length L and cross-sectional area A is given by $R = \frac{\rho L}{A}$, in which ρ the resistivity, is a constant (at constant temperature) for the material of the wire. **Unit: Ω m**
2.2 (k)	Superconducting transition temperature, T_c	The temperature at which a material, when cooled, loses all its electrical resistance, and becomes *super-conducting*. Some materials (e.g. copper) never become superconducting however low the temperature becomes.
2.3 (a)	The law of conservation of charge	Electric charge cannot be created or destroyed, (though positive and negative charges can neutralise each other). Charge cannot pile up at a point in a circuit.
2.3 (g)	Emf, E	The emf of a source is the energy converted from some other form (e.g. chemical) to electrical potential energy per coulomb of charge flowing through the source. **Unit: V**
2.4 (a)	Progressive wave	A pattern of disturbances travelling through a medium and carrying energy with it, involving the particles of the medium oscillating about their equilibrium positions.
2.4 (b)	Transverse wave	A transverse wave is one where the particle oscillations are at right angles to the direction of travel (or propagation) of the wave.
	Longitudinal wave	A longitudinal wave is one where the particle oscillations are in line with (parallel to) the direction of travel (or propagation) of the wave.
2.4 (c)	Polarised wave	A polarised wave is a transverse wave in which particle oscillations occur in only one of the directions at right angles to the direction of wave propagation.
2.4 (d)	In phase	Waves arriving at a point are said to be *in phase* if they have the same frequency and are at the same point in their cycles at the same time. [Wave *sources* are in phase if the waves have the same frequency and are at the same point in their cycles at the same time, as they leave the sources.]
2.5 (e)	Wavelength of a progressive wave	The wavelength of a progressive wave is the minimum distance (measured along the direction of propagation) between two points on the wave oscillating in phase.

	Frequency of a wave	The frequency of a wave is the number of cycles of a wave that pass a given point in one second, [or equivalently the number of cycles of oscillation per second performed by any particle in the medium through which the wave is passing.]
	Speed of a wave	The speed of a wave is the distance that the wave profile moves per unit time.
2.5 (a)	Diffraction	Diffraction is the spreading out of waves when they meet obstacles, such as the edges of a slit. Some of the wave's energy travels into the geometrical shadows of the obstacles.
2.5 (f)	The principle of superposition	The principle of superposition states that if waves from two sources [or travelling by different routes from the same source] occupy the same region then the total displacement at any one point is the vector sum of their individual displacements at that point.
2.5 (m)	Phase difference	Phase difference is the difference in position of 2 points within a cycle of oscillation. It is given as a fraction of the cycle or as an angle, where one whole cycle is 2π or 360°], together with a statement of which point is ahead in the cycle.
	Coherence	Waves or wave sources, which have a constant phase difference between them (and therefore must have the same frequency) are said to be coherent.
2.5 (o)	Stationary (or standing) wave	A stationary wave is a pattern of disturbances in a medium, in which energy is not propagated. The amplitude of particle oscillations is zero at equally-spaced *nodes*, rising to maxima at *antinodes*, midway between the nodes.
2.6 (a)/(b)	Refractive index, n	For light, Snell's law may be written: $n_1 \sin\theta_1 = n_2 \sin\theta_2$ in which θ_1 and θ_2 are angles to the normal for light passing between medium 1 and medium 2; n_1 and n_2 are called the *refractive indices* of medium 1 and medium 2 respectively. The refractive index of a vacuum is fixed by convention as exactly 1. For air, n = 1.000
2.6 (b)	Snell's law	At the boundary between any two given materials, the ratio of the **sine** of the angle of incidence to the **sine** of the angle of refraction is a constant.
2.6 (e)	Critical angle, C	When light approaches the boundary between two media from the 'slower' medium, the critical angle is the largest angle of incidence for which refraction can occur. The refracted wave is then travelling at 90° to the normal.
2.7 (b)	Photoelectric effect	When light or ultraviolet radiation of short enough wavelength falls on a surface, electrons are emitted from the surface.
2.7 (e)	Work function, ϕ	The work function of a surface is the minimum energy needed to remove an electron from the surface. **Unit: J** or **eV**
2.7 (j)	Electron volt (eV)	This is the energy transferred when an electron moves between two points with a potential difference of 1 V between them. 1 eV = 1.60×10^{-19} J So for an electron being accelerated it is the kinetic energy acquired when accelerated through a pd of 1 V.
2.7 (k)	Ionisation	The removal of one or more electrons from an atom.
	Ionisation energy	The ionization energy of an atom is the minimum energy needed to remove an electron from the atom in its ground state. **Unit: J**
2.8 (a)	Stimulated emission	This is the emission of a photon from an excited atom, triggered by a passing photon of energy equal to the energy gap between the excited state and a state of lower energy in the atom. The emitted photon has the same frequency, phase, direction of travel and polarisation direction as the passing photon.

2.8 (b)	Population inversion	A *population inversion* is a situation in which a higher energy state in an atomic system is more heavily populated than a lower energy state (i.e. a less excited state or the ground state) of the same system.
2.8 (e)	Pumping	*Pumping* is feeding energy into the amplifying medium of a laser to produce a population inversion.

A2 Unit 3

Section	Item	Definition
3.1 (a)	Period, T for a point describing a circle	Time taken for one complete circuit.
	Frequency, f	The number of circuits or cycles per second.
3.1 (b)	Radian	A unit of measurement of angles equal to about 57.3°, equivalent to the angle subtended at the centre of a circle by an arc equal in length to the radius. **UNIT: rad**
3.1 (d)	Angular velocity, ω	For an object describing a circle at uniform speed, the angular velocity ω is equal to the angle θ swept out by the radius in time Δt divided by t ($\omega = \frac{\Delta\theta}{\Delta t}$) **UNIT: rad s^{-1}**
3.2 (a)	Simple harmonic motion (shm)	Shm occurs when an object moves such that its acceleration is always directed toward a fixed point and is proportional to its distance from the fixed point. ($a = -\omega^2 x$) **Alternative definition:** The motion of a point whose displacement x changes with time t according to $x = A\cos(\omega t + \varepsilon)$, where A, ω and ε are constants. [Variations of this kind are said to be *sinusoidal*.]
3.2 (e)	Period, T for an oscillating body	The time taken for one complete cycle.
	Amplitude, A of an oscillating object	The maximum value of the object's displacement (from its equilibrium position).
	Phase	The phase of an oscillation is the angle ($\omega t + \varepsilon$) in the equation $x = A\cos(\omega t + \varepsilon)$. [$\varepsilon$ is called the *phase constant*.] **UNIT: rad**
	Frequency, f	The number of oscillations per second. **UNIT: Hz**
3.2 (l)	Free oscillations [Natural oscillations]	Free oscillations occur when an oscillatory system (such as a mass on a spring, or a pendulum) is displaced and released. [The frequency of the free oscillations is called the system's *natural frequency*.]
	Damping	Damping is the dying away, due to resistive forces, of the amplitude of free oscillations.
3.2 (n)	Critical damping	Critical damping is the case when the resistive forces on the system are just large enough to prevent oscillations occurring at all when the system is displaced and released.
3.2 (o)	Forced oscillations	These occur when a sinusoidally varying 'driving' force is applied to an oscillatory system, causing it to oscillate with the frequency of the applied force.
	Resonance	If, in forced vibrations, the frequency of the applied force is equal to the natural frequency of the system (e.g. mass on spring), the amplitude of the resulting oscillations is large. This is resonance.
3.3 (a)	Ideal gas	An ideal gas strictly obeys the equation of state $pV = nRT$, in which n is the number of moles, T is the kelvin temperature and R is the *molar gas constant*. R = 8.31 J mol^{-1} K^{-1}. With the exception of very high densities a real gas approximates well to an ideal gas.
3.3 (d)	The mole	The mole is the S.I. unit of an 'amount of substance'. It is the amount containing as many particles (e.g. molecules) as there are atoms in 12 g of carbon-12.
	Avogadro constant, N_A	This is the number of particles per mole. ($N_A = 6.02 \times 10^{23}$ mol^{-1})

3.4 (a)	Internal energy, U, of a system	This is the sum of the kinetic and potential energies of the particles of a system.
3.4 (d)	Heat, Q	This is energy flow from a region at higher temperature to a region at lower temperature, due to the temperature difference. In thermodynamics we deal with heat going into or out of a system. It makes no sense to speak of heat *in* a system.
3.4 (f)	Work, W	If the system is a gas, in a cylinder fitted with a piston, the gas does work of amount $p\Delta V$ when it exerts a pressure p and pushes the piston out a small way, so the gas volume increases by ΔV. Work, like heat, is energy in transit from (or to) the system.
3.4 (i)	First law of thermodynamics	The increase, ΔU, in internal energy of a system is $\Delta U = Q - W$ in which Q is the heat **entering** the system and W is the work done **by** the system. Any of the terms in the equation can be positive or negative, e.g. if 100 J of heat is *lost* from a system Q = –100 J**.**
3.4 (k)	Specific heat capacity, c	The heat required, per kilogram, per degree celsius or kelvin, to raise the temperature of a substance. **UNIT: J kg^{-1} K^{-1} or J kg^{-1} °C^{-1}**
3.5 (a)	Alpha (α) radiation	Fast moving particles, helium nuclei, ejected from certain radioactive nuclei.
	Beta (β) radiation	Electrons with speeds just less than the speed of light, ejected from certain radioactive nuclei.
	Gamma (γ) radiation	Photons of high energy (high frequency, short wavelength) ejected from radioactive nuclei.
	${}^{A}_{Z}\mathrm{X}$ notation	X is the chemical symbol of the element, A the mass number (number of protons plus number of neutrons) and Z the atomic number (number of protons).
3.5 (d)	Half-life, $T_{\frac{1}{2}}$ of a nuclide	The time taken for the number of radioactive nuclei, N (or the activity A) to reduce to one half of the initial value. **Unit: s or any unit of time**
3.5 (e)	Activity, A	The rate of decay (number of disintegrations per second) of a sample of radioactive nuclei. **Unit: becquerel (Bq) = s^{-1}**
3.5 (f)	Decay constant, λ	The constant which appears in the exponential decay law $N = N_0 e^{-\lambda t}$ and determines the rate of decay (the greater λ, the more rapid the rate of decay). λ is related to half-life by . $\lambda = \frac{ln2}{T_{\frac{1}{2}}}$ **Unit: s^{-1} or any (unit of time)$^{-1}$**
3.6 (b)	Unified atomic mass unit, u	The unified atomic mass unit is defined as exactly one twelfth of the mass of one atom of carbon-12. Thus one atom of carbon-12 has a mass of exactly 12 u. (1 u = 1.66 × 10^{-27} kg)
	Binding energy of a nucleus	The energy that has to be supplied in order to dissociate a nucleus into its constituent nucleons. [It is therefore *not* energy which a nucleus *possesses*.] **Unit: J [or MeV]**
3.6 (d)	Conservation of mass-energy	Energy cannot be lost or gained, only transferred from one form to another. We can measure the energy in a body by multiplying its mass by c^2.

A2 Unit 4

Section	Item	Definition
4.1 (a)	Capacitor	A capacitor is a pair of conducting plates separated by an insulator. If a potential difference is placed across the plates, they acquire equal and opposite charges.
4.1 (c)	Capacitance, C, of a capacitor	$\text{capacitance} = \dfrac{\text{chargeon either plate}}{\text{pdbetweenplates}}$ **Unit: F [= C V^{-1}]**
4.1 (e)	Dielectric	Insulator between the plates of a capacitor, also serving to make the capacitance larger than if there were just empty space.
4.2 (a)	Newton's law of gravitation	The gravitational force between two particles is proportional to the product of their masses, m_1 and m_2, and inversely proportional to their separation squared, r^2. $F = \dfrac{Gm_1m_2}{r^2}$ in which G is *the gravitational constant*. $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}.
	Coulomb's law	The electrostatic force, F, between two small bodies is proportional to the product of their charges, Q_1 and Q_2, and inversely proportional to their separation squared, r^2. $F = \dfrac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$ in which ε_0 is *the permittivity of free space* = 8.85 $\times 10^{-12}$ F m^{-1}
	Electric field strength, E	The force experienced per unit charge by a small positive charge placed in the field. **Unit: V m^{-1} or N C^{-1}**
	Gravitational field strength, g	The force experienced per unit mass by a mass placed in the field. **Unit: m s^{-2} or N kg^{-1}**
	Electric potential, V_E	Electric potential at a point is the work done per unit charge in bringing a positive charge from infinity to that point. **Unit: V or JC^{-1}**
	Gravitational potential, V_g	Gravitational potential at a point is the work done per unit mass in bringing a mass from infinity to that point. **Unit: J kg^{-1}.**
4.3 (a)	Kepler's laws of planetary motion: 1	Each planet moves in an ellipse with the Sun at one focus.
	Kepler's laws of planetary motion: 2	The line joining a planet to the centre of the Sun sweeps out equal areas in equal times.
	Kepler's laws of planetary motion: 3	T^2, the square of the period of the planet's motion, is proportional to r^3, in which r is the semi-major axis of its ellipse. [For orbits which are nearly circular, r may be taken as the mean distance of the planet from the Sun.]
4.3 (e)	Dark matter	Matter which we can't see, or detect by any sort of radiation, but whose existence we infer from its gravitational effects.
4.3 (i)	Radial velocity of a star [in the context of Doppler shift]	This is the component of a star's velocity along the line joining it and an observer on the Earth.
4.3 (k)	Galactic radial velocity	This is the mean component of a galaxy's velocity along the line joining it and an observer on Earth.

4.4 (b)	Magnetic field, B (or magnetic flux density)	This is a vector quantity. Its direction is that in which the North pole of a freely-pivoted magnet points. Its magnitude is defined by $B = \frac{F}{I\,l}$ in which F is the force on a length l of wire carrying a current I, placed perpendicular to the direction of the field. **Unit: T [= N A^{-1} m^{-1}]**
4.4 (d)	Hall voltage	When a magnetic field, $\boldsymbol{B}$, is applied to conductor carrying a current I, at right angles to the field direction, a so-called *Hall voltage* appears across the specimen, at right angles to the B and I directions.
4.5 (a)	Magnetic flux, Φ	If a single-turn coil of wire encloses an area A, and a magnetic field B makes an angle θ with the normal to the plane of the coil, the magnetic flux through the coil is given by $\Phi = AB \cos\theta$. **Unit: Wb =T m^2**
	Flux linkage, $N\Phi$	If the above coil consists of N turns, the <u>flux linkage</u> is given by $N\Phi$. **Unit: Wb** or **Wb turn.**
4.5 (b)	Faraday's law	When the flux linking an electrical circuit is changing, an emf is induced in the circuit of magnitude equal to the rate of change of flux linkage. $E = -\frac{\Delta(N\Phi)}{\Delta t}$ [Note: the – sign is from Lenz's law, see below]
	Lenz's law	The direction of any current resulting from an induced emf is such as to oppose the change in flux linkage that is causing the current.

Option A – Alternating Currents

Section	Item	Definition
Opt A (d)	Root-mean-square (rms) value	If an alternating voltage is read at regular intervals throughout a cycle, giving the values $V_1, V_2 \ldots V_n$, the rms pd, V_{rms}, is defined as $V_{\text{rms}} = \sqrt{\frac{1}{n}(V_1^2 + V_2^2 + \ldots V_n^2)}$ I_{rms}, is defined similarly for current. [A *steady* pd of magnitude V_{rms} (and a steady current of I_{rms}) would give the same power dissipation in a resistor as the alternating pd and current.]
Opt A (i)	Reactance, X_L of an inductor	When a sinusoidal AC voltage is applied to an inductor, the reactance is given by $X_L = \frac{V_{\text{rms}}}{I_{\text{rms}}}$ where V_{rms} and I_{rms} are the rms values of the voltage across, and the current in, the inductor. It is equal to ωL (or $2\pi fL$). **UNIT: Ω**
Opt A (j)	Reactance, X_C of a capacitor	When a sinusoidal AC voltage is applied to a capacitor, the reactance is given by $X_C = \frac{V_{\text{rms}}}{I_{\text{rms}}}$ where V_{rms} and I_{rms} are the rms values of the voltage across the capacitor and the current in its connecting wires. It is equal to $\frac{1}{\omega C}$ (or $\frac{1}{2\pi fC}$). **UNIT: Ω**
Opt A (l)	Phasor	This is an imaginary vector rotating at the frequency, f of the alternating current. Its length can represent the rms (or peak) value of a current or a pd, or the value of a resistance or reactance.
Opt A (m)	Impedance, Z	When an AC voltage is applied to a combination of resistance and capacitance or inductance (or both), the impedance is given by $Z = \frac{V_{\text{rms}}}{I_{\text{rms}}}$ where V_{rms} and I_{rms} are the rms values of the voltage across the combination and the current in it. **UNIT: Ω**
Opt A (n)	Resonance frequency, f_0 of an LCR circuit	This is the frequency of applied pd at which I_{rms} is maximum, for a given V_{rms}. For a series LCR circuit it is given by: $2\pi f_0 = \frac{1}{\sqrt{LC}}$
Opt A (o)	Q factor of an LCR circuit	This is defined by $Q = \frac{2\pi f_0 L}{R}$ in which f_0 is the resonance frequency. The Q factor is a measure of the sharpness of the resonance curve – the larger the Q factor, the sharper the resonance curve.

Option B – Medical Physics

Section	Item	Definition
Opt B (b)	X-ray beam intensity	This is the X-ray energy per unit area, per unit time, passing normally through a surface.
Opt B (d)	X-ray attenuation	This is the decrease in intensity of X-rays as they pass through a material. The attenuation equation is: $$I = I_0\, e^{-\mu x}$$ in which I is the intensity of X-rays having passed through a thickness, x of material, and I_0 is the original intensity. μ is a constant dependent on the material, called the *attenuation constant*.
Opt B (e)	X-ray contrast media	These are substances introduced into parts of the body to give greater contrast between them and surrounding areas. Usually they have high attenuation constants e.g. 'barium meals' for highlighting the stomach and intestines.
Opt B (g)	CT scanner	A device which collects data on X-ray transmission at different angles through slices of the body, and uses it to produce a 3-dimensional picture. 'CT' stands for *computed tomography*.
Opt B (h)	Piezoelectric crystal	One of several types of crystal which deform when a voltage is applied between two of their faces, and which, conversely, produce a voltage when deformed.
	Piezoelectric transducer	This is a piezoelectric crystal used either to *generate* ultrasound when an alternating voltage of ultrasonic frequency is applied, or to *sense* ultrasound by producing an alternating voltage in response.
Opt B (i)	Ultrasonic A-scan	Scan in which the strength of reflections of an ultrasound pulse from interfaces in the body is shown by the **a**mplitude of a trace.
	Ultrasonic B-scan	Scan in which the strength of reflection of an ultrasound pulse from interfaces in the body is shown by the **b**rightness of a trace. An array of transducers can produce a two dimensional picture.
Opt B (j)	Acoustic impedance, Z of a material	The acoustic impedance Z of a material of density ρ, in which the speed of sound is c, is defined by $Z = c\,\rho$. The greater the difference in Z between two materials the greater the fraction of ultrasound power reflected at an interface between them.
	Coupling medium	Gel or oil used to exclude air between the skin and the ultrasound transducer. It reduces the mismatch in Z, and enables more ultrasound to enter the body instead of being reflected off the skin.
Opt B (k)	Doppler effect	Change in frequency of waves due to the relative motion of wave source, sensor, medium or reflector.
Opt B (l)	Precession of spin of proton	Protons have 'spin' and behave like tiny magnets. In a strong magnetic field their spins wobble or *precess* around the magnetic field direction, rather as a spinning top's axis wobbles around the vertical. There is a natural frequency of wobble (the *Larmor frequency*).
	Magnetic resonance of protons	This is the strong absorption of radio waves of the Larmor frequency by protons in a magnetic field. It results in the spin-flipping direction.
	Relaxation time of spin-flipped protons	This is a characteristic time for spin-flipped protons in hydrogen atoms in a magnetic field to return to their original spin orientation when the radio frequency is removed. It depends on, and so tells us about, the tissue which contains the hydrogen atoms.

Opt B (p)(q)	Absorbed dose	This is the radiation energy (for α, β, or γ radiation, or for X-rays) absorbed per kilogram of tissue.
	The gray (Gy)	This is the unit of absorbed dose. 1 Gy = 1 joule per kilogram
	The sievert (Sv)	This is the unit of equivalent dose and effective dose.
	Equivalent dose, H	This is the absorbed dose, D, multiplied by a radiation weighting factor, W_R. $H = DW_R$
	Effective dose, E	This is the equivalent dose, H, multiplied by a tissue weighting factor W_T. $E = HW_T$
Opt B (s)	Collimator	Device for producing (or selecting) a parallel beam (e.g. of gamma radiation).
	Scintillations	These are flashes of light (or ultraviolet radiation) given out by certain crystals (e.g. sodium iodide) when high energy particles, e.g. gamma ray photons, strike them.
	Photomultiplier	This is an arrangement of electrodes, with different voltages applied to them, so that electrons emitted from one electrode by the photoelectric effect are effectively multiplied in number to make a much larger current.
Opt B (t)	Positron emission tomography (PET)	The positrons annihilate electrons in adjacent tissue and send out pairs of gamma photons which are detected outside the body.

Option C – The Physics of Sports

Section	Item	Definition
Opt C (d)	Coefficient of restitution, e	The coefficient of restitution is defined as the ratio of the relative speed after a collision to the relative speed before a collision i.e. $e = \dfrac{\text{Relative speed after collision}}{\text{Relative speed before collision}}$. Also it can be determined from the equation $e = \sqrt{\dfrac{h}{H}}$ where h is the bounce height and H is the drop height.
Opt C (e)	Moment of inertia, I	The moment of inertia of a body about a given axis is defined as $I = \sum m_i r_i^2$ for all points in the body, where m_i and r_i are the mass and distance of each point from the axis. The moment of inertia can be determined using equations for specific objects e.g. For a solid sphere $I = \frac{2}{5}mr^2$ A thin spherical shell $I = \frac{2}{3}mr^2$ **Unit: kg m^2**
Opt C (g)	Angular acceleration, α	The angular acceleration of a rotating object is defined as the rate of change of angular velocity, ω. If the angular velocity changes from an initial value, ω_1 to a final value, ω_2, then the angular acceleration, α, can be written as $\alpha = \dfrac{\omega_2 - \omega_2}{t}$ **Unit: rad s^{-2}**
Opt C (h)	Torque, τ	The torque is defined as $\tau = Ia$ where α is the angular acceleration and I is the moment of inertia. Also torque can be defined as the rate of change of angular momentum. **Unit: N m** or **kg m^2 rad s^{-2}**
Opt C (i)	Angular momentum, J	The angular momentum of a rigid body is defined as $J = I\omega$ where ω is the angular velocity and I is the moment of inertia. **Unit: N m s** or **kg m^2 rad s^{-1}**
Opt C (j)	Conservation of angular momentum	The total angular momentum of a system remains constant provided no external torque acts on the system.
Opt C (n)	Bernoulli's equation	Bernoulli's equation is given in the form: $p = p_0 - \frac{1}{2}\rho v^2$ where p is the pressure, p_o is the static pressure, ρ is the density and v is the speed. This will be applied in sporting contexts.
Opt C (o)	Drag coefficient, C_D	This is a quantity that has no units and is used to quantify the drag or resistance of an object in an environment such as air or water.

Option D – Energy and the Environment

Section	Item	Definition
Opt D (a)(i)	Greenhouse effect	The glass of a greenhouse transmits the visible radiation from the Sun (and some of the near ultraviolet and near infra-red), but does not transmit the far infra-red given out by the ‘cool’ contents of the greenhouse, instead absorbing it and re-radiating back into the greenhouse. Certain gases in the Earth’s atmosphere act much like greenhouse glass. The higher the concentration of these gases the warmer the Earth’s surface and atmosphere.
Opt D (a)(iv)	Archimedes principle	Any object, wholly or partially immersed in a fluid experiences a force equal to the weight of the fluid dispersed by the object.
Opt D (b)(i)	Solar constant	This is the solar radiated energy crossing a plane perpendicular to the line joining the Earth to the Sun, just outside the Earth’s atmosphere, per second per unit area. The mean value is 1.35 kW m^{-2}.
Opt D (b)(iv)	Nuclear fusion	If light nuclei are brought together with enough kinetic energy they can join together to make a heavier nucleus. Usually a proton or neutron is produced as well. The fusion products have more kinetic energy than the original kinetic energy supplied.
	Nuclear fission	Certain nuclei of large mass number (e.g. uranium-235) are *fissile*: they can absorb a (slow) neutron and will then split into (usually) two smaller, beta-radioactive, nuclei. Two or more neutrons are also released. The ‘fragments’ have large kinetic energies. This is nuclear fission.
	Enrichment of uranium	This is the process of increasing the proportion of the fissile uranium-235 to the non-fissile uranium-238 in a sample of uranium.
	Breeding (of Pu-239)	If U-238 is bombarded with fast (high energy) neutrons, the resulting U-239 decays by beta emission in two steps to produce Pu-239 (plutonium-239). This will undergo fission with slow (‘thermal’) neutrons. Thus nuclear fuel can be ‘bred’ from U-238.
Opt D (c)	Fuel cell	Device which uses chemical energy from fuel to provide electrical energy directly. In a hydrogen fuel cell hydrogen combines with oxygen producing electrical energy – the electrolysis of water in reverse.
Opt D (d)	Thermal conduction equation and thermal conductivity, K	The rate of flow of heat, $\frac{\Delta Q}{\Delta t}$ through a slice of material of cross-sectional area *A* is given by: $$\frac{\Delta Q}{\Delta t} = -KA\frac{\Delta \theta}{\Delta x}$$ in which $\frac{\Delta Q}{\Delta x}$ is the temperature gradient: the temperature difference across the faces of the slice divided by the thickness of the slice, and K is a constant for the material called its *thermal conductivity*.
Opt D (e)	U values	This describes how well a building material conducts heat. It is the rate of transfer of heat through one square metre of the material divided by the difference in temperature across the material. A low U value indicates a high level of insulation. **UNIT: W m^{-2} K^{-1}**