This Glossary provides an alphabetical list of terms used in the IB Physics book, with meanings and definitions. All equations and constants from the data booklet are also included.

Many of the terms also appear in the Key Terms boxes seen in the margins of the book.

You should find that reading through the Glossary is very helpful in your revision process, but it is provided mainly for reference, not as a list of essential knowledge to be remembered.

Glossary

Standard and Higher Level

A

Absolute temperature scale: Temperature scale that has its zero at absolute zero. See Kelvin scale of temperature.

Absolute zero: Temperature at which (almost) all molecular motion has stopped (0 K or −273 °C).

Absorption: When the energy of incident particles or radiation is transferred to other forms within a material, so that they are not transmitted.

Absorption spectrum: A series of dark lines across a continuous spectrum produced when white light passes through a gas at low pressure.

Abstract concept: An idea or way of thinking that has no physical form.

Acceleration, *a*: Rate of change of velocity with time, $a = \Delta v/\Delta t$ (SI unit: $m\,s^{-2}$). Can be determined from the gradient of a velocity–time graph. Acceleration is a vector quantity.

Acceleration due to gravity, *g*: Acceleration of a mass falling freely towards Earth. Numerically equal to the gravitational field strength. On or near the Earth's surface, $g \approx 9.8 \times 10\,m\,s^{-2}$. Also called acceleration of free fall.

Accuracy: A single measurement is described as accurate if it is close to the correct result. A series of measurements of the same quantity can be described as accurate if their mean is close to the correct result. Accurate results have small systematic errors.

Activity (of a radioactive source): The number of nuclei which decay in a given time (second). See Bequerel.

Aerial: A structure that receives or emits electromagnetic signals.

Air resistance: Resistive force opposing the motion of an object through air. It depends on the cross-sectional area and shape of the object, and also its speed. A type of drag force.

Albedo: The total scattered or reflected power / total incident power. Albedo depends on the nature of the surface and inclination of the radiation to the surface. The Earth's annual mean albedo is approximately 0.3 (30%).

Alpha particle: A fast-moving helium-4 nucleus emitted by a radioactive nucleus. Consists of two protons and two neutrons tightly bound together.

Alternating current (ac): A flow of electric charge that changes direction periodically.

Altitude: Height of an object above the surface of a planet.

Ammeter: An instrument that measures electric current.

Ambiguity: Having more than one meaning or possible understandings.

Amount of gas: The quantity of gas in a container, expressed in term of the number of particles it contains. See Mole.

Amount of substance, *n*: Measure of the number of atomic-scale particles it contains (SI unit: mole).

Ampere, A: SI (fundamental) unit of electric current. $1\,A = 1\,C\,s^{-1}$.

Amplitude, x_0: The maximum displacement of a wave or oscillation.

Analogue instrument: Measuring instrument that has a pointer moving over a continuous scale.

Analogy: Applying knowledge of one subject to another because of some similarities.

Analyse (Command term used in examination questions): Break down in order to bring out the essential elements or structure.

Angle of reflection (rays): Angle between a reflected ray and the normal.

Angular frequency, ω: Similar to angular velocity, but used to represent the frequency of an oscillation in $rad\,s^{-1}$ (because of the mathematical similarities between uniform circular motion and simple harmonic oscillations). $\omega = 2\pi f$.

Angular velocity, ω: Change of angle / change of time, $\omega = \Delta\theta/\Delta t$ (SI unit: $rad\,s^{-1}$). Sometimes called angular speed. For uniform motion in a circle, $\omega = 2\pi/T = 2\pi f$. Linear velocity = angular velocity × radius, $v = \omega r$.

Annihilation: When a particle and its antiparticle interact, their mass is totally converted to electromagnetic energy.

Annotate (Command term used in examination questions): Add brief notes to a diagram or graph.

Anode: An electrode into which (conventional) current flows.

Anomalous: Different from the pattern of other similar observations.

Antenna: See Aerial.

Antimatter: Matter consisting of antiparticles.

Antineutrino: Low-mass, uncharged and very weakly interacting particle emitted during beta-negative decay. Antiparticle of neutrino.

Antinodes: The positions in a standing wave where the amplitude is greatest.

Antiparticle: Every particle has an antiparticle that has opposite physical properties.

Aperture: A hole or gap designed to restrict the width of a beam of light (or other radiation).

Apparent brightness, *b*: Intensity of radiation received on Earth from a star (SI unit: $W\,m^{-2}$). Related to luminosity by: $b = \frac{L}{4\pi r^2}$.

Archimedes' principle: When an object is wholly or partially immersed in a fluid, it experiences an upthrust (buoyancy force) equal to the weight of the fluid displaced.

Arc-second: An angle which is 1/3600 of one degree.

Astronomical unit (AU): Non-SI unit of distance used by astronomers, equal to an agreed average distance between the Sun and the Earth. ($= 1.50 \times 10^{11}$ m)

Atmospheric pressure: Pressure due to the motions of the gas molecules in the air. Can be considered as being due to the weight of the air above an area of $1\,m^2$. Acts equally in all directions.

Atoms: The particles from which chemical elements are composed. They contain subatomic particles.

Atomic energy level: One of a series of possible discrete energy levels of an electron within an atom.

Atomic mass unit (amu), u: Non-SI unit of mass widely used in atomic physics. Approximately equal to the mass of a single nucleon. Defined to be exactly $1.660\,539\,066\,60 \times 10^{-27}$ kg.

Audible range: Range of sound frequencies that can be heard by humans.

Average value: Any single number used to represent a quantity which is varying.

Avogadro constant, N_A: The number of particles in 1 mole of a substance, 6.02×10^{23}.

B

Background count: Measure of background radiation.

Background radiation: Radiation from radioactive materials in rocks, soil and building materials, as well as cosmic radiation from space and any radiation escaping from artificial sources.

Balanced forces: If an object is in mechanical equilibrium, we describe the forces acting on it as 'balanced'.

Banked track: A sloping surface to enable faster motion around curves.

Barometer: Instrument for measuring atmospheric pressure.

Battery: One or more electric cells.

Becquerel, Bq: The SI unit for (radio) activity. 1 Bq = one nuclear decay every second.

Beta-negative decay: Radioactive decay resulting in the emission of an electron and an antineutrino.

Beta-positive decay: Radioactive decay resulting in the emission of a positron and a neutrino.

Beta particle: A high-speed electron that is released from a nucleus during beta-negative decay, or a high-speed positron released during beta-positive decay.

Bias: A preference for one opinion, one side of a discussion etc., usually without fair consideration of the other.

Big Bang model: Currently accepted model of the Universe, in which matter, space and time began at a point 13.7 billion years ago. The Universe has been expanding ever since.

Binding energy: The energy released when a nucleus is formed from its constituent nucleons. Alternatively, it is equal to the work required to completely separate the nucleons. Binding energy is the energy equivalent of the mass defect.

Binding energy per nucleon (average): Binding energy of a nucleus divided by the number of nucleons it contains. It is a measure of the stability of a nucleus.

Black body: An idealized object that has a surface which absorbs all the electromagnetic radiation that falls upon it. A perfect black body also emits the maximum possible radiation.

Black-body radiation (spectrum): Radiation emitted from a 'perfect' emitter. The characteristic ranges of different radiations emitted at different temperatures are commonly shown in graphs of intensity against wavelength.

Black hole: Extremely dense remnant of a giant star formed after a supernova. Gravitational forces are so great that even light cannot escape.

Blueshift: Decrease in wavelength of electromagnetic radiation (from a 'nearby' star) due to the fact that the observer and the source are moving closer together.

Boil: Change from a liquid to a gas at a well-defined temperature. Occurs throughout the liquid.

Boltzmann constant, k_B: Important constant that links microscopic particle energies to macroscopic temperature measurements. ($= 1.38 \times 10^{-23}\,J\,K^{-1}$) Linked to the universal gas constant, R, by the equation: $k_B = \frac{R}{N_A}$.

Boundary conditions: The conditions at the ends of a standing wave system. These conditions affect whether there are nodes or antinodes at the ends.

Boyle's law: Pressure of a fixed amount of gas is inversely proportional to volume (at constant temperature).

Buoyancy force: Vertical upwards force on an object placed in or on a fluid. Sometimes called upthrust. Buoyancy force, $F_b = \rho V g$.

C

Calculate (Command term used in examination questions): Obtain a numerical answer showing the relevant stages in the working.

Calculus: Branch of mathematics which deals with continuous change.

Calibrate: Put numbered divisions on a scale.

Calorimeter: Apparatus designed for (calorimetry) experiments investigating thermal energy transfers.

Carbon dating: Using the radioactive decay of carbon-14 to estimate the age of once-living material.

Cathode: An electrode out of which (conventional) current flows.

Celestial objects: Any naturally occurring objects that can be observed in space.

Cell (electric): Device that transfers chemical energy to the energy carried by an electric current. Also called an electrochemical cell, chemical cell or a voltaic cell.

Celsius (scale of temperature): Temperature scale based on the melting point (0 °C) and boiling point (100 °C) of pure water.

Centre of mass: Average position of all the mass of an object. The mass of an object is distributed evenly either side of any plane through its centre of mass.

Centripetal acceleration and force: Any object moving in a circular path has an acceleration towards the centre of the circle, called its centripetal acceleration. It can be calculated from the expression $a = v^2/r = \omega^2 r = 4\pi^2 r/T^2$. The force producing this acceleration is called a centripetal force, $F = mv^2/r$.

CERN: European organization for nuclear research.

Chain reaction (nuclear): If, on average, one of the neutrons produced in a nuclear fission process causes further fission, the process will not stop and will become a self-sustaining chain reaction.

Charge: Fundamental property of some subatomic particles that makes them experience electric forces when they interact with other charges. Charges can be positive or negative (SI unit: coulomb, C).

Charge carrier: A charged particle which is free to move (mobile).

Charge density: Number of mobile charge carriers in unit volume of a material.

Charge (to): Add or remove electrons, so that an object acquires an overall net charge, for example, by friction. In everyday use, 'to charge' a battery means something different: to transfer energy to a battery by passing a (reverse) current through it.

Charge to mass ratio (of a particle), q/m: The ratio affects the motion of charged particles in electric and magnetic fields (important when charge and mass are not known separately).

Charles law: Volume of a fixed amount of gas is proportional to absolute temperature (at constant pressure).

Chart of nuclides: A chart which displays every possible nuclide on axes of proton number and neutron number.

Chemical potential energy: Energy related to the arrangement of electrons within the structure of atoms and molecules.

Circuit (electrical): A complete conducting path that enables an electric current to continuously transfer energy from a voltage source to various components.

Circuit breaker: Electromagnetic device used to disconnect an electrical circuit in the event of a fault.

Classical physics: Physics theories that pre-dated the paradigm shifts introduced by quantum physics and relativity.

Climate change (anthropogenic): Changes in the climate due to human activities. Also called global warming.

Climate model: A complex computerized model that attempts to predict the future climate of the planet, especially how it will be affected by global warming.

CNO cycle: Nuclear fusion process in larger main sequence stars which forms helium from hydrogen.

Coefficient: A multiplying constant placed before a variable, indicating a physical property.

Coefficient of friction, μ: Constant used to represent the amount of friction between two different surfaces. $F_f \leq \mu_s F_N$ (for static friction), $F_f = \mu_d F_N$ (for dynamic friction).

Coherent waves: Waves that have the same frequency and a constant phase difference.

Collaboration (scientific): Two or more people sharing information or working together on the same project.

Collision: Two (or more) objects coming together and exerting forces on each other, often for a relatively short time. If total kinetic energy before and after the collision is the same, the collision is described as *elastic*. In any *inelastic collision* the total kinetic energy is reduced after the collision. If the objects stick together, it is described as a *totally inelastic collision*.

Combustion (of fuels): Burning. Release of thermal energy from a chemical reaction between the fuel and oxygen in the air.

Command terms: Words used in examination questions which tell the student what to do.

Compass: A device for determining direction. Small plotting compasses are used to investigate the shapes of magnetic fields in the laboratory.

Components of a vector: For convenience, any single vector quantity can be considered as having two parts (components), usually perpendicular to each other. The combined effect of these components is exactly the same as the single vector.

Compression (force): Force that tries to squash an object or material.

Compression (of a gas): Decrease in volume. Compare with expansion.

Compressions (in a longitudinal wave): Places where there are increases in the density and pressure of a medium as a wave passes through it.

Condense: Change from gas (or a vapour) to a liquid.

Conduction (thermal): Passage of thermal energy through a substance as energy is transferred from particle to particle.

Conductor (electrical): A material through which an electric current can flow because it contains significant numbers of mobile charges (usually free electrons).

Conservation laws: *Charge*: the total charge in any isolated system remains constant; *Energy*: the total energy in any isolated system remains constant. Energy cannot be created or destroyed. *Momentum*: The total momentum in any isolated system remains constant provided that no external forces are acting on it.

Conservative force: A force, the action of which conserves mechanical energy. There is no energy dissipation.

Constant: A multiplying constant placed before a variable, indicating a physical property.

Contact (normal) forces: Forces that occur because surfaces are touching each other. Typically, we can identify forces which are perpendicular (normal) to the surface, and frictional forces which are parallel to the surfaces.

Contour lines: Lines on a map joining places of the same altitude.

Control rods: Used for adjusting the rate of fission reactions in nuclear reactors by absorbing more, or fewer, neutrons.

Controlled and uncontrolled nuclear fission: In a nuclear power station the number of neutrons in the reactor core is carefully controlled in order to maintain the rate of the nuclear reactions. In nuclear weapons the number of neutrons is uncontrolled.

Convection: Passage of thermal energy through liquids and gases due to the movement of the substance because of differences in density.

Conventional current: The direction of flow of a direct current is *always* shown as being from the positive terminal of the power source, around the circuit, to the negative terminal. Conventional current is opposite in direction from electron flow.

Correlation: There is a correlation between two sets of varying data if they show similarities that would not be expected to occur because of chance alone.

Coulomb, C: The derived SI unit of measurement of electric charge. 1 coulomb of charge passes a point in 1 second if the current is 1 amp.

Coulomb constant, *k*: The constant that occurs in the Coulomb's law equation. $k = \frac{1}{4\pi\varepsilon_0}$, where ε_0 is the electrical permittivity of free space. $k = 8.99 \times 10^9\,\mathrm{N\,m^2\,C^{-2}}$.

Coulomb's law: There is an electric force between two point charges, q_1 and q_2 given by $F = \frac{kq_1q_2}{r^2}$, where r is the distance between them and k is the Coulomb constant.

Count rate (radioactivity): The number of nuclear radiation events detected in a given time (per minute or per second) by a GM tube and a ratemeter or 'counter'. See Bequerel.

Crest: Highest part of a transverse mechanical wave.

Critical angle: Largest angle (to a normal) at which a ray of light can strike a boundary with another medium of lower refractive index, without being totally internally reflected.

Critical mass: The minimum mass needed for a self-sustaining nuclear chain reaction.

Current (electric), *I*: A flow of electric charge. Equal to the amount of charge passing a point in unit time: $I = \Delta q/\Delta t$. (SI unit: amp, A. $1\,\mathrm{A} = 1\,\mathrm{C\,s^{-1}}$).

Cycle (oscillation): One complete oscillation.

D

Damping: Occurs when resistive forces act on an oscillating system, dissipating energy and reducing amplitude.

Damping (critical): When an oscillating system returns relatively quickly to its equilibrium position without oscillating.

Data logging: Connecting sensors to a computer with suitable software to enable physical quantities to be continuously measured and processed digitally.

Daughter product: The resulting nuclide when a radioisotope ('parent') decays.

Decay series: A series of nuclides linked in a chain by radioactive decay. Each nuclide in the chain decays to the next until a stable nuclide is reached.

Deceleration: Term commonly used to describe a decreasing speed.

Decibel: A measure of sound level.

Deformation: Change of shape.

Delocalized electrons: Electrons which are not bound to any particular atom or molecule. Sometimes called 'free' electrons.

Density: mass / volume. $\rho = m/V$ (SI unit: $\mathrm{kg\,m^{-3}}$).

Derive (Command term used in examination questions): Explain in detail the origin of an equation.

Derived units: Units of measurement that are defined in terms of other units.

Describe (Command term used in examination questions): Give a detailed account.

Determine (Command term used in examination questions): Obtain the only possible answer.

Determinism: The belief that future events are completely controlled by past events, so that full knowledge of the present can only lead to one future outcome.

Dielectric constant: permittivity of a medium / permittivity of free space.

Differentiate: Mathematically determine an equation for a rate of change.

Diffraction: The spreading of waves as they pass obstacles, or through apertures.

Diffusion: Random movement of particles from a place of high concentration to places of lower concentration.

Digital instrument: Instrument that displays a measurement only as digits (numbers), rather than using a pointer on a continuous (analogue) scale.

Dimensional analysis: Method of checking if an equation may be correct. The units (dimensions) of all terms should be the same.

Diode: An electrical component that only allows current to flow in one direction.

Dipole: Two close electric charges (or magnetic poles) of equal magnitude but of opposite sign (or polarity).

Direct current (dc): A flow of electric charge that is always in the same direction.

Discharge: Flow of electrons to or from an object that reduces the overall charge on it.

Discrete variable: A quantity that can only have certain values, that is, a quantity which is not continuous.

Discuss (Command term used in examination questions): Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.

Dispersion (light): Separate into different wavelengths / colours (to form a spectrum, for example).

Displacement, angular: The angle through which a rigid body has been rotated from a reference position.

Displacement, linear: The distance from a reference point in a specified direction. A vector quantity.

Dissipated or degraded energy: Energy that has spread into the surroundings and cannot be recovered to do useful work.

Distance: Total length travelled, without consideration of directions (SI unit: m).

Doppler effect: When there is relative motion between a source of waves and an observer, the emitted frequency and the received frequency are not the same. Sometimes called a Doppler shift. If wave speed, c, is very much greater than the speed of motion, v: $\Delta f/f = \Delta\lambda/\lambda \approx v/c$.

Drag: Force(s) opposing motion through a fluid; sometimes called fluid resistance.

Draw (Command term used in examination questions): Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.

Dynamics: The science which explains the motion of objects.

Dynamo: A type of electricity generator that produces direct current.

E

Earth (ground) connection: A good conductor connected between a point on a piece of apparatus and the ground. This may be part of a safety measure, or to ensure that the point is kept at 0 V.

Echo: A reflected sound that is heard distinctly from the original sound.

Edge effects: The electric field between parallel plates is assumed to be uniform except at the edges, where it halves in value.

Efficiency: In thermodynamics, the ratio of the useful energy (or power) output from a device to the total energy (or power) input; often expressed as a percentage.

Elastic behaviour: A material or spring shows elastic behaviour if it regains its original shape after a force causing deformation has been removed.

Elastic limit: The maximum extension that a material, or spring, can sustain before it becomes permanently deformed.

Elastic (strain) potential energy: Form of energy that is stored in a material or spring that has been deformed elastically. The energy is transferred when the material returns to its original shape. If force is proportional to extension, Δx, elastic potential energy, $E_H = \frac{1}{2}k\Delta x^2$

Electric field: A place where a charge experiences an electric force.

Electric field strength, *E*: The electric force per unit charge that would be experienced by a small test charge placed at that point. $E = F/q$ (SI unit: $N C^{-1}$). The electric field strength between charged parallel metal plates, $E = V/d$. Alternative unit: $V m^{-1}$.

Electric forces: Fundamental forces that act across space between all charges. The forces between opposite charges are attractive. The forces between similar charges are repulsive.

Electrical components: The separate, useful parts of an electrical circuit.

Electrical energy: Energy transferred in a circuit by an electrical current.

Electric potential energy: Energy stored due to the position of a charge in an electric field.

Electrode: Conductor used to make an electrical connection to a non-metallic part of a circuit.

Electromagnet: Magnet which needs the flow of an electric current in a coil to produce magnetic effects.

Electromagnetic radiation: Waves which consist of combined oscillating electric and magnetic fields that can travel across free space with a speed of $3.0 \times 10^8 m s^{-1}$.

Electromagnetic spectrum: Electromagnetic waves of all possible different frequencies, displayed in order. In order of increasing frequency: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, gamma rays. The visible spectrum in order of increasing frequency: red, orange, yellow, green, blue, indigo, violet.

Electromotive force (emf), *ε*: The total energy transferred in a source of electrical energy per unit charge passing through it.

Electron: Elementary subatomic particle with a negative charge ($-1.6 \times 10^{-19} C$) and mass of $9.110 \times 10^{-31} kg$; present in all atoms and located in energy levels outside the nucleus.

Electron degeneracy: Process occurring within white dwarf stars that keeps them stable and stops them collapsing.

Electron gun: Component that fires a beam of electrons across a vacuum.

Electronvolt, eV: An amount of energy equivalent to that which is transferred when an electron is accelerated by a p.d. of 1 V. $1 eV = 1.60 \times 10^{-19} J$.

Electrostatic induction: Movement of charged particles caused by the influence of a nearby charged object, but without physical contact.

Electrostatics: The study of the effects of charges at rest (that is, not electric currents).

Elementary charge: Charge of a single proton. ($+1.60 \times 10^{-19}$ C). Equal in magnitude to the charge of an electron (-1.60×10^{-19} C)

Elementary particles: Particles that have no internal structure. They are not composed of other particles. For example, electrons.

Ellipse: Closed curve consisting of points whose distances from each of two fixed points (focuses, foci) always add up to the same value.

Emission spectrum: Line spectrum associated with the emission of electromagnetic radiation by atoms, resulting from electron transitions from higher to lower energy states.

Emissivity: The power radiated by an object divided by the power radiated from a black body of the same surface area and temperature. Always less than one. No unit.

Emit: To send out from a source.

Empirical: Based on observation or experiment.

Energy: Ability to do work.

Energy density: The energy transferred from unit volume of fuel (SI unit: $J\,m^{-3}$).

Energy–mass equivalence: Any mass is equivalent to a certain amount of energy, according to the equation $E = mc^2$.

Equations of motion: Equations that can be used to make calculations about objects that are moving with uniform acceleration.

$v = u + at$;

$s = \frac{(u + v)t}{2}$;

$v^2 = u^2 + 2as$;

$s = ut + \frac{1}{2}at^2$

Equation of state for an ideal gas: Describes the macroscopic physical behaviour of ideal gases. See ideal gas law/equation.

Equilibrium: Something is in equilibrium if it stays the same under the effects of balanced influences.

Equilibrium (translational): An object is in translational equilibrium if there is no resultant force acting on it, so that it remains at rest or continues to move with a constant velocity.

Equilibrium position: Position in which there is no resultant force acting on an object.

Error: When a measurement is not the same as the correct value (if it is known).

Estimate (Command term used in examination questions): Obtain an approximate value.

Evaporation: The change from a liquid to a gas (vapour) at any temperature below the boiling point of the liquid. Occurs only at the liquid surface.

Evolution (stellar): Describes the changes that occur in a star during its 'lifetime'.

Evolutionary path: The evolution of a star as drawn on a Hertzsprung–Russell diagram.

Excitation: The addition of energy to a particle, changing it from its ground state to an excited state. Excitation of a nucleus, an atom or a molecule can result from absorption of photons or from inelastic collisions with other particles.

Excited state: When a particle is at a higher energy level than its ground state.

Expand: Increasing in size. An expansion of a gas is an increase in volume.

Expansion of the Universe: The redshift of light (similar to the Doppler effect) from distant galaxies provides evidence of an expanding universe.

Explain (Command term used in examination questions): Give a detailed account including reasons or causes.

Explosion: Term used in physics to describe when two or more masses, which were initially at rest, are propelled apart from each other.

Exponential change: A change which occurs when the rate of change of a quantity at any time is proportional to the actual quantity at that moment. Can be an increase or a decrease.

Extension: Displacement of the end of an object that is being stretched.

Extrapolate: Predict behaviour that is outside of the range of available data.

F

Feedback: Occurs when a response within a system influences the continuing behaviour of the same system.

Ferromagnetic materials: Materials from which permanent magnets are made.

Field (gravitational, electric or magnetic): A region of space in which a mass (or a charge , or a magnet, or a current) experiences a force due to the presence of one or more other masses (charges, magnets or currents).

Field lines and patterns: Representation of fields in drawings by a pattern of lines. Each line shows the direction of force on a mass (in a gravitational field), of force on a positive charge (in an electric field), or on a north pole (in a magnetic field). In any particular drawing, the field is strongest where the lines are closest together.

Filament lamp: Lamp that emits light from a very hot metal wire. Also called incandescent lamp.

Finite: Limited.

Fissile: Capable of sustaining a nuclear fission chain reaction.

Fission fragments: The nuclei produced in a fission reaction.

Fluid: Liquid or gas.

Fluid resistance (friction): Force(s) opposing motion through a fluid; sometimes called drag.

Fluorescent lamp: Lamp that produces light by passing electricity through mercury vapour at low pressure.

Force meter: Instrument used to measure forces. Also called a newton meter or a spring balance.

Fossil fuels: Naturally occurring fuels that have been produced by the effects of high pressure and temperature on dead organisms (in the absence of oxygen) over a period of millions of years. Coal, oil and natural gas are all fossil fuels.

Free-body diagram: Diagram showing all the forces acting on a single object, and no other forces.

Free electrons: See delocalized electrons.

Free fall: Motion through the air under the effects of gravity but without air resistance. (In common use, free fall can also mean falling towards Earth without an open parachute.)

Free space: Place where there is no air (or other matter). Also called a vacuum.

Freeze: Change from a liquid to a solid. Also called solidify.

Frequency, *f*: The number of oscillations per unit time, or the number of waves passing a point in unit time (usually per second). $f = 1/T$ (SI unit: hertz, Hz).

Frequency, driving: The frequency of an oscillating force (periodic stimulus) acting on a system from outside. Sometimes called forcing frequency.

Frequency, natural: The frequency at which a system oscillates when it is disturbed and then left to oscillate on its own, without influence from outside.

Frequency–response graph: Graph used to show how the amplitude of a system's oscillations responds to different driving frequencies.

Friction: Resistive forces opposing relative motion. Occurs between solid surfaces, but also with fluids. *Static friction* prevents movement, whereas *dynamic friction* occurs when there is already motion.

Fuel: A store of energy (chemical or nuclear) that can be transferred to do useful work (for example, to generate electricity or power vehicles).

Fuel enrichment: Increasing the percentage of 235-U in uranium fuel in order to make it of use in a nuclear power station or for a nuclear weapon.

Fundamental: Having no simpler explanation.

Fundamental constants: Numbers which are assumed to have exactly the same numerical values under all circumstances and all times.

Fundamental forces (interactions): Strong nuclear, electromagnetic and gravitational forces are fundamental forces (also weak nuclear).

Fundamental units: Units of measurement that are not defined as combinations of other units.

Fuse: A device used to disconnect an electrical circuit in the event of a fault or over-loading. It comprises a thin wire that melts if the current gets too large. Similar in action to a circuit breaker.

Fusion (thermal): Melting.

G

Galaxy: A very large number of stars (and other matter) held together in a group by the forces of gravity.

Gamma radiation / ray: Electromagnetic radiation (photons) emitted from some radionuclides and having an extremely short wavelength.

Gas laws: Laws of physics relating the temperature, volume and pressure of a fixed amount of a gas: Boyle's law, Charles's law and the Pressure law.

Geiger–Marsden–Rutherford experiment: The scattering of alpha particles by a thin sheet of gold foil, which demonstrated that most particles passed through the foil completely undeflected, while a few were deflected at extremely large angles. This demonstrated that atoms consist of mostly empty space with a very dense positively charged core (the nucleus).

Geiger–Muller tube: Apparatus used with a counter or ratemeter to measure the radiation from a radioactive source.

Generator (electrical): Device that converts kinetic energy into electrical energy.

Geostationary orbit: A satellite is described as geostationary if it appears to remain 'above' the same location on the Earth's surface. This can be very useful for communications. Geostationary satellites follow a type of geosynchronized orbit, which is in the same plane as the equator.

Geosynchronized orbit: Any satellite orbit that has the same period as the Earth spinning on its axis. The orbit must have exactly the correct radius.

Global positioning system (GPS): A navigation system that provides accurate information on the location of the GPS receiver, by continually communicating with several orbiting satellites.

Giant (and super giant) stars: Usually relatively cool stars, so they are yellow / red in colour; their luminosity is high because of their large size. Most stars will become red giants (or red super giants) at the end of their time on the Main sequence.

Global warming: Increasing average temperatures of the Earth's surface, atmosphere and oceans.

Gradient: The rate at which one physical quantity changes in response to changes in another physical quantity. Commonly, for an y–x graph, gradient $= \Delta y/\Delta x$.

Gravitational field strength, *g*: The gravitational force per unit mass that would be experienced by a small test mass placed at that point. $g = F_g/m$ (SI unit: $\mathrm{N\,kg^{-1}}$). Numerically equal to the acceleration of free fall.

Gravitational field strength around a planet, or moon, of mass *M*: $g = GM/r^2$

Gravitational forces: Fundamental attractive forces that act across space between all masses. Gravitational force reduces with an inverse square law with increasing distance between point masses.

Gravitational potential energy, E_p: Energy that masses have because of the gravitational forces between them. Changes in gravitational potential energy in a uniform field can be calculated from $\Delta E_p = mg\Delta h$.

Greenhouse: Structure made mostly from a transparent material (usually glass) used for controlling plant growth.

Greenhouse effect: The natural effect that a planet's atmosphere has on reducing the amount of radiation emitted into space, resulting in a planet warmer than it would be without an atmosphere.

Greenhouse effect (enhanced): The reduction in radiation emitted into space from Earth due to an increasing concentration of greenhouse gases in the atmosphere (especially carbon dioxide) caused by human activities; believed by most scientists to be the cause of global warming.

Greenhouse gases: Gases in the Earth's atmosphere that absorb and re-emit infrared radiation, thereby affecting the temperature of the Earth. The principal greenhouse gases are water vapour, carbon dioxide, methane and nitrous oxide. Atmospheric concentrations of the last three of these have been increasing significantly in recent years.

Ground: See earth.

Ground state: The lowest energy state of an atom / electron (or nucleus).

H

Half-life (radioactive): The time taken for the activity, or count rate, from a pure source to be reduced to half. Also, equals the time taken for the number of radioactive atoms in a pure source to be reduced to half.

Harmonics: Different frequencies (modes) of standing wave vibrations of a given system. The frequencies are all multiples of the frequency of the first harmonic.

Heat engine: Device that uses the flow of thermal energy to do useful work.

Heat exchanger: Apparatus designed to efficiently transfer thermal energy from one system to another.

Helical: In the shape of a spiral.

Hertz, Hz: Derived SI unit of frequency. 1 Hz = one oscillation per second.

Hertzsprung–Russell (HR) diagram: Diagram that displays order in the apparent diversity of stars by plotting the luminosity of stars against their surface temperatures.

Hooke's law: The force needed to deform a spring is proportional to the extension (or compression). $F_H = -kx$, where k is the spring constant.

Humidity: A measure of the amount of water vapour present in air.

Hydroelectric power: The generation of electrical power from falling water.

I

***I–V* characteristic:** Graph of current–p.d., representing the basic behaviour of an electrical component.

Ideal gas: Gas which obeys the ideal gas law equation perfectly. The kinetic model of an ideal gas makes the following assumptions. i, The molecules are identical. ii, The molecules are point masses with negligible size or volume. iii, The molecules are in completely random motion. iv, There are negligible forces between the molecules, except when they collide. v, All collisions are elastic, that is, the total kinetic energy of the molecules remains constant.

Ideal gas law: $pV = nRT$. Also called the equation of state for an ideal gas. Can also be expressed as $PV = Nk_BT$, and sometimes used in the form PV/T = constant.

Ideal electrical meters: Meters which have no effect on the electrical circuits in which they are used. An ideal ammeter has zero resistance, and an ideal voltmeter has infinite resistance.

Imagination: Formation of new ideas that are not related to direct sense perception or experimental results.

Immersion heater: Heater placed inside a liquid or object.

Impact: Collision involving relatively large forces over a short time. The effect of such an impact may be different from the same impulse (Ft) delivered by a smaller force over a longer time.

Impulse, *J*: The product of force and the time for which the force acts $J = F\Delta t$. It is equal to the change of momentum (SI unit: N s).

Incandescent: Emitting light when very hot.

Incidence, angle: The angle between an incident ray and the normal (or between the incident wave and the boundary).

Incident wave, or ray: Wave (or ray) arriving at an object or a boundary.

Inclined plane: Flat surface at an angle to the horizontal (but not perpendicular). A simple device that can be used to reduce the force needed to raise a load; sometimes called a ramp.

Incompressible: Volume cannot be decreased.

Induced charge (electrostatic): Charge separation caused, without contact, by another nearby charged object.

Induced magnetism: When a ferromagnetic material becomes magnetized because it is in an external magnetic field.

Inertia: Resistance to a change of motion. Depends on the mass of the object.

Infinite: Without limits.

Infrared: Electromagnetic radiation emitted by all objects (depending on temperature) with wavelengths longer than visible light.

Inspiration: Stimulation (usually to be creative).

Instability strip: A region of the Hertzsprung–Russell diagram containing pulsating, variable stars.

Instantaneous value: The value of a quantity (that may be changing) at an exact instant (moment).

Insulator (electrical): A non-conductor. A material through which a (significant) electric current cannot flow, because it does not contain many charge carriers.

Insulator (thermal): A material that significantly reduces the flow of thermal energy.

Integration: Mathematical process used to determine the area under a graph which is described by a known equation.

Intensity, *I*: Wave power / area: $I = P/A$ (SI unit: $W\,m^{-2}$). The intensity of a wave is proportional to its amplitude squared, $I \propto x_0^2$.

Interaction: Any event in which two or more objects exert forces on each other.

Interference: Superposition effect that may be produced when similar waves pass through each other. Most important for waves of the same frequency and similar amplitude. Waves arriving in phase will interfere constructively because their path difference = $n\lambda$. Waves completely out of phase will interfere destructively because their path difference = $(n + ½)\lambda$.

Interference pattern (fringes): Pattern observed when coherent waves interfere.

Internal energy: Total potential energies and random kinetic energies of all the particles in a substance.

Internal energy of an ideal gas, *U*: The sum of the random translational kinetic energies of all the molecules.
$U = \frac{3}{2}nRT = \frac{3}{2}nkBT.$

Internal resistance, *r*: Sources of electrical energy, for example batteries, are not perfect conductors. The materials inside them have resistance in themselves, which we call internal resistance. This results in energy dissipation in the battery / source and a reduction in the useful potential difference supplied to the circuit. See lost volts.

Interpolate: Estimate a value within a known data range.

Interstellar matter: Matter that exists in the space between stars (usually at very low density).

Intuition: Immediate understanding, without reasoning.

Inverse proportionality: Two quantities are inversely proportional if, when one increases by a factor x, the other decreases by the same factor. For example: $x \propto 1/y$ (xy = constant).

Inverse square law: For waves / energy / particles / fields spreading equally in all directions from a point source without absorption or scattering, the intensity is inversely proportional to the distance squared. $I \propto r^{-2}$ (Ir^2 = constant).

Ion: An atom or molecule that has gained or lost one or more electrons.

Ionization: The process by which an atom or molecule becomes an ion.

Ionization energy: Minimum amount of energy needed to remove an electron from an atom or molecule.

Ionizing ability: An indication of how much ionization is caused when a particular type of radiation passes through a material.

Ionizing radiation: Radiation which has particles or photons with enough energy to cause ionization.

Isochronous: Describing repeating events that take equal times.

Isotherm: A line connecting points at the same temperature. An isothermal process occurs at constant temperature.

Isotope: One of two or more atoms of the same element with different numbers of neutrons (and therefore different masses). A *radioi*sotope is unstable and will emit radiation.

J

Jet engine: An engine that achieves propulsion by emitting a fast-moving stream of gas or liquid in the opposite direction from the intended motion.

Joule, J: Derived SI unit of work and energy. 1 J = 1 N m.

K

Kelvin scale of temperature: Also known as the absolute temperature scale. Temperature scale based on absolute zero (0 K) and the melting point of water (273 K). The kelvin, K, is the fundamental SI unit of temperature. T (in K) = 0 °C + 273. The kelvin (absolute) temperature is a measure of the mean random translation kinetic energy of one molecule of an ideal gas: $\bar{E}_k = \frac{3}{2}k_B T$. The total translational kinetic energy of the molecules in one mole of an ideal gas is $\frac{3}{2}RT$.

Kilogramme, kg: SI unit of mass (fundamental).

Kilowatt hour, kWh: A non-SI unit. The amount of electrical energy transferred by a 1 kW device in 1 hour. (= 3.60×10^6 J)

Kinematics: Describes the motion of objects (without explanations).

Kinetic energy, E_k: Energy of moving masses. We can distinguish E_k of translation, E_k of vibration and E_k of rotation. Translational E_k is calculated from $½mv^2$ or $p^2/2m$.

Kinetic theory of ideal gases: Applying the macroscopic concepts of mechanics to the idealised microscopic motions of gas particles in order to predict gas behaviour. Results in the equation $P = ⅓\rho v^2$

Kinetic theory of matter: All matter is composed of a very large number of small particles that are in constant motion (to various extents).

L

Lagging: Thermal insulation.

Laser: Source of intense, coherent, monochromatic light.

Latent heat: Thermal energy that is transferred at constant temperature during any change of physical phase. See specific latent heats of fusion and vaporization.

Left-hand rule (Fleming's): Rule for predicting the direction of the magnetic force on moving charges, or a current in a wire.

Lever: A simple machine consisting of a rigid bar and a pivot. Used to change the direction and magnitude of a force.

Lifetime (of main sequence star): The duration for which a star is fusing hydrogen into helium, emitting radiation and maintaining stellar equilibrium.

Light-dependent resistor (LDR): A resistor, the resistance of which depends on the light intensity incident upon it.

Light-emitting diodes (LEDs): Small semiconducting diodes that emit light of various colours at low voltage and power.

Light gate: Electronic sensor used to detect motion when an object interrupts a beam of light.

Light-year, ly: Non-SI unit of distance used by astronomers equal to the distance travelled by light in a vacuum in 1 year. ($= 9.46 \times 10^{15}$ m)

Line of action (of a force): A line through the point of action of a force, showing the direction in which the force is applied.

Linear relationship: One which produces a straight line graph.

Logarithmic scale (on a graph): Instead of equal divisions (for example, 0, 1, 2, 3, …), with a logarithmic scale each division increases by a constant multiple (for example, 1, 10, 100, 1000, …).

Longitudinal wave: Waves in which the oscillations are parallel to the direction of transfer of energy, for example sound waves. Sometimes called a compression wave.

Lost volts: Term sometimes used to describe the voltage drop (becoming less than the emf) that occurs when a source of electrical energy delivers a current to a circuit. Lost volts (Ir) increase with larger currents. $\varepsilon = IR + Ir$

Loudness: A subjective measure of our ears' response to the level of sound received.

Luminosity (stellar), *L*: Total power of electromagnetic radiation emitted by a star, $L = \sigma AT^4$ (SI unit: W).

M

Macroscopic: Can be observed without the need for a microscope.

Magnetic field strength, *B*: Defined in terms of the force on a current: The force acting per unit length on unit current (1 A) at an angle θ: $B = \dfrac{F}{IL\sin\theta}$ (SI unit: tesla. $1\ \text{T} = 1\ \text{N A}^{-1}\text{m}^{-1}$)

Magnetic force acting on a charged particle crossing a magnetic field: $F = qvB\sin\theta$

Magnetic force per metre between parallel currents: $F/L = \mu_0(I_1I_2/2\pi r)$

Magnetic forces: Fundamental forces that act across space between moving charges, currents and/or permanent magnets.

Magnetic poles (north and south): Regions in a magnetic material where the field is strongest.

Magnitude: Size.

Main sequence stars: Stable stars which are fusing hydrogen into helium in their cores.

Mains electricity: Electrical energy supplied to homes and businesses by cables from power stations. Also called utility power.

Mapping: Representing the interrelationships between ideas, knowledge or data by drawing.

Mass: A measure of an object's resistance to a change of motion (inertia).

Mass defect: The difference in mass between a nucleus and the total mass of its nucleons if they were separated. Equal to nuclear binding energy.

Mass spectrometer: A device that can measure the masses and relative abundances of gaseous ions.

Mass and spring oscillator: Approximates to SHM. Time period can be determined from $T = 2\pi\sqrt{(m/k)}$.

Mean: A certain type of average: the sum of all of the numbers divided by the number of values involved.

Mechanical energy: Sum of kinetic energy, gravitational potential energy and elastic potential energy.

Mechanical wave: A wave which involves oscillating masses (including sound).

Mechanics: Study of the effects of forces on objects.

Medium (of a wave): Substance through which a wave is passing (plural: media).

Meltdown (thermonuclear): Common term for the damage to the core and reactor vessel that results from overheating following some kind of accident at a nuclear power station.

Melting: Change from a solid to a liquid. Usually at a specific temperature (melting point).

Mesons: Unstable subatomic particles involved with the strong nuclear force.

Methodology: An outline of the way in which a study, investigation or project is carried out.

Metre, m: SI unit of length (fundamental).

Microscopic: Describes anything that is too small to be seen with the unaided eye.

Milky Way: The galaxy in which our Solar System is located.

Modelling: A central theme of science that involves representing reality with simplified theories, drawings, equations, etc., in order to achieve a better understanding and make predictions.

Moderator: Material used in a nuclear reactor to slow down neutrons to low energies and enable nuclear fission.

Modes of vibration: The different ways in which a standing wave can arise in a given system. See also harmonics.

Molar mass: The mass of a substance that contains 1 mole of its defining particles.

Mole, mol: SI unit of amount of substance (fundamental). The number of moles equals the number of particles divided by Avogadro's constant, $n = N/N_A$

Momentum (linear), *p*: Mass times velocity: $p = mv$ (SI unit: kg m s^{-1}). A vector quantity.

Monochromatic: Containing only one colour / frequency / wavelength (often, more realistically, a narrow range).

Moral and ethical issues (scientific): Changes to the world, brought about by scientific and technological developments, that some individuals and societies believe to be wrong.

Motor (electric): A machine that transfers electrical energy into kinetic energy (usually of rotation). Can be ac or dc.

Motor effect: Magnetic force on a current in a magnetic field, as used in electric motors.

N

Natural gas: Naturally occurring fossil fuel: mixture of gases (mainly methane).

Natural philosophy: The name used to describe the (philosophical) study of nature and the universe before modern science.

Nebula (plural: nebulae): Observable, diffuse 'cloud' of interstellar matter; mainly gases (mostly hydrogen and helium) and dust.

Negligible: Too small to be significant.

Neutral: Uncharged, or zero net charge.

Neutrino: Low-mass, and very weakly interacting uncharged particle emitted during beta-positive decay. Antiparticle of antineutrino.

Neutron: Neutral subatomic particle with a mass of 1.675×10^{-27} kg. The number of neutrons in a nucleus is called the neutron number (N).

Neutron capture: Nuclear reaction in which a neutron is absorbed to form a more massive nucleus.

Neutron number: The number of neutrons in a nucleus.

Neutron stars: Very dense stars formed after a supernova.

Newton, N: Derived SI unit of force. $1\,\text{N} = 1\,\text{kg m s}^{-2}$.

Newton's laws of motion: *First law*: an object will remain at rest, or continue to move in a straight line at a constant speed, unless a resultant force acts on it. *Second law*: acceleration is proportional to resultant force: $F = ma$ or $F = \Delta p/\Delta t$. *Third law*: whenever one body exerts a force on another body, the second body exerts exactly same force on the first body, but in the opposite direction.

Newton's universal law of gravitation: There is a gravitational force between two point masses, m_1 and m_2, given by $F = G\dfrac{m_1 m_2}{r^2}$, where r is the distance between them and G is the universal gravitation constant.

Nodes: The positions in a standing wave where the amplitude is zero. See also antinodes.

Non-renewable energy sources: Energy sources that take an extremely long time to form and which are being rapidly used up (depleted). Examples include oil, natural gas and coal.

Normal: Perpendicular to a surface.

Nuclear equation: An equation representing a nuclear reaction. The sum of nucleon numbers (A) on the left-hand side of the nuclear equation must equal the sum of the nucleon numbers on the right-hand side of the equation. Similarly with proton numbers (Z).

Nuclear fission: A nuclear reaction in which a massive nucleus splits into more stable smaller nuclei whose total binding energy is greater than the binding energy of the initial nucleus, thereby releasing energy.

Nuclear fusion: Nuclear reaction in which two low-mass nuclei combine to form a more stable and more massive nucleus whose binding energy is greater than the combined binding energies of the initial nuclei, with the release of energy.

Nuclear potential energy: Energy related to the forces between nucleons.

Nuclear waste: Radioactive materials associated with the production of nuclear power that are no longer useful, and which may have to be stored safely for a long period of time.

Nucleon: A particle in a nucleus, either a neutron or proton.

Nucleon number, *A*: The total number of protons and neutrons in a nucleus.

Nucleosynthesis: Creation of new nuclides (elements) from existing, less massive, nuclei.

Nucleus: The central part of an atom containing protons and neutrons (except for hydrogen-1). A nucleus is described by its atomic number and nucleon number. See nuclide.

Nuclide: Term used to identify one particular species (type) of atom, as defined by the structure of its nucleus. A *radio*nuclide is unstable and will emit radiation.

O

Objective: Free from bias and emotion. Compare with subjective.

Observer effect: When the act of observation, or measurement, changes the phenomenon being observed.

Ohm, Ω: The derived SI unit of electric resistance. $1\,\Omega = 1\,\text{V}/1\,\text{A}$.

Ohmic (and non-ohmic) behaviour: The electrical behaviour of an ohmic component is described by Ohm's law. A non-ohmic device does not follow Ohm's law.

Ohm's law: The current in a conductor is proportional to the potential difference across it, provided that the temperature is constant.

Opaque: Unable to transmit light (or , possibly, other forms of energy).

Opposite charge: Positive and negative charges are described as opposite charges.

Optical fibre: Thin, flexible fibre of high-quality glass that uses total internal reflection to transmit light along curved paths and/or over large distances.

Optically dense: If light travels slower in medium A, compared to medium B, then medium A is described as more optically dense.

Orbit: The curved path (may be circular) of a mass, or charge, around a much more massive central mass, or charge.

Order of magnitude: An approximate value rounded to the nearest power of ten.

Oscillation: Repetitive motion about a fixed point.

Oscillator: Something which oscillates.

Oscilloscope: An instrument for displaying and measuring potential differences that change with time.

Outlier: A value which is significantly different from the others in the same data set.

Outline (Command term used in examination questions): Give a brief account or summary.

P

Parabolic: In the shape of a parabola. The trajectory of a projectile is parabolic if air resistance is negligible.

Paradigm: The complete set of concepts and practices etc. that characterize a particular area of knowledge at a particular time. When these change significantly, it is described as a paradigm shift.

Parallax: The displacement in the apparent position of an object (compared to its background) viewed along two different lines of sight. Can be quantified in terms of a *parallax angle*.

Parallax error: Error of measurement that occurs when reading a scale from the wrong position.

Parallel connection: Two or more electrical components connected between the same two points, so that they have the same potential difference. across them.
$I = I_1 + I_2 + ...$
$V = V_1 = V_2 = ...$
$1/R_P = 1/R_1 + 1/R_2 + ...$

Parsec, pc: Non-SI unit of distance used by astronomers; equal to the distance to a star that has a parallax angle of one arc-second. (= 3.26 ly)

Particle accelerator: Apparatus designed to produce particle beams.

Particle beams: Streams (flows) of very fast-moving particles, most commonly charged particles (electrons, protons or ions), moving across a vacuum. Properties of the individual particles can be investigated by observing the behaviour of the beams in electric and/or magnetic fields.

Pascal: Derived SI unit for pressure. $1\,Pa = 1\,N\,m^{-2}$.

Path difference: The difference in the distances from a particular point to two sources of waves. If the path difference between coherent waves is a whole number of wavelengths, constructive interference will occur.

Peer review: Evaluation of scientific results and reports by other scientists with expertise in the same field of study.

Pendulum: A weight, which is suspended below a pivot, which is able to swing from side to side. The weight is sometimes called the pendulum bob. The concept of *a simple pendulum* is a point mass on the end of an inextensible string. Its SHM time period can be determined from the equation: $T = 2\pi\sqrt{(l/g)}$.

Penetrating power: The penetrating power of nuclear radiation depends upon the ionizing ability of the radiation. The radiation continues to penetrate matter until it has lost (nearly) all of its energy. The greater the ionization per cm, the less penetrating power it will possess.

Permanent magnet: Magnetized material that creates a significant and persistent magnetic field around itself. Permanent magnets are made from ferromagnetic materials, like certain kinds of steel. Soft (pure) iron cannot be magnetized permanently.

Permeability (magnetic): Constant that represents the ability of a particular medium to transfer a magnetic force and field.

Permeability of free space, μ_0: Fundamental constant that represents the ability of a vacuum to transfer a magnetic force and field, $\mu_0 = 4\pi \times 10^{-7}\,T\,mA^{-1}$.

Permittivity of free space, ε_0: Fundamental constant that represents the ability of a vacuum to transfer an electric force and field, $\varepsilon_0 = 8.85 \times 10^{-12}\,C^2\,N^{-1}\,m^{-2}$.

Permittivity (electric) of a medium, ε: Constant that represents the ability of a particular medium to transfer an electric force and field. Often expressed as relative permittivity: $\varepsilon_r = \varepsilon/\varepsilon_0$ (no units), which is also sometimes called dielectric constant.

Phase (of matter): A substance in which all the physical and chemical properties are uniform. In physics, the term phase change is used to describe changes between solids, liquids and gases of the same substance.

Phase (oscillations): Oscillators are in phase if they have the same frequency and they are at the same points in their oscillations at the same time.

Phase difference: When oscillators that have the same frequency are out of phase with each other, the difference between them is defined by the angle (usually in terms of π radians) between the oscillations. Phase differences can be between 0 and 2π radians.

Photon: A quantum of electromagnetic radiation, with an energy given by $E = hf$.

Photovoltaic cell: Device that converts electromagnetic radiation (mainly light and infrared) into electrical energy. Also called a solar cell.

Piston: A solid cylinder that fits tightly inside a hollow cylinder, trapping a fluid. Designed to move as a result of pressure differences.

Pitch: The sensation produced in the human brain by sound of a certain frequency.

Pivot: A fixed point supporting something which turns or balances.

Planck relationship: The amount of energy carried by a photon, $E = hf$, where h represents Planck's constant.

Planck's constant, h: Fundamental constant of quantum physics which connects the energy and frequency of a photon ($= 6.63 \times 10^{-34}$ J s).

Plane waves: Waves which have three-dimensional wavefronts on parallel planes and which can be represented by parallel rays.

Planetary nebula: Material emitted from the outer layers of a red giant star at the end of its lifetime. The core then becomes a white dwarf star.

Plasma: State of matter that is similar to a gas, but which contains a predominance of charged particles (ions).

Point particle, mass or charge: Theoretical concept used to simplify the discussion of forces acting on objects (especially in gravitational and electric fields).

Polar satellite orbit: Descriptive of the path of a low-orbit satellite that passes over the poles of the Earth and completes many orbits every day, passing over many different parts of the planet.

Polarity: Separation of opposite electric charges or opposite magnetic poles, which produces uneven effects in a system.

Positron: Antiparticle of the electron; released during beta-positive decay.

Potential differenc, p.d. *V*: The electrical potential energy transferred (work done) as a unit charge moves between two points, $V = W/q$. Commonly referred to as voltage.

Potential dividing circuit: Two resistors used in series with a constant potential difference across them. When one resistance is changed, the potential difference across each resistor will change, and this can be used for controlling another part of the circuit.

Potential energy: Energy that arises because of forces between different parts of the system. See chemical potential energy, elastic strain potential energy, gravitational potential energy and nuclear potential energy. Sometimes described as stored energy.

Potentiometer: Variable resistor (with three terminals) used as a potential divider.

Power, *P*: Energy transferred / time taken ($P = E/t$) or, for mechanical energies, work done / time taken ($P = \Delta W/\Delta t$) (SI unit: watt). $1\,\text{W} = 1\,\text{J s}^{-1}$.

Power to maintain a constant velocity: $P = Fv$

Power (electrical): The rate of dissipation of energy in a resistance. $P = VI = I^2R = V^2/R$.

Precautionary principle: The idea that scientific research should not continue unless scientists are able to confirm that the research will not be harmful.

Precision: A measurement is described as precise if a similar result would be obtained if the measurement was repeated. Precise measurements have small random errors. A precise measurement may, or may not, be accurate.

Predict (Command term used in examination questions): Give an expected result.

Prefixes (for units): Used immediately before a unit to represent powers of ten. For example, 'milli-' in front of a unit represents $\times 10^{-3}$, as in millimetre.

Pressure, *P*: Force acting normally per unit area: pressure = force / area (SI unit: pascal, Pa). $1\,\text{Pa} = 1\,\text{N m}^{-2}$.

Pressure law: For a fixed mass of gas with a constant volume, the pressure is proportional to the Kelvin temperature.

Prism: A regularly shaped piece of transparent material (such as glass) with flat surfaces, which can be used to refract, reflect, and disperse light.

Processed data: Data produced by calculations made from raw experimental data.

Projectile: An object that has been projected through the air and which then moves only under the action of the forces of gravity and air resistance.

Propagation (of waves): Transfer of energy by waves.

Proportional variables: Two numbers are (directly) proportional to each other if they always have the same ratio.

Propulsion: Method by which force is provided to produce motion.

Proton: Subatomic particle with a positive charge ($+1.6 \times 10^{-19}\,\text{C}$) and mass of $1.673 \times 10^{-27}\,\text{kg}$. The number of protons in a nucleus is called the *proton number* (Z).

Proton–proton cycle: The simplest nuclear fusion process which converts hydrogen into helium, releasing large amounts of energy in medium and smaller-sized main sequence stars.

Pulley: Simple machine with a rotating wheel used to change the direction of a force. When two or more pulleys are combined, the system can reduce the force needed to do work.

Pulse (wave): A travelling wave of short duration.

***PV* diagram**: A pressure–volume graph showing possible states of a gas.

Q

Qualitative: Involving qualities, rather than quantities.

Quantitative: Involving quantities, measurements.

Quantized: Can only exist in certain definite (discrete) numerical values.

Quantum: The minimum amount of a physical quantity that is quantized. Plural: quanta.

Quantum physics: Study of matter and energy at the subatomic scale. At this level quantities are quantized.

R

Radar: A system which uses microwaves to detect the distance, direction and speed of moving objects.

Radial: Diverging in straight lines from a point.

Radial field: Field (electric or gravitational) that spreads out from a point equally in all directions.

Radian, rad: Unit of measurement of angle. There are 2π radians in 360°. (1 rad = 57.3°)

Radiation: Particles or waves that radiate away from a source. Usually this refers to various kinds of electromagnetic radiation or particles emitted from unstable nuclei.

Radiation energy: Energy transferred by electromagnetic waves

Radioactive: Describes a substance which contains unstable nuclei which will decay and emit radiation.

Radioactive decay (radioactivity): Spontaneous transmutation of an unstable nucleus, accompanied by the emission of ionizing radiation in the form of alpha particles, beta particles or gamma rays.

Radioactive decay equation: Balanced equation which shows a radionuclide and its decay products.

Radioactive source: A radionuclide used for the nuclear radiation it emits.

Radioastronomy: Study of space utilizing the detection of radio waves emitted by astronomical sources.

Radioisotope / radionuclide: Isotope / nuclide with an unstable nucleus which emits radiation when it decays.

Random: Without pattern or predictability.

Random errors: Measurements of any quantity that are bigger or smaller than the correct value and which are scattered randomly around that value (for various or unknown reasons).

Range (data): Spread of data from smallest to largest values.

Range (of a projectile): Horizontal distance travelled before impact with the ground.

Rarefactions (in a longitudinal wave): Places where there are reductions in density (and pressure) of a gas as a sound wave passes through it.

Ratemeter: Meter which is connected to a Geiger–Muller tube (or similar) to measure the rate at which radiation is detected.

Raw data: Measurements made during an investigation.

Ray: A line showing the direction in which a wave is transferring energy. Rays are perpendicular to wavefronts.

Ray diagrams: Drawings that represent the directions of different waves or particles as they pass through a system.

Reaction time: The time delay between an event occurring and a response. For example, the delay that occurs when using a handheld stopwatch.

Real gases: Modelling of gas behaviour is idealized. Real gases do not behave exactly the same as the model of an ideal gas

Recession speed: The speed with which a galaxy (or star) is moving away from Earth.

Recoil: When a bullet is fired from a gun (or similar), the gun must gain equal momentum in the opposite direction.

Redshift (Doppler effect): Increase in wavelengths (and decrease of frequency) of electromagnetic radiation due to the fact that the distance between the observer and the source is increasing.

Reflection (waves): Change of direction that occurs when waves meet a boundary between two media such that the waves return into the medium from which they came.

Reflection, law of: Angle of incidence = angle of reflection.

Refraction: Change of direction that can occur when a wave changes speed (most commonly when light passes through a boundary between two different media).

Refractive index, *n*: The ratio of the speed of waves in vacuum (or air) to the speed of waves in a given medium. Also: n = sine of angle in air / sine of angle in medium.

Refrigerant: Fluid used in the refrigeration cycle of refrigerators, air conditioners and heat pumps.

Regenerative braking: Decelerating a vehicle by transferring kinetic energy into a form that can be of later use (rather than dissipating the energy into the surroundings). For example, by generating an electric current that charges a battery.

Renewable energy: Energy from sources that will continue to be available for our use for a very long time. They cannot be used up (depleted), except in billions of years, when the Sun reaches the end of its lifetime.

Resistance (electrical), *R*: Ratio of potential difference across a conductor to the current flowing through it. $R = V/I$ (SI unit: ohm, Ω).

Resistive force: Any force that opposes motion, for example friction, air resistance, drag.

Resistivity, *ρ*: Resistance of a specimen of a material that has a length of 1 m and cross-sectional area of 1 m^2. $R = \rho L/A$.

Resistor: A resistance made to have a specific value or range of values.

Resolve (vector): To express a single vector as components (usually two components which are perpendicular to each other).

Resonance: The increase in amplitude that occurs when an oscillating system is acted on by an external periodic force that has the same frequency as the natural frequency of the system. The driving force must be in phase with the natural oscillations of the system.

Resonant frequency: The frequency at which resonance occurs.

Rest: An object is considered to be at rest if it stays in the same position.

Rest mass: Mass of an isolated particle that is at rest relative to the observer.

Restoring force: Force acting in the opposite direction to displacement, returning an object to its equilibrium position.

Resultant: The single vector that has the same effect as the combination of two or more separate vectors.

Resultant force: The vector sum of the forces acting on an object, sometimes called the unbalanced or net force.

Rheostat: Variable resistance used to control current.

Right-hand grip rule: Rule for determining the direction of the magnetic field around a current.

Ripple tank: A tank of shallow water used for investigating wave properties.

Rocket engine: Similar to a jet engine, but there is no air intake. Instead, an oxidant is carried on the vehicle, together with the fuel.

Rotational kinetic energy: Kinetic energy because of rotation.

S

Sankey diagram: Diagram representing the flow of energy in a system (shown from left to right). The widths of the arrows are proportional to the amounts of energy (or power). Degraded / dissipated energy is directed downwards.

Satellite: Object that orbits a much larger mass. Satellites can be natural (like the Earth around the Sun, or the Moon around the Earth), or artificial (as used for communication, for example).

Scalars: Quantities that have only magnitude (no direction).

Scattering: Irregular reflections of waves or particles from their original path by interactions with matter.

Scientific notation: Every number is expressed in the following form: $a \times 10^b$, where a is a decimal number larger than 1 and less than 10 and b is an exponent (integer).

Second, s: SI unit of time (fundamental).

Self-sustaining nuclear chain reaction: Occurs when enough of the neutrons created during fissions then go on to cause further fissions.

Semiconductor: Material (such as silicon) with a resistivity between that of conductors and insulators. Such materials are essential to modern electronics.

Sense perception: How we receive information, using the five human senses.

Sensor: An electrical component that responds to a change in a physical property with a corresponding change in an electrical property (usually resistance). Also called a transducer.

Series connection: Two or more electrical components connected such that there is only one path for the electrical current, which is the same through all the components.
$I = I_1 = I_2 = ...$
$V = V_1 + V_2 + ...$
$R_s = R_1 + R_2 + ...$

Shielding (reactor): Protective barrier around a nuclear reactor designed to absorb and reflect dangerous radiations.

Short circuit: An unwanted (usually) electrical connection that provides a low resistance path for an electric current. It can result in damage to the circuit, unless the circuit is protected by a fuse or circuit breaker.

Show (Command term used in examination questions): Give the steps in a calculation or derivation.

SI format for units: For example, the SI unit for momentum is kilogram metre per second and should be written as $\mathrm{kg\,m\,s^{-1}}$ (not kg m/s).

SI system of units: International system of standard units of measurement (from the French 'Système International') which is widely used around the world. It is based on seven fundamental units and the decimal system. Non-SI units are in common use when the SI units involve very large or very small numbers.

Signal generator: Electronic equipment used to supply small alternating currents of a wide range of different frequencies.

Significant figures (digits): All the digits used in data to carry meaning, whether they are before or after a decimal point.

Simple harmonic energy transfers: All mechanical oscillators continuously interchange energy between potential and kinetic.

Simple harmonic motion (SHM): Oscillations in which the acceleration, a, is proportional to the displacement, x, and in the opposite direction, directed back to the equilibrium position. $a = -\omega^2 x$.

Simulation: Simplified visualization (imitation) of a real physical system and how it changes with time. Usually part of a computer modelling process.

Sinusoidal: In the shape of a sine wave (maybe equivalent to a cosine wave).

Sketch (Command term used in examination questions): Represent by means of a diagram or graph (labelled appropriately). The sketch should give a general idea of the required shape or relationship, and should include relevant features.

Slow neutrons: Low-energy neutrons (typically less than 1 eV) that are needed to sustain a chain reaction. They are slowed down in a nuclear reactor by the use of a moderator. They are sometimes called thermal neutrons because they are in approximate thermal equilibrium with their surroundings.

Snell's law (of refraction): Connects the sines of the angles of incidence and refraction to the refractive indices in the two media (or the wave speeds).
$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$.

Soft iron: Form of iron (pure or nearly pure) that is easily magnetized and demagnetized. Soft iron cores are used in a wide variety of electromagnetic devices.

Solar cell: Device which converts light and infrared directly into electrical energy. Also called photovoltaic cell. A collection of solar cells connected together electrically is commonly called a solar panel.

Solar constant, *S*: Intensity of the Sun's radiation arriving perpendicularly to the Earth's upper atmosphere ($= 1.36 \times 10^3\ \mathrm{W\,m^{-2}}$).

Solar heating panel: Device for transferring radiated thermal energy from the Sun to internal energy in water.

Solar System: The Sun and all the objects that orbit around it.

Solenoid: Long coil of wire with turns that do not overlap (helical). Solenoids are often used because of the strong uniform magnetic fields inside them when they carry a current.

Sonar: The use of reflected ultrasound waves to locate objects.

Sound: Longitudinal waves in air or other media that are audible to humans.

Specific energy: Amount of energy that can be transferred from unit mass of an energy source (SI unit: $\mathrm{J\,kg^{-1}}$).

Specific heat capacity, *c*: The amount of energy needed to raise the temperature of 1 kg of a substance by 1 K. $c = \frac{Q}{m\Delta T}$.

Specific latent heat, L_f or L_v: The amount of energy needed to melt (fusion) or vaporize 1 kg of a substance at constant temperature. $L = Q/m$ (SI unit: $\mathrm{J\,kg^{-1}}$).

Spectroscopy: The production and analysis of spectra using instruments called spectroscopes or spectrometers.

Spectrum, continuous: The components of radiation displayed in order of their wavelengths, frequencies or energies (plural: spectra).

Spectrum, line: A spectrum of separate lines (rather than a continuous spectrum), each corresponding to a discrete wavelength and energy.

Speed, *v*: Average speed is defined as distance travelled / time taken, $v = \Delta s/\Delta t$ (SI unit $m\,s^{-1}$). Instantaneous speed is determined over a very short time interval, during which it is assumed that the speed does not change. It can also be determined from the gradient of a distance–time graph. Speed is a scalar quantity; compare with velocity, a vector quantity.

Speed of light: the speed in a vacuum (free space) is a fundamental constant ($= 3.00 \times 10^8\,m\,s^{-1}$)

Spontaneous: (decay, for example) Without any cause, cannot be controlled.

Spreadsheet (computer): Electronic document in which data is arranged in the rows and columns of a grid, and can be manipulated and used in calculations.

Spring constant, *k*: Constant that represents the stiffness of a spring (or other material) as seen in the Hooke's law equation: $F_H = -kx$

Standard candle: Term used by astronomers to describe the fact that the distance to a galaxy can be estimated from a knowledge of the luminosity of a certain kind of star within it.

Standing wave: The kind of wave that can be formed by two similar travelling waves moving in opposite directions. The most important examples are formed when waves are reflected back upon themselves. The wave pattern does not move and the waves do not transfer energy.

Star: Massive sphere of plasma held together by the forces of gravity. Because of the high temperatures, thermonuclear fusion occurs and radiation is emitted.

Star map: Two-dimensional representation of the relative positions of stars as seen from Earth.

State (Command term used in examination questions): Give a specific name, value or other brief answer without explanation or calculation.

State of a gas: Specified by quoting the pressure, *P*, temperature, *T*, and volume, *V*, of a known amount, *n*, of gas.

States of matter: Solid, liquid or gas (or plasma).

Stefan–Boltzmann law: An equation that can be used to calculate the total power radiated from the surface of a black-body, $P = \sigma AT^4$. σ is known as the *Stefan–Boltzmann constant* ($= 5.67 \times 10^{-8}\,W\,m^{-2}\,K^{-4}$).

Stellar equilibrium: Main sequence stars are in equilibrium under the balanced effects of radiation pressure acting outwards against gravitational forces acting inwards.

Stellar parallax: Method of determining the distance, *d*, to a nearby star from measurement of its parallax angle: d (parsec) $= 1/p$ (arc-second), where p is the parallax angle of the star.

Stokes's law: Viscous drag acting on a smooth, spherical object undergoing no-turbulent flow, $F_d = 6\pi\eta rv$.

Strain: If a material has a strain, it has been deformed.

Streamlined: Having a shape that reduces the resistive forces (drag) acting on an object that is moving through a fluid.

Stroboscope: Apparatus used for observing rapid motions. It produces regular flashes of light at an appropriate frequency chosen by the user.

Strong nuclear force: Fundamental force that is responsible for attracting nucleons together. It is a short-range attractive force (the range is about 10^{-15} m), but for smaller distances it is repulsive, and hence it also prevents a nucleus from collapsing.

Subatomic particle: Any particle contained within an atom.

Subjective: Describes an opinion based on personal experiences and emotions.

Suggest (Command term used in examination questions): Propose a solution, hypothesis or other possible answer.

Superconducting: Without significant electrical resistance; only occurring at very low temperatures.

Supernova: Sudden and very luminous explosion of a massive star, resulting in a neutron star or black hole.

Superposition (principle of): The resultant of two or more waves arriving at the same point can be determined by the vector addition of their individual displacements.

Surroundings: Everything apart from the system that is being considered; similar to the 'environment'.

System: The object(s) being considered (and nothing else). An *isolated system* describes a system into which matter and energy cannot flow in, or out.

Systematic error: A reading with a systematic error is always either bigger or smaller than the correct value by the same amount, for example a zero-offset error.

T

Tangent: Line which touches a given curve at a single point.

Technology: The application and use of scientific knowledge for practical purposes.

Temperature: Determines the direction of thermal energy transfer (higher to lower). It is a measure of the average random translational kinetic energy of the molecules of a substance.

Tension (force): Force that tries to stretch an object or material.

Terminal potential difference: The potential difference across the terminals of a battery (or other voltage supply) when it is supplying a current to a circuit (less than the emf).

Terminal speed (velocity): The greatest downwards speed of a falling object that is experiencing resistive forces (for example, air resistance). It occurs when the object's weight is equal to the sum of resistive forces (+ upthrust).

Terminals (electrical): Points at which connecting wires are joined to electrical components.

Terminology: The words and phrases used in a particular area of study.

Tesla, T: SI unit of measurement of magnetic field strength. $1\,\mathrm{T} = 1\,\mathrm{N\,A^{-1}\,m^{-1}}$.

Test charge (or mass): Idealized model of a small charge (or mass) placed in a field in order to determine the properties of that field, but without affecting those properties.

Theory: (A term that can have many different interpretations.) A scientific theory is a fully tested and checked explanation of particular observations.

Thermal capacity: The amount of energy needed to raise the temperature of a particular object by 1 kelvin.

Thermal conductivity, *k*: Constant that represents the ability of a substance to conduct thermal energy: $\frac{\Delta Q}{\Delta t} = kA\left(\frac{\Delta T}{\Delta x}\right)$.

Thermal contact: Objects can be considered to be in thermal contact if thermal energy can be transferred between them.

Thermal energy, *Q* (heat): The (non-mechanical) transfer of energy between two or more bodies at different temperatures (from hotter to colder).

Thermal equilibrium: All temperatures within a system are constant.

Thermal radiation: Electromagnetic radiation emitted because of the movement of charged particles in the atoms of all matter at all temperatures. Most commonly, infrared.

Thermionic emission: Release of electrons from a very hot metal surface.

Thermistor (negative temperature coefficient): A resistor that has less resistance when its temperature increases. Also called a temperature-dependent resistor.

Thermometer: An instrument for measuring temperature.

Thermostat: Component that is used with a heater or cooler to maintain a constant temperature.

Thought experiment: An experiment that is carried out in the mind, rather than actually being done, normally because it is otherwise impossible.

Time period, *T*: The duration of an event which occurs regularly. $T = 1/f$.

Total internal reflection: All waves are reflected back within the medium. Occurs when a wave meets a boundary with another medium with a lower refractive index (in which it would travel faster). The angle of incidence must be greater than the critical angle.

Tracer (radioactive): Radioisotope introduced into a system (for example, a human body) to track where it goes by detecting the radiation that it emits.

Trajectory: Path followed by a projectile.

Transducer: Device that converts one form of energy to another. The word is most commonly used with devices that convert to or from changing electrical signals.

Transition (between energy levels): A photon is emitted when an atom (or nucleus) makes a transition to a lower energy level. The energy of the photon is equal to the difference in energy of the levels involved.

Translational: Moving from place to place.

Translational equilibrium: Remaining at rest or continuing to move with constant velocity.

Transmission: Passage through a medium without absorption or scattering.

Transmit: To send out / emit (usually a signal).

Transmutation: When a nuclide changes to form a different element during radioactive decay.

Transparent: Describes a medium that transmits light without scattering.

Transverse wave: A wave in which the oscillations are perpendicular to the direction of transfer of energy, for example light waves.

Travelling wave: A wave which transfers energy from one place to another.

Trough: Lowest point of a transverse mechanical wave.

Tuning fork: Device designed to vibrate at only one precise frequency.

Turbine: Device that transfers the energy from a moving fluid to do mechanical work and cause (or maintain) rotation.

Turbulence: Flow of a fluid which is erratic and unpredictable.

U

Ultrasound: Frequencies of sound above the range that can be heard by humans (approximately 20 kHz).

Ultraviolet: Part of the electromagnetic spectrum which has frequencies just greater than can be detected by human eyes.

Uncertainty (random): The range, above and below a stated value, over which we would expect any repeated measurements to occur. Uncertainty can be expressed in absolute, fractional or percentage terms.

Uncertainty bars: Vertical and horizontal lines drawn through data points on a graph to represent the uncertainties in the two values. Sometimes called error bars.

Uniform: Unchanging.

Universal (molar) gas constant: The constant, R, that appears in the equation of state for an ideal gas ($pV = nRT$). $R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$.

Universal gravitation constant, *G*: The constant that occurs in Newton's universal law of gravitation. $G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$.

Upthrust: A force exerted vertically upwards on any object that is in or floating on, a fluid. Also called buoyancy force.

Utility power: Electrical energy supplied to homes and businesses by cables from power stations. Also called mains electricity.

V

Vacuum: A space without any matter. Also called free space.

Vaporization: Change from a liquid to a vapour (gas) by boiling or evaporation.

Vapour: Gas (which can be condensed by pressure to a liquid).

Variable: Quantity that can change during the course of an investigation. Variables can be continuous or discrete. A variable can be measurable (quantitative) or just observable (qualitative). A quantity being deliberately changed is called the *independent variable* and the measured, or observed, result of those changes occurs in a *dependent variable*. Usually, all other variables will be kept constant (as far as possible); they are called the *controlled variables*.

Variable resistor: A resistor (usually with three terminals) that can be used to control currents and/or potential differences in a circuit.

Vector: A quantity that has both magnitude and direction.

Velocity, linear, *v*: Rate of change of displacement with time, $v = \Delta s/\Delta t$ (SI unit: $\mathrm{m\,s^{-1}}$). Velocity is a vector quantity and can be considered as speed in a specified direction. Velocity can also be determined from the gradient of a displacement–time graph. If the velocity (speed) of an object changes during a period of time t, the initial velocity (speed) is given the symbol u and the final velocity (speed) is given the symbol v.

Verify: To show that something is true or accurate.

Vibration: Mechanical oscillation (usually of relatively small amplitude).

Vibration (forced): Vibration affected by external periodic forces.

Vibration (free): Vibration without any external influence.

Vibration (mode): Describes a standing wave pattern.

Vibrational kinetic energy: Kinetic energy due to vibration / oscillation.

Video analysis: Analysis of video recordings of moving objects by freeze-frame or slow-motion replay.

Viscosity: Resistance of a fluid to movement.

Viscous drag: The drag force acting on a moving object due to the viscosity of the fluid through which it is moving.

Visualization: Helping understanding by using images (mental or graphic).

Volt: Derived unit of measurement of potential difference. $1\,\mathrm{V} = 1\,\mathrm{J\,C^{-1}}$.

Voltage: See potential difference.

Voltmeter: An instrument used to measure potential difference (voltage).

W

Watt, W: Derived SI unit of power. $1\,\mathrm{W} = 1\,\mathrm{J\,s^{-1}}$.

Wave (electromagnetic): A transverse wave composed of perpendicular electric and magnetic oscillating fields travelling at a speed of $3.0 \times 10^8\,\mathrm{m\,s^{-1}}$ in free space.

Wave (mechanical): A wave involving oscillating masses (includes sound).

Wave (travelling): A wave that transfers energy away from a source. Sometimes called a progressive wave.

Waveform: Shape of a wave.

Wavefront: A line connecting adjacent points moving in phase (for example, crests). Wavefronts are one wavelength apart and perpendicular to the rays that represent them.

Wavelength, λ: The distance between two adjacent crests of a wave. More precisely: the shortest distance between two points moving in phase.

Wave speed, *v*: The speed at which energy is transferred by a wave. $v = f\lambda$.

Weigh: Determine the weight of an object. In everyday use the word 'weighing' usually means quoting the result as the equivalent mass: 'my weight is 60 kg' actually means 'I have the weight of a 60 kg mass' (about 590 N).

Weight, F_g: Gravitational force acting on a mass. $F_g = mg$.

White dwarf stars: Relatively hot stars, so that they are blue / white in colour, but their luminosity is low because of their small size. They are formed after the end of the lifetime of smaller red giant stars.

White light: Light which contains all the colours of the visible spectrum with approximate equal intensity.

Wien's displacement law: Relationship between absolute temperature and the wavelength emitted with maximum power by a black body at that temperature: $\lambda_{max} T = 2.90 \times 10^{-3}\,\mathrm{m\,K}$.

Wind generator: Device that transfers the kinetic energy of wind into electrical energy.

Work, *W*: The energy transfer that occurs when an object is moved with a force. More precisely, work done = force × displacement in the direction of the force: $W = Fs\cos\theta$, where θ is the angle between the direction of movement and the direction of the force.

Y

Young's interference experiment: Famous experiment which provided the first evidence that light travelled as waves. The wavelength can be determined from the equation: $s = \lambda D/d$.

Z

Zero-offset error: A measuring instrument has a zero-offset error if it records a non-zero reading when it should be zero.

Higher Level

A

Adiabatic: Occurring without thermal energy being transferred into or out of a thermodynamic closed system. $Q = 0$, so that $-\Delta U = W$: any work done by the gas in expansion is equal to a decrease in internal energy; any work done on the gas in compression is equal to an increase in internal energy. These are idealized situations but approximated to by rapid changes to well-insulated systems. For an adiabatic change in an ideal monatomic gas $pV^{5/3}$ = constant.

Alpha particle spectrum: The range of discrete energies possessed by alpha particles emitted from the same radionuclide.

Alternator: ac electrical generator.

Angular acceleration, α: The rate of change of angular velocity with time, $\alpha = \Delta\omega / \Delta t$ (SI unit: rad s^{-2}). It is related to the linear acceleration, a, of a point at a distance r from the axis of rotation by $\alpha = a/r$.

Angular impulse: The product of torque and the time for which the torque acts. No symbol is used. It is equal to the change of angular momentum. $\Delta L = \tau \Delta t = \Delta(I\omega)$. SI unit: N m s, or kg m^2 s^{-1}.

Angular momentum, L: Moment of inertia multiplied by angular velocity: $L = I\omega$ (SI unit: kg m^2 s^{-1}).

Axiom: An unproven assumption that is accepted to be true, which is then used as starting point for further discussion. Similar in meaning to a postulate.

Axis of rotation: Line about which an object can rotate.

B

Back-emf: An induced potential difference that opposes a change of current in the same circuit. (Explained by Lenz's law.)

Beta particle spectra: The continuous range of different energies possessed by beta particles emitted from the same radionuclide.

Bohr model: A theory of atomic structure that explains the spectrum of hydrogen atoms. It assumes that the electron orbiting around the nucleus can exist only in certain energy states at specific radii. In this model the electron could only have values of angular momentum (mvr) that fitted the equation $mvr = nh/2\pi$, where n is an integer, known as the principal quantum number.

C

Carnot cycle: The most efficient thermodynamic cycle. An isothermal expansion followed by an adiabatic expansion; the gas then returns to its original state by isothermal and adiabatic compressions.

Closed system: Thermodynamic system that allows the free flow of thermal energy, but not matter.

Compton effect (scattering): The increase in wavelength (decrease in energy) of high frequency photons when they interact (collide) with electrons. Important evidence for the particle nature of electromagnetic radiation.

$$\lambda_f - \lambda_i = \Delta\lambda = \left(\frac{h}{m_e c}\right)(1 - \cos\theta)$$

Conservation of angular momentum: The total angular momentum of a system is constant provided that no resultant external torque is acting on it.

Coordinate system: An agreed numerical way of identifying the location and time of an event.

Couple (forces): Pair of equal-sized forces that have different lines of action, but which are parallel to each other and act in opposite directions, tending to cause rotation.

Cycle (thermodynamic): A series of thermodynamic processes that return a system to its original state (for example, the Carnot cycle). Usually, the process repeats continuously.

D

Davisson–Germer experiment: Experiment that verified the wave properties of matter by showing that a beam of electrons is diffracted by a crystal (at an angle dependent upon the velocity of the electrons).

de Broglie's hypothesis: All particles exhibit wave-like properties, with a de Broglie wavelength, $\lambda = h/p$, where p is the momentum of the particle and h is Planck's constant.

Decay constant: The probability of decay of an unstable nucleus per unit time: $\lambda = \dfrac{(-\Delta N/N)}{\Delta t}$ (SI unit: s^{-1}). The decay constant is linked to the half-life by the equation: $T_{½} = \ln 2/\lambda$.

Diffraction grating: A large number of parallel slits very close together. Used to disperse and analyse light. Angles for constructive interference are predicted by the equation $n\lambda = d\sin\theta$.

Doppler shift: The frequency received from a moving source can be determined from the equation $f' = f\dfrac{v}{(v \pm u_s)}$; the frequency received by a moving observer can be determined from the equation $f' = f\dfrac{(v \pm u_o)}{v}$.

E

Eddy currents: Circulating currents induced in solid pieces of metal when changing magnetic fields pass through them.

Efficiency (thermodynamic), η: Useful work done / energy input. For a Carnot cycle, maximum efficiency, $\eta_{carnot} = 1 - (T_c/T_h)$.

Electric potential energy, E_p: For two point charges, potential energy can be determined from the equation: $E_p = kq_1q_2/r$.

Electric potential, V_e: Work done in moving a test positive charge +1C to a specified point from infinity. Around a point charge, Q, potential can be determined from the equation: $V_e = kQ/r$.

Electric potential difference, ΔV_e: Can be determined from the equation: $W = q\Delta V_e$.

Electric potential gradient: Rate of change of electric potential with distance. Equal in magnitude to the field strength. $E = -\Delta V_e/\Delta r$.

Electromagnetic induction: Production of an emf across a conductor that is experiencing a changing magnetic flux. This may be as a result of moving through a magnetic field, moving a magnetic field through a conductor, or a time-changing magnetic flux passing from one circuit to another (without the need for any physical motion).

Electromagnetic induction in a straight conductor: When a straight wire moves perpendicularly across a magnetic field the induced emf can be determined from the equation $\varepsilon = BvL$ (or $\varepsilon = BvlN$ if there are N turns).

Energy levels of hydrogen: Because hydrogen is the atom with the simplest structure, scientists were very interested in determining the energy levels of the electron within the atom by examining hydrogen's line spectrum. They were able to show that the energy levels could be predicted by the empirical equation $E = 13.6/n^2$ (eV). This equation was explained later by using the Bohr model of the hydrogen atom.

Entropy, S: A measure of the disorder of a thermodynamic system of particles. $S = k_B \ln \Omega$, where Ω is the number of possible microstates. The SI units of entropy are JK^{-1}.

Entropy change: When an amount of thermal energy, ΔQ, is added to, or removed from, a system at constant temperature T, the change in entropy, ΔS, can be calculated from the equation $\Delta S = \Delta Q/T$.

Equations for rotational motion with uniform acceleration:

$\Delta\theta = \frac{(\omega_f + \omega_i)t}{2}$;

$\omega_f = \omega_i + \alpha t$;

$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$;

$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$.

Equipotential line (or surface): Line (or surface) joining points of equal potential. Equipotential lines are always perpendicular to field lines.

Escape speed: Minimum theoretical speed that an object must be given in order to move to an infinite distance away from a planet (or moon, or star): $v_{escape} = \sqrt{\frac{2GM}{R}}$. This assumes that air resistance is insignificant.

Ether (or aether): A hypothetical substance, proposed (falsely) to be the medium through which electromagnetic waves travel.

Event (relativity): A single incident that occurs exactly at a specified time and place.

Exponential radioactive decay: Represented by the equation $N = N_0 e^{-\lambda t}$. N_0 is the number of undecayed nuclei at the start of time t and N is the number remaining at the end of time t. Alternatively, equations of the same form can be used with activity, A, or the count rate. Activity is linked to the initial number of atoms by the equation $A = \lambda N_0 e^{-\lambda t}$.

Extended object: An object that has dimensions. Not a point.

F

Faraday's law of electromagnetic induction: The magnitude of an induced emf is equal to the rate of change of magnetic flux, $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$. For an explanation of the negative sign, see Lenz's law.

Fermi radius, R_0: Constant in the equation for nuclear radius ($R = R_0 A^{1/3}$). Equal to the value of R for $A = 1$. ($= 1.20 \times 10^{-15}$ m).

First law of thermodynamics: If an amount of thermal energy, $+Q$, is transferred *into* a system, then the system will *gain* internal energy, $+\Delta U$, and/or the system will expand and do *work on the surroundings*, $+W$: $Q = \Delta U + W$. (This is an application of the principle of conservation of energy.)

Flywheel: Dense, cylindrical (usually) mass with a high moment of inertia – added to the axes of rotating machinery to resist changes of motion and/or to store rotational kinetic energy.

Fulcrum : See pivot.

G

Galilean relativity: How relative motions were described before the discovery of special relativity.

Galilean transformation: The non-relativistic method of mathematically relating observations between reference frames. $x' = x - vt$ and $t' = t$

Galvanometer: Ammeter that measures very small currents.

Gamma ray spectrum: Range of discrete photon energies that may be emitted from a single radionuclide.

Generator (ac): A device containing coils that rotate in a magnetic field (or a field that rotates within coils), transferring kinetic energy to the energy carried by an alternating electric current.

Gravitational potential, V_g: Work done in moving a test mass of 1 kg to a specified point from infinity. In a radial field around a point mass M, $V_g = -GM/r$

Gravitational potential difference: Difference in gravitational potential, ΔV_g, between two points. Can be determined from the equation: $W = m\Delta V_g$

Gravitational potential gradient: Rate of change of potential with distance, equal in magnitude to field strength. $g = -\Delta V_g/\Delta r$

Gravitational potential energy, E_p: For two point masses, this can be determined from the equation: $E_p = -Gm_1m_2/r$.

H

Heat pump: Device which transfers thermal energy from a hotter place to a colder place by doing work.

Hinge: Device which connects two solid objects allowing one (or both) to rotate in one direction.

Hollow charged sphere: There is a constant potential within the sphere, which means that the electric field is zero. Faraday cages are examples.

Hypothesis: A suggested explanation of a phenomenon (but not proven).

I

Inertial reference frame: A frame of reference that is neither accelerating nor experiencing a gravitational field, in which masses, having no unbalanced forces on them, obey Newton's first law, i.e. they move in straight lines with constant speed. The postulates of special relativity are valid in an inertial frame.

Internal energy of an ideal gas (changes), ΔU: Changes of internal energy can be determined from: $\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}Nk_B\Delta T$.

Invariant quantity: A quantity that has a value that is the same in all reference frames. In relativity, examples are the speed of light in a vacuum, space–time interval, proper time interval, proper length, rest mass and electrical charge.

Irreversible process: A process which cannot be reversed, and in which entropy always increases. All real macroscopic processes are irreversible.

Isobaric: Occurring at constant pressure. $\Delta p = 0$.

Isothermal: Occurring at constant temperature, $\Delta T = 0$. In a closed thermodynamic system, $\Delta U = 0$, so that $Q = W$. An idealized isothermal process can be approximated to by slow changes.

Isovolumetric: Occurring at constant volume. In a closed thermodynamic system, $W = 0$, so that $Q = \Delta U$.

Iteration: Mathematical procedure that repeatedly calculates the changes that occur during small increments, in order to determine an overall result.

L

Law of radioactive decay: The number of nuclei that decay per second, $\Delta N/\Delta t$ (called the activity, A, of the source) is proportional to the number of radioactive atoms still present that have not yet decayed, N: $-\Delta N/\Delta t = \lambda N$, where λ represents a constant, known as the decay constant. If N_0 is the number of undecayed atoms at the start of time t: $N = N_0 e^{-\lambda t}$

Length contraction: The contraction of a measured length of an object relative to the proper length of the object due to the relative motion of an observer.

Length contraction formula: $L = L_0/\gamma$, where L represents the length, L_0 represents the proper length as measured by an observer who is stationary relative to the length being measured and γ represents the Lorentz factor.

Lenz's law (of electromagnetic induction): The direction of an induced emf is such that it will oppose the change that produced it. This is represented mathematically by the negative sign in the equation representing Faraday's law.

Lorentz factor, γ: Scaling factor that describes the distortion of (non-invariant) quantities when moving between different relativistic reference frames: $\gamma = \frac{1}{(\sqrt{1 - v^2/c^2})}$, where c is the speed of light in a vacuum and v is the relative speed of the second reference frame. The Lorentz factor ranges from close to one at classical speeds to infinity near the speed of light in a vacuum.

Lorentz transformations: The mathematical formulae used to calculate the new position and time coordinates, or spatial and temporal intervals, when transferring from one relativistic reference frame to another. $x' = \gamma(x - vt)$ and $t' = \gamma(t - vx/c^2)$

M

Magnetic flux, Φ : Defined as the product of an area, A, and the component of the magnetic field strength perpendicular to that area, $B\cos\theta$. $\Phi = BA\cos\theta$ (SI unit: Weber, Wb).

Magnetic flux density, B: The term more commonly used at Higher Level for magnetic field strength. $B = \Phi/A$. (SI unit: $\mathrm{Wb\,m^{-2}}$)

Magnetic flux linkage, $N\Phi$: The product of magnetic flux and the number of turns in a circuit (SI unit: Weber, Wb).

Matter waves: Waves that represent the behaviour of elementary particles, atoms, ions or molecules under certain conditions. See de Broglie's hypothesis.

Michelson–Morley experiment: An experiment designed to measure the Earth's speed through the ether. The famous null result was the prime reason for the abandonment of the ether idea, which then contributed to the development of special relativity.

Microstates: The numerous possible combinations of microscopic properties of a thermodynamic system.

Modulation: Changing the amplitude (or frequency) of a wave according to variations in a secondary signal or effect.

Moment (of a force): Term sometimes used as an alternative to torque, especially if rotation is incomplete.

Moment of inertia, I : The resistance to a change of rotational motion of an object, which depends on the distribution of mass around the chosen axis of rotation. The moment of inertia of a point mass is given by $I = mr^2$ (SI unit: $\mathrm{kg\,m^2}$). The moment of inertia of any real, extended mass can be determined by the addition of the individual moments of inertia of its particles. This is represented by $I = \Sigma mr^2$.

Multiple slits: By increasing the number of parallel slits (of the same width) on which a light beam is incident, it is possible to improve the resolution of the fringes / spectra formed. A large number of parallel slits close together is called a diffraction grating.

Muon: Subatomic particle with the same charge as an electron but with 207 times the rest mass. It is unstable, decaying with a half-life of 1.5×10^{-6} s, typically into an electron, a neutrino and an antineutrino.

Muon decay experiment: A important experiment supporting both time dilation and length contraction. The experiment compares the levels of high-energy muons found in the atmosphere at around 10 km with those found at the Earth's surface, using the muon half-life as a means of measuring time. Classical physics predicts that the number of muons reaching the Earth's surface should be a tiny fraction of those that are formed in the upper atmosphere. The measured result of around 20% matches the predictions of relativity.

Mutual induction: Electromagnetic induction between separate circuits.

N

Newton's second law for angular motion: $\Gamma = I\alpha$.

Nuclear density: Assuming that the nucleus is spherical, nuclear density can be determined from nuclear mass ($\approx Au$) divided by the volume of a sphere having the appropriate nuclear radius. All nuclear densities are similar in magnitude and are extremely large.

Nuclear energy levels: The emission of alpha particles and gamma rays with discrete energies during radioactivity indicates that nuclei have discrete energy levels.

Nuclear radius, *R*: R is proportional to the cube root of the nucleon number. $R = R_0A^{1/3}$, where R_0 is called the Fermi radius.

Nuclear transition: A change in nuclear energy level that results in the emission (or absorption) of a high-energy photon.

O

Observer: The concept of an (often imaginary) person able to use their senses, or instrumentation, to record information about events.

Orbital energy: An orbiting satellite has both gravitational potential energy and kinetic energy: $E_p = -G\frac{Mm}{r}$ and $E_k = +\frac{1}{2}G\frac{Mm}{r}$.

Adding these together gives the total energy: $E_T = -\frac{1}{2}G\frac{Mm}{r}$.

Orbital speed: For a satellite in a circular orbit, its speed must have the correct value for the chosen radius: $v_{orbital} = \sqrt{\frac{GM}{r}}$.

Order and disorder (particle): The way in which particles are arranged, or energy is distributed, can be described in terms of the extent of patterns and similarities. See entropy.

P

Phase angle: The difference in angular displacement of an oscillation compared to an agreed reference oscillation. Expressed in terms of π radians.

Photoelectric effect: Ejection of electrons from a metal surface by incident electromagnetic radiation. Sometimes called photoemission.

Photoelectric equation: The maximum kinetic energy of an emitted photoelectron is the difference between the incident photon's energy and the work function, Φ: $E_{max} = \frac{1}{2}mv_{max}^2 = hf - \Phi$.

Photoelectrons: Electrons ejected in the process of the photoelectric effect.

Postulate: See axiom.

Postulates of classical (Newtonian) physics: A unit of time, space or mass is invariant throughout the Universe. The laws of mechanics are true in all reference frames.

Postulates of special relativity: The speed of light in a vacuum is the same for all inertial observers. The laws of physics are the same for all inertial observers.

Principal quantum number, *n*: Number used to describe the energy level of an atom. The lowest energy level is called the ground state, with $n = 1$, the next level has $n = 2$ and so on.

Principle of moments: If an object is in rotational equilibrium, the sum of the clockwise moments (torques) equals the sum of the anticlockwise moments (torques).

Proper length L_0: The proper length of an object is the length measured by an observer who is at rest relative to the length being measured. The proper length is always the longest length measurable by any observer; all other observers must measure a contracted length.

Proper time interval t_0: The time interval between two events as measured by an observer who records the two events occurring at the same point in space. It is the shortest time interval between events measured by any observer.

***PV* diagram:** A graphical way of representing changes to the state of a gas during a thermodynamic process.

Q

Quantum mechanics: The mathematical aspects of quantum physics.

R

Radial force fields: Surround point masses and point charges.

Reference frame: A coordinate system from which events in space and time are measured. The reference frame is commonly a set of objects that remain at rest relative to one another, from which spatial measurements can be taken, and a timing system consisting of a set of virtual clocks.

Relativistic motion: Travelling at a significant fraction of the speed of light so that the Lorentz factor cannot be assumed to be 1.

Reservoir (thermal): Part of the surroundings of a thermodynamic system that is kept at (approximately) constant temperature and is used to encourage the flow of thermal energy.

Resolution (optical): The ability of an imaging system to identify objects as separate.

Reversible process: A process that can be reversed so that the system and all of its surroundings return to their original states and there is no change in entropy. An impossibility in the macroscopic world.

Revolve: To move around a central point or axis (usually outside of the revolving object).

Rigid: Does not change shape.

Roll: Rotation of an object along a surface in which the lowest point of the object is instantaneously stationary. Requires friction. Compare with slipping.

Rotate: To move around a central point or axis (usually inside the rotating object).

Rotational dynamics: Branch of physics and engineering that deals with rotating objects.

Rotational equilibrium: Describes an object that is rotating with constant angular velocity (including being stationary). Occurs when there is no resultant torque acting.

Rotational kinetic energy, E_k: Kinetic energy due to rotation, rather than translation. $E_k = \frac{1}{2}I\omega^2 = L^2/2I$

Rutherford scattering: Sometimes called Coulomb scattering. The scattering of alpha particles by nuclei, which can only be explained by the action of an inverse square law of electric repulsion. For particles that are scattered through 180°, their initial kinetic energy can be equated to the electric potential energy when closest to the nucleus. This provides an estimate for the radius of the nucleus. When high-energy particles are used, they may get very close to the nucleus, so that strong nuclear forces are also involved and then the scattering will no longer follow the same pattern.

S

Second law of thermodynamics: The overall entropy of the universe is always increasing. This implies that energy cannot spontaneously transfer from a place at low temperature to a place at high temperature. Or, in the Kelvin version: when extracting energy from a heat reservoir, it is impossible to convert it all into work.

Secondary waves: The propagation of waves in two or three dimensions can be explained by considering that each point on a wavefront is a source of secondary waves.

Self-induction: Electromagnetic induction within a single circuit.

Simple harmonic motion (SHM): General equation: $a = -\omega^2 x$. Equation for displacement: $x = x_0 \sin(\omega t + \phi)$. Equation for velocity: $v = \omega x_0 \cos(\omega t + \phi)$. The velocity can also be determined from the displacement and amplitude: $v = \pm\omega\sqrt{x_0^2 - x^2}$.

Simple harmonic oscillator energies: All SHM continuously interchanges potential energy ($E_P = \frac{1}{2}m\omega^2x^2$) and kinetic energy. Total energy, $E_T = \frac{1}{2}m\omega^2x_0^2$)

Simultaneous events: Events that occur at the same time in a specific reference frame, so that in this reference frame they have the same time coordinates. Events that are simultaneous in one frame may not be so in another frame.

Single-slit diffraction: The simplest diffraction pattern is that produced by wavefronts interfering after they have passed through a narrow, rectangular slit. Minima occur at angles such as that $\theta = n\lambda/b$.

Sliding: Surfaces moving over each other without any rotation involved.

Slipping (wheel): Occurs when there is not enough friction between a wheel and the surface to maintain a rolling motion.

Slip rings and brushes: In an ac generator these are used for connecting the rotating coil to the external circuit.

Space-time: The combination in relativity of space and time into a single entity that is used to describe the fabric of the Universe. Fundamentally, in relativity, time and space are not independent of each other. They are observed differently depending on the relative motion of an observer.

Space–time diagram: A graph showing variations of objects' positions with time, adapted to compare different frames of reference.

Space–time interval, Δs: Δs^2 as the distance between two events across space–time squared. A space–time interval combines both the spatial and temporal elements of spacetime into a single value. $(\Delta s)^2 = (c\Delta t)^2 - \Delta x^2$

Spatial: To do with the dimensions of space. A spatial interval is a length in space.

Special relativity: Theory connecting space and time developed by Albert Einstein based on two postulates. The consequences lead to time dilation, length contraction and the equivalence of mass and energy.

Spectral orders: Considering the diffraction grating equation, $n\lambda = d\sin\theta$: different orders correspond to different values of n.

Stopping voltage (potential): The minimum voltage required to reduce a photoelectric current to zero.

Synchronization: Arrangement of events so that they occur at the same time.

Synchronized: Two clocks are said to be synchronized if, according to an observer, they are reading the same time.

T

Temporal: To do with time. A temporal interval is an interval of time.

Thermodynamics: Branch of physics involving transfers of thermal energy to do useful work.

Threshold frequency, f_0 : The minimum frequency of a photon that can eject a photoelectron from the surface of a metal.

Time dilation: Relative to an observer who sees the two events occurring in the same place, and so measures the proper time between the two events. All other observers measure an increase in the time interval between two events. The faster an observer is moving, relative to the observer measuring proper time, the greater the time dilation.

Time dilation formula: $\Delta t = \gamma\Delta t_0$, where Δt_0 represents the proper time interval as measured by an observer who sees the first and second events occur in the same place, Δt represents that time interval between the same two events as measured by an observer in a different reference frame, and γ represents the Lorentz factor.

Torque, τ: Product of a force and the perpendicular distance from the axis of rotation to its line of action: $\tau = Fr\sin\theta$ (SI unit: N m).

Transformer: A device that transfers electrical energy from one circuit to another using electromagnetic induction between coils wound on an iron core. Transformers are used widely to transform one alternating voltage to another of different magnitude.

Transmission of electrical power: Electrical power is sent (transmitted) from power stations to different places around a country along wires (cables), which are commonly called transmission (or power) lines. These lines are linked together in an overall system called the transmission grid.

Twin paradox: A paradox that appears to challenge special relativity, based on the impossibility that two twins should each find that they are older than the other. One twin remains on Earth while the other travels at high speed to a distant star and returns. Both twins claim that in their own reference frame they are stationary throughout while the other twin moves, so that the paradox appears to be symmetrical. However, the situation is not symmetrical because the travelling twin has not been in an inertial reference frame throughout and will be younger when returned to Earth than the Earth-bound twin.

V

Velocity addition: If, in reference frame S the velocity of an object is u, in a reference frame S′, which has relative velocity of v compared to S, the same movement will be recorded as having a velocity: in Galilean relativity $u' = u - v$; in special relativity $u' = \dfrac{u - v}{1 - uv/c^2}$.

W

Wave–particle duality: Theory that all particles have wave properties and that all electromagnetic waves have particle properties.

Weber, Wb: SI unit of magnetic flux. $1\,\text{Wb} = 1\,\text{T m}^2$.

Work done when a gas changes volume, W: Work is done by a gas when it expands (W is positive). Work is done on a gas when it is compressed (W is negative). At constant pressure $W = P\Delta V$. If the pressure changes, the work done can be determined from the area under a PV diagram.

Work function, Φ: The minimum amount of energy required to free an electron from the attraction of ions in a metal's surface. Since the energy of the incident photons is equal to hf, $hf_0 = \Phi$, where f_0 represents the threshold frequency.

Working substance: The substance (usually a gas) used in thermodynamic processes to do useful work.

World line: The path that an object traces on a space–time diagram. The angle between the world line and the time axis is given by $\tan\theta = v/c$.

X

X-ray diffraction (crystallography): Investigating the arrangments of atoms and molecules in matter by detecting how X-rays are diffracted by crystalline materials. X-ray wavelengths are comparable to atomic dimensions.