

## A

**AC generator** a generator in which the induced current alternates or changes its direction every half-cycle; the current from an AC generator has a sinusoidal form (16.3)

**acceleration** the rate of change of velocity of an object; the quotient of the change in velocity and the time interval over which the velocity is changing; acceleration is a vector quantity; also known as *average acceleration* (2.4)

**acceleration due to gravity** acceleration of an object towards the centre of a planet due to the gravitational attraction of the mass of the planet on the object (4.2)

**accuracy** describes the degree to which the results of an experiment or calculation approximate the true value; compare to *precision* (Skill Set 1)

**action at a distance** the description of the force between two objects not in contact (14.2)

**air resistance** friction due to the motion of an object through air; proportional to the object's velocity (5.3)

**alpha particle** one or more helium nuclei ejected from a radioactive nucleus (20.2)

**alternator** a device that uses diodes to rectify the output of an AC generator (16.3)

**ammeter** a device that measures the current to or from a circuit element (13.2)

**ampere** the unit of electric current equivalent to one Coulomb of charge passing a point in a circuit in one second (15.2)

**amplitude** the distance from the rest position to the maximum displacement for an object in periodic motion; or, for a wave, the distance from the rest position to the maximum point of the crest or minimum point of the trough (7.1, 8.1)

**angle of incidence** the angle between the normal and the ray representing the incoming wave or light (8.4)

**angle of reflection** angle between the normal and the ray reflected from a surface, such as a mirror (8.4)

**angle of refraction** angle that the refracted light ray or wave makes with the normal of the surface or boundary (9.2)

**anode** the positive pole of a primary cell or battery (15.1)

**antineutrino** see neutrino

**antinodal line** a stationary line of points caused by constructive interference of individual waves (8.4)

**antinode** positions of maximum amplitude of a standing wave, located halfway between the nodes, caused by the constructive interference of two individual waves travelling in opposite directions (8.3)

**apparent weight** the weight measured by a scale; same as true weight, unless the scale is placed on an object that is accelerating (5.3)

**armature** see rotor

**atomic mass number** the number ( $A$ ) that represents the total number of protons and neutrons in an atomic nucleus (20.1)

**atomic mass unit** the value of mass equal to mass of the most common carbon isotope ( $^{12}_6\text{C}$ ) divided by 12;  $1 \text{ u} = 1.6605 \times 10^{-27} \text{ kg}$  (20.1)

**atomic number** the number ( $Z$ ) that represents the number of protons in the nucleus; also represents the charge of the nucleus in units of  $e$  (20.1)

**average acceleration** another term for *acceleration*, calculated as the quotient of the change in velocity and the time interval over which the velocity is changing; the calculation of the average acceleration ignores the fact that the acceleration could change within the time interval (2.4)

**average velocity** another term for *velocity*; calculated as the quotient of the displacement and the time interval; the calculation of the average velocity ignores the fact that the velocity could change within the time interval (2.2)

## B

**back *emf*** an *emf* generated by a current-carrying wire moving in a magnetic field; its direction opposes the direction of the current (16.3)

**Balmer series** spectral lines of hydrogen that lie in the visible wavelength range (19.1)

**battery** a combination of two or more voltaic cells that can convert chemical energy into electrical energy (15.1)

**beat frequency** the number of cycles of loud-quiet-loud produced per second; determined as the absolute value of the difference between the frequencies of the two component waves (9.3)

**beats** periodic variations in amplitude of a wave caused by two waves of nearly the same frequency producing sound waves at the same time (9.3)

**beta particle** high speed electrons or positrons ejected from a radioactive nucleus (20.2)

**binding energy** the amount of energy that must be supplied to nuclear particles in order to separate them (20.1)

**blackbody** an object that absorbs and emits all radiation of all possible frequencies (18.1)

**Bohr radius** the distance from the nucleus of the lowest allowed energy level in the hydrogen atom:  $r = 0.052\ 917\ 7\ \text{nm}$  (19.1)

## C

**cathode** the negative electrode of an electrolytic cell; the positive pole of a primary cell or a battery (15.1)

**centre of mass** the point at which an object can be balanced (10.3)

**centripetal acceleration** the centre-directed acceleration of a body moving continuously along a circular path; the quotient of the square of the object's velocity and the radius of the circle (11.2)

**centripetal force** the centre-directed force required for an object to move in a circular path (11.2)

**Cerenkov radiation** the eerie blue glow due to particles such as electrons travelling in a medium (such as water) at a speed faster than the speed of light; same effect for light as Doppler effect is for sound (9.2)

**chemical symbol** a shorthand symbol for an element (20.1)

**circuit elements** parts of a circuit, such as the loads and power source (15.2)

**classical mechanics** see Newtonian mechanics

**classical physics** the long-established parts of physics, including Newtonian mechanics, electricity and magnetism, and thermodynamics, studied before the twentieth century (18.1)

**closed air column** an air column that is closed at one end and open at the other (9.3)

**closed circuit** a complete circuit, in which current is able to flow (15.2)

**closed system** a system that can exchange energy with its surroundings, but not with matter (7.2)

**coefficient of friction** the ratio of frictional force to the normal force between two object surfaces (4.2)

**coherence source** source producing waves of the same frequency and in phase of each other (9.3)

**commutator** a device which passes current to or from the rotor (or armature) in an electric motor or generator (16.2)

**component wave** a wave that combines with another wave to produce a resultant wave (8.3)

**compression** a region of higher air pressure compared to the surrounding medium; longitudinal waves have both compressions and rarefactions (9.1)

**Compton effect** a phenomenon involving the scattering of an X-ray photon with a “free” electron, in which, through conservation of energy and momentum, some of the photon's energy is transferred to the electron (18.2)

**conductor** a material, like a metal, that allows electric charges to flow easily (15.1)

**conservation of mechanical energy** when all the work done throughout a process is done by conservative forces, the total mechanical energy (kinetic plus potential) of the isolated system after the process is zero (7.1)

**conservation of momentum** the total momentum of two objects before a collision is the same as the total momentum of the same two objects after they collide (7.2)

**conservative force** a force that does work on an object in such a way that the amount of work done is independent of the path taken; work done by conservative forces is zero for motions in which the object returns to the starting point; force of gravity is an example of a conservative force (7.1)

**constant acceleration** acceleration that is not changing over a certain interval of time; also known as *uniform acceleration* (2.4)

**constructive interference** the situation when a combined or resultant wave has a larger amplitude than its component waves (8.3, 9.3)

**contact force** the force exerted by an object in direct contact with another object (4.2)

**control rods** rods made of cadmium or boron used to keep fission reactions in nuclear reactors at the critical level; the rods absorb exactly the right amount of neutrons so that exactly one neutron from each fission reaction causes one more fission reaction (21.2)

**coolant** link between the energy released by fission reactions in nuclear reactors and the production of electrical energy (21.2)

**coordinate system** a frame of reference for an observation or a vector diagram; typically consists of perpendicular axes that are divided into positive and negative sections (3.2)

**Coulomb's constant** the proportionality constant in Coulomb's law:  $k = 9.00 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$  (14.1)

**Coulomb's law** the electrostatic force between charges at rest is directly proportional to the magnitudes of the charges and inversely proportional to the square of the distance between their centres (14.1)

**counterweight** a heavy, movable mass that balances another mass (10.2)

**crest** the highest point on a wave (8.2)

**critical** the condition that one neutron from each fission event causes one more nucleus to fission: the reaction will be sustained at a constant rate (21.2)

**critical angle** the angle of incidence that produces a refracted light ray at an angle of  $90^\circ$  from the normal (9.2)

**Curie point** the temperature above which a magnet, when heated, loses its permanent magnetism and is totally destroyed (16.1)

**current** see electric current

**cycle** one complete repeat of a pattern of periodic motion, such as the crest of a wave to the next crest (8.1)

## D

**daughter nucleus** the nucleus remaining after a transmutation reaction (20.2)

**DC generator** a generator in which the current always leaves in the same direction (16.3)

**de Broglie wavelength** the wavelength associated with a particle; the quotient of Planck's constant and the momentum of the particle (18.2)

**destructive interference** the situation when a combined or resultant wave has a smaller amplitude than its component waves (8.3, 9.3)

**diffraction** the bending of waves around a barrier (8.4)

**diffuse reflection** the reflection in which the reflected light rays are not parallel to one another, as they are from a rough surface (9.1)

**dilated time** the time measured by an observer who sees a clock in a frame of reference that is moving relative to the observer (17.2)

**displacement** a vector quantity that points between the initial position and final position of an object in a particular frame of reference (2.2)

**displacement antinode** location of a region of maximum amplitude for a standing wave in a column (9.3)

**displacement node** location of a region of minimum amplitude for a standing wave in a column (9.3)

**domain** small region under a particular magnetic influence so that all its magnets point a particular direction (16.1)

**Doppler effect** change in the observed frequency (or wavelength) of a sound due to motion of the source or the observer (9.2)

**dynamics** the study of the motions of bodies while considering their masses and the responsible forces; simply, the study of *why* objects move the way they do (4.1)

## E

**echolocation** procedure used by some animals to locate obstacles and prey; sound pulses are emitted and the reflected pulses are interpreted to determine the size and location of the object, as well as its speed and direction (9.1)

**eddy currents** electric currents induced within the body of a conductor when that conductor is subjected to a changing magnetic field; these currents create their own magnetic field which opposes the motion that caused the currents (16.3)

**efficiency** the ratio of useful energy (or work output) to the total energy (or work input); describes how well a machine or device converts input energy or work into output energy or work (6.4)

**elastic** the description of a material that can return precisely to its original form after the applied force, such as a stretch or a compression, is removed (6.3)

**elastic collision** a collision in which both momentum and kinetic energy are conserved (7.2, 10.4)

**elastic potential energy** a form of energy that accumulates when an elastic object is bent, stretched, or compressed (6.3)

**electric current** the quantity of positive charge passing a given point during a particular time interval in a circuit, measured in amperes; the flow of positive charge from anode to cathode in a circuit (15.2)

**electric field** a region in space that influences electric charges in that region (14.2)

**electric field intensity** the quotient of the electric force on a unit charge and the magnitude of the charge located at that point; the product of

- Coulomb's constant and the charge, divided by the square of the distance from the charge (14.2)
- electric field lines** imaginary directed lines that indicate the path a tiny point charge with zero mass would take if free to move in the electric field; these lines radiate away from positive charges and toward negative charges (14.2)
- electric potential difference** a measure of the amount of electric effort a battery or power supply can expend to push a current through a conductor; calculated as the change in electrical potential energy per unit charge between two locations, such as between two points in a circuit (14.3, 15.1)
- electric resistance** the resistance to the flow of electric current in a circuit; like frictional force that resists motion (15.3)
- electrode** an electric conductor through which a current enters or leaves an electric device, such as a voltaic cell (15.1)
- electrolyte** a solution that conducts electricity between two electrodes in a voltaic cell (15.1)
- electromagnet** a magnet created by placing an iron core inside a solenoid (16.1)
- electromagnetic induction** the generation of a current in a wire (circuit) due to the relative motion of the wire and a magnetic field (16.3)
- electromagnetism** phenomena associated with moving electrons producing a magnetic field and a changing magnetic field causing electrons to move (16.1)
- electromotive force (*emf*)** the potential difference across the terminals of a source of electrical energy; equivalent to the terminal voltage plus the potential difference across the internal resistance (15.4)
- electron flow** the flow of negative charge from cathode to anode in a circuit (15.2)
- electron volt** the energy gained by one electron as it falls through the potential difference of one volt:  $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$  (18.1)
- electrostatic force** the force between charges at rest; see also: Coulomb's law (14.1)
- electrostatics** the study of electrical charges at rest (15.1)
- elementary charge** the quantity of charge on an electron or proton, the basic unit of charge:  $e = 1.60 \times 10^{-19} \text{ C}$  (15.2)
- empirical equation** an equation that fits the observed data but is not based on any theory (18.1)
- enriched uranium** fissionable isotope of uranium with the percent of uranium-235 increased (21.2)
- equations of motion** set of mathematical equations describing uniform acceleration that relate velocity, displacement, acceleration, and time (3.1)
- equipotential surface** a surface in which all points have the same electric or gravitational potential (14.3)
- equivalent resistance** the calculated total resistance of a group of resistors combined either in series or parallel or both (15.4)
- error analysis** the process of estimating the errors in each measurement of an investigation; individual errors are written as percentages of the measured value (Skill Set 1)
- estimated uncertainty** error in a measurement due to the natural limitations of the measuring device; usually described as half of the smallest division of the measuring device (Skill Set 1)
- external force** any force exerted by an object that is not part of the system on an object within the system (7.2)

## F

- fictitious force** an inertial effect that is perceived as a force in a non-inertial frame of reference, but does not exist in an inertial frame of reference (5.3)
- field** a region in space that influences a mass, charge, or magnet placed in the region (14.2)
- force** an action, like a push or a pull, that causes a change in motion of an object (4.1)
- frame of reference** a subset of the physical world defined by an observer in which positions or motions can be discussed or compared (2.1)
- framing the problem** is a way to set parameters (important boundaries) and organize them in a way best suited to a particular problem (1.2)
- force of gravity** see gravitational force
- free body diagram** a diagram used to aid in solving dynamics problems in which all the forces acting on an object are shown as acting on a point representing the object (4.2)
- free fall** a situation in which gravity is the only force acting on an object (5.3)
- frequency** number of cycles of periodic motion completed in a unit of time; frequency is the inverse of the period and is measured in  $\text{s}^{-1}$  or hertz (1.3, 8.1)

**friction** a force that resists motion (4.2)

**fringe** a bright or dark band produced by interference of light (9.3)

**fundamental frequency** the lowest natural frequency that will produce resonance in a standing wave pattern (8.3)

**fundamental mode of vibration** the standing wave pattern for a medium vibrating at its fundamental frequency and displaying the fewest number of nodes and antinodes (8.3)

## G

**gamma ray** high frequency electromagnetic wave emitted from a radioactive nucleus (20.2)

**generator effect** the generation of a current in a coil due to the motion of a magnet (16.3)

**geostationary orbit** the orbit of a satellite around Earth's equator, which gives the satellite the appearance of hovering over the same spot on Earth's surface at all times (12.2)

**gravitational field intensity** the quotient of the gravitational force and the magnitude of the test mass at a given point in the field; the product of the universal gravitational constant and mass, divided by the square of the distance from the centre of the object creating the field (14.2)

**gravitational field lines** imaginary directed lines that indicate the path a tiny test mass would take if free to move in the gravitational field; these lines radiate inward toward the mass that generates them (14.2)

**gravitational force** the force that operates between masses; the gravitational force has an infinite range (4.2)

**gravitational mass** the property of matter that determines the strength of the gravitational force; compare to: inertial mass (4.1)

**gravitational potential difference** the gravitational potential energy per unit mass, which depends only on the altitude and the acceleration due to gravity (15.1)

**gravitational potential energy** the potential energy an object has because of its location in a gravitational field; objects at higher altitudes have greater gravitational potential energy than objects at lower altitudes (6.3)

**ground state** the lowest possible state that an electron can occupy in an atom (19.2)

## H

**half-life** the time in which the amount of a radioactive nuclide decays to half its original amount (20.2)

**harmonic** an overtone whose frequency is a whole number multiple of the fundamental frequency (9.3)

**hertz (Hz)** unit used to measure frequency, defined as  $s^{-1}$  (8.1)

**Hooke's law** states that the applied force is directly proportional to the amount of extension or compression of a spring (6.3)

## I

**impulse** the product of the force exerted on an object and the time interval over which the force acts (5.4)

**impulse-momentum theorem** states that the impulse is equal to the change in momentum of an object involved in an interaction (5.4)

**in phase** the periodic motion of two individual systems vibrating with the same frequency is said to be in phase if they each reach the same amplitude at the same time (8.1)

**index of refraction** the ratio of the speed of light in a vacuum to the speed of light in a specific medium (9.2)

**inelastic collision** a collision in which momentum is conserved, but kinetic energy is not conserved (7.2, 10.4)

**inertia** the natural tendency of an object to stay at rest or continue its motion in a straight line at constant speed in the absence of outside forces; objects with greater mass have greater inertia (4.1)

**inertial frame of reference** a frame of reference in which the law of inertia is valid; it is a non-accelerating frame of reference (5.1)

**inertial mass** the property of matter that resists a change in motion; compare to: gravitational mass (4.1)

**instantaneous acceleration** the acceleration of an object at a particular time; calculated as the slope of the tangent to the curve of an object's velocity-time graph at that particular time (2.4)

**instantaneous velocity** the velocity of an object at one instant in time; calculated as the slope of the tangent to the curve of an object's position-time graph at that particular time (2.3)

**insulator** a material that does not allow electric charges to move easily (15.1)

**interference of waves** how waves react when they meet (8.3)

**interferometer** an instrument for measuring wavelengths of light by allowing light beams to interfere with each other (17.1)

**internal force** any force exerted on an object in the system due to another object in the system (7.2)

**internal resistance** the resistance inside a battery or power supply (15.4)

**inverse square law** the relationship in which the force between two objects is inversely proportional to the square of the distance that separates the centres of the objects; for example, the gravitational and electrostatic forces (14.1)

**ionizing radiation** radiation of sufficient energy to liberate the electrons from the atoms or molecules (20.2)

**isolated system** a system that does not exchange either matter or energy with its surroundings (7.2)

**isotope** two or more atoms of an element that have the same number of protons but a different number of neutrons in their nuclei (20.1)

## J

**joule (J)** the SI unit of energy or work; equivalent to applying one newton of force on an object over a distance of one metre (6.1)

## K

**Kepler's laws** three empirical relationships that describe the motion of planets (12.1)

**kilowatt-hour** the energy transformed by a power output of 1000 W for one hour; equivalent to  $3.6 \times 10^6$  J (15.5)

**kinematics** the study of the motions of bodies without reference to mass or force; the study of *how* objects move in terms of displacement, velocity, and acceleration (4.1)

**kinetic energy** the energy of an object due to its motion (6.1)

**kinetic frictional force** a frictional force that acts to slow the motion of an object; measured as the force required to just keep an object sliding over another object (4.2)

## L

**law of conservation of energy** the total energy of an isolated system, including all forms of energy, always remains constant; energy can neither be

created nor destroyed, but it may be converted from one form to another or transferred from one object to another (7.2)

**law of reflection** the angle of incidence of a light ray on any surface is equal to the angle of reflection (both angles are measured with respect to the normal of the surface) (9.1)

**law of refraction** see Snell's law

**law of universal gravitation** the force of gravity between any two objects is proportional to the product of their masses and inversely proportional to the square of the distance between their centres (12.1)

**length contraction** a consequence of special relativity, in which an object at rest in one frame of reference will appear to be shorter in the direction parallel to its motion in another frame of reference (17.2)

**Lenz's law** when a conductor interacts with a magnetic field, there must be an induced current that opposes the interaction, because of the law of conservation of energy (16.3)

**lever arm** the perpendicular distance between the line along which the force is acting and the pivot point of a rotation (10.3)

**light ray** an imaginary arrow that points in the direction of the propagation of light; like mechanical waves, a light ray is perpendicular to a wavefront (9.1)

**light ray model** a model for finding the image of an object by using light rays to indicate the path that light travels (9.1)

**linear propagation of light** the principle which asserts that in a uniform medium, light always travels in a straight line (9.1)

**loads** devices in an electric circuit that receive power (15.2)

**longitudinal wave** a wave in which the particles of a medium vibrate parallel to the direction of motion of the wave; for example, sound waves (8.2)

**Lorentz-Fitzgerald contraction** contraction of an object in the direction of its motion (17.1)

**loudness** a measure of the strength of a sound (9.1)

## M

**Mach number** ratio of the speed of an object to the speed of sound (9.2)

**magnetic damping** the use of induced magnetic fields to slow down the motion of a conductor moving in a magnetic field (16.3)

**magnetic dipole** another name for a magnet that always has two poles such as a bar magnet (16.1)

**magnetic field intensity** the magnetic force acting on a unit length of a current-carrying wire placed at right angles to the magnetic field, measured in tesla (T) (14.2)

**magnetic field lines** imaginary directed lines that indicate the direction in which the N-pole of a compass would point when placed at that location; these lines radiate out of the magnet's N-pole and into its S-pole and form closed loops in the magnet (14.2)

**magnetic monopole** a theoretical magnet, never observed or created in the lab, which contains only a single pole (either north or south) (16.1)

**magnetic quantum number** determines the orientation of the electron orbitals when the atom is placed in an external magnetic field (19.2)

**mass** the quantity of matter an object contains; determined through the inertial properties of an object or its gravitational influence on other objects (4.1, 4.2)

**mass defect** the difference between the mass of a nucleus and the sum of the masses of its constituent particles; the mass equivalent of the *binding energy* of a nucleus (20.1)

**mechanical energy** the sum of the kinetic energy and potential energy (7.1)

**mechanical wave** a wave that travels through a medium as a disturbance in that medium; the speed of a mechanical wave depends on the medium through which it is travelling (8.2)

**mechanics** the branch of physics comprising kinematics and dynamics; simply, the how and the why of simple motion (4.1)

**medium** a substance, such as air or water or a solid, through which a wave disturbance travels (8.2)

**microgravity** the condition of apparent weightlessness (12.2)

**model** a representation of a phenomenon in a variety of forms; for example, pencil lines on paper or an object that can be manipulated (1.1)

**moderator** a substance that will slow down neutrons (21.2)

**momentum** the product of an object's mass and its velocity (5.4)

**motor effect** the force exerted by a magnet on (the magnetic field of) a current-carrying conductor which drives electric motors (16.2)

**music** a mixture of sound frequencies dominated by harmonics, whole number multiples of the fundamental frequency (9.3)

## N

**natural frequency** the lowest resonant frequency at which an object, like a simple pendulum or mass on a spring, will vibrate when it is allowed to vibrate freely (8.1)

**net force** the vector sum of all forces acting on an object (4.2, 5.2)

**neutrino or antineutrino** a chargeless, very low-mass particle that accounts for all the missing momentum and energy of beta decay (20.2)

**neutron** a particle with zero charge, found in the nucleus of all atoms except the hydrogen atom (20.1)

**Newtonian mechanics** the study of forces and motions by using Newton's laws of motion; these laws are able to describe all large-scale motion on the Earth and in the universe; also called *classical mechanics* (5.1)

**Newton's laws of motion** three fundamental laws of motion which are the basis of Newtonian mechanics are: 1) an object will remain at rest or in straight-line motion unless acted on by an outside force; 2) the acceleration of an object is proportional to the force acting on it and inversely proportional to its mass; 3) for every action force on an object, the object exerts an equal and opposite reaction force (5.1, 5.2, 5.3)

**nodal line** a stationary line of points caused by destructive interference of individual waves (8.4)

**node** stationary points in a medium, half a wavelength apart, produced by destructive interference of two waves travelling in opposite directions (8.3)

**noise** a sound that has no specific pitch; a mixture of many sound frequencies with no recognizable relationship to one another (9.3)

**non-conservative force** a force that does work on an object in such a way that the amount of work done is dependent on the path taken; work done by non-conservative forces is nonzero for motions in which the object returns to the starting point; friction and air resistance are examples of non-conservative forces (7.1)

**non-contact force** the force that acts even though objects are separated by a distance, such as attraction or repulsion between magnets (4.2)

**non-inertial frame of reference** an accelerating frame of reference (5.1)

**non-linear or non-ohmic resistance** devices or materials that do not obey Ohm's law (15.3)

**non-uniform acceleration** the acceleration that is changing with time (2.4)

**non-uniform motion** the velocity is changing, either in magnitude or in direction, or both (2.3)

**normal force** a force that acts in a direction perpendicular to the common contact surface between two objects (4.2)

**normal line** a line perpendicular to a surface or barrier (8.4)

**north-seeking pole** the end of a magnet that points toward the north; commonly known as the north pole (16.1)

**nuclear fission** the splitting of a large nucleus into two lighter nuclei plus two or more neutrons; usually caused by the impact of a neutron and accompanied by the release of energy (21.1)

**nuclear fusion** the formation of a larger nucleus from two lighter nuclei, accompanied by the release of energy (21.1)

**nuclear model** a model for the atom in which all of the positive charge and most of the mass are concentrated in a small area at the centre of the atom, while negatively charged electrons circulate around this "nucleus" (19.1)

**nucleon** the collective term for a particle (proton and/or neutron) in the atomic nucleus (20.1)

**nucleon number** the total number of nucleons (protons and neutrons) in the nucleus; also called *atomic mass number* (20.1)

**nuclide** the nucleus of a particular atom, as characterized by its atomic number and atomic mass number (20.1)

## O

**observation** information gathered by using one or more of the five senses (1.1)

**ohm** the unit of electric resistance that will allow one ampere of current to move through the resistor when a potential difference of one volt is applied across the resistor,  $1\Omega = \frac{1\text{ V}}{1\text{ A}}$  (15.3)

**Ohm's law** the potential difference across a load equals the product of the current through the load and the resistance of the load (15.3)

**open air column** an air column that is open at both ends (9.3)

**open circuit** an incomplete circuit, in which current is unable to flow (15.2)

**open system** a system that can exchange both matter and energy with its surroundings (7.2)

**optical fibre** a very fine strand of glass; when light shines into one end of an optical fibre, total internal reflection causes the energy to be confined within the fibre (9.2)

**optically dense** a refractive medium in which the speed of light is low (9.2)

**orbital** "region in space" occupied by an electron of the atom (19.2)

**orbital quantum number** specifies the shape of an electron's orbital or energy level; has integer values of one less than the principal quantum number (19.2)

**out of phase** the periodic motion of two individual systems vibrating with the same frequency is said to be out of phase if they both do not reach the same amplitude at the same instant (8.1)

**overtone** all natural frequencies higher than the fundamental frequency in a standing wave pattern (8.3)

## P

**parabola** a geometric figure formed by slicing a cone with a plane that is parallel to the axis of the cone (11.1)

**parallel** a connection in a circuit in which there is more than one path for the current to follow (15.2)

**parent nucleus** the initial nucleus involved in a transmutation reaction (20.2)

**Pauli exclusion principle** states that no two electrons in the same atom can occupy the same state; alternatively, no two electrons in the same atom can have the same four quantum numbers (19.2)

**percent deviation** a description of the accuracy of a measured value as compared to a theoretical value; calculated as  $\frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}} \times 100$  (Skill Set 1)

**percent difference** a description of the precision of a set of observations; calculated as  $\frac{\text{maximum value} - \text{minimum value}}{\text{average value of data}} \times 100$  (Skill Set 1)

**period** the time required for an object to complete one cycle of its repeated pattern of motion (1.3, 8.1)

**periodic motion** the motion of an object in a repeated pattern over regular time intervals (8.1, 13.1)



**permanent magnet** a magnet that maintains its magnetic properties when removed from an external magnetic field (16.1)

**perturbation** deviation of a body in orbit from its regular path, caused by the presence of one or more other bodies (12.2)

**phase difference** the angular difference between two systems in periodic motion that are not in phase; if a wave begins half a cycle before, or after, another wave, the two waves will have a phase difference of  $180^\circ$  (8.1)

**photoelectric effect** the ejection of electrons from metal surface by ultraviolet light (18.1)

**photon** a quantum of light or electromagnetic radiation (18.1)

**physics** the study of the relationships between matter and energy (1.1)

**pitch** an attribute of a sound that determines its position in a musical scale; pitch is measured in frequency, but depends also on the loudness and quality of the sound (9.1)

**pivot point** the point around which rotational motion occurs (10.3)

**position vector** a vector which points from the origin of a coordinate system to the location of an object at a particular instant in time (2.2)

**positron** a particle with the same mass as the electron, but with a positive charge; an antielectron (20.2)

**potential difference** see electric potential difference

**potential energy** energy stored by an object (6.1)

**power** the rate at which work is done, measured in watts ( $W$ ), or joules per second; also defined as the rate at which energy is transferred (6.4)

**power supply** a device such as a cell, battery, or generator which supplies current to a circuit (15.2)

**precision** describes the exactness and repeatability of a value or set of values; compare to *accuracy* (Skill Set 1)

**principal quantum number** an integer that describes the orbital or energy level of an electron in an atom (19.1)

**principle of reversibility of light** when a light ray is directed backward, it travels back along its original path (9.2)

**projectile** an object that is given an initial thrust and allowed to move through space under the force of gravity only (11.1)

**proper length** the length of an object measured by an observer at rest relative to the object (17.2)

**proper time** the duration of an event measured by an observer at rest relative to the event (17.2)

**proton** a positively charged particle found in the nucleus of all atoms; equal in magnitude to the charge on the electron (20.1)

## Q

**qualitative observation** a verbal description of an object or phenomena; for example, “the book is heavy” (1.1)

**quality** an attribute of a sound used to distinguish between sounds that are the same pitch and loudness (9.1)

**quantitative observation** a numerical description of an object or phenomena; for example, “the book weighs 5 kg”; quantitative observations typically involve measurements of a particular quantity (1.1)

**quantized** a property of a system that occurs only in multiples of a minimum amount (18.1)

**quantum** a discrete amount of energy, given by the product of Planck’s constant ( $h$ ) and the frequency of the radiation ( $f$ ):  $hf$  (18.1)

**quantum mechanics** a branch of modern physics that deals with matter and energy on atomic scales (5.1)

## R

**radioactive isotope or radioisotope** an isotope of an element that has an unstable nucleus and therefore disintegrates or decays, emitting alpha, beta, or gamma radiation (20.2)

**radioactive material** material that contains radioactive nuclei (20.2)

**random error** results from small variations in measurements due to randomly changing conditions such as weather, humidity, equipment, level of care, etc; can be reduced but not eliminated by repeating the measurement (Skill Set 1)

**range** the horizontal distance a projectile travels (11.1)

**rarefaction** a region of lower air pressure compared to the surrounding medium; longitudinal waves have both compressions and rarefactions (9.1)

**ray** a line drawn perpendicular to the wavefronts of a wave (8.4)

**recoil** the interaction that occurs when two stationary objects push against each other and then move apart (7.3)

**rectified DC current** an alternating current that is transformed into a pulsating direct current (16.3)

**refraction** the change in the speed and direction of a wave or light ray due to its travelling from one medium to another (8.4, 9.2)

**refractive index** see index of refraction

**regular reflection** a reflection in which the reflected light rays are parallel to one another, as from the surface of a mirror; also known as *specular reflection* (9.1)

**relative velocity** a velocity relative to a frame of reference, such as an air current, that itself is moving with a velocity relative to another frame of reference, such as the ground (3.3)

**relative uncertainty** the ratio of the estimated uncertainty to the actual measured value, written as a percentage (Skill Set 1)

**relativistic mass** the mass of an object measured by an observer who sees the object moving with a particular speed (17.3)

**relativistic speeds** speeds close to the speed of light (17.2)

**resistance** see electric resistance

**resistivity** the product of the area and resistance of a circuit wire, divided by the length (15.3)

**resolved vectors** components of a vector that are at right angles to each other; the components lie in the axes of the coordinate system (10.1)

**resonance** phenomena that occurs when energy is added to a vibrating system at the same frequency as its natural frequency; during resonance, the amplitudes of the vibrations of the object become very large (8.1)

**resonance lengths** the specific lengths of a column at which resonance occurs, typically measured in fractions of wavelength (9.3)

**rest energy** the energy of the rest mass of an object (17.3)

**rest mass** the mass of an object measured by an observer at rest relative to the object (17.3)

**rest position** the position of an object, such as a simple pendulum or a mass on a spring, when it is allowed to hang freely and is not moving; sometimes called the equilibrium position (8.1)

**restoring force** the force exerted by a spring on an object in the direction opposite to the direction that the spring is stretched or compressed; proportional to the amount of extension or compression of the spring (6.3)

**resultant vector** a vector representing the sum of two or more vectors (3.2)

**resultant wave** a wave produced by combining two or more individual waves (8.3)

**retroreflector** an optical device used to reflect light directly back parallel to its original path (9.2)

**right-hand rules** the rules which help to visualize the directions of vectors by using the fingers and thumb of your right hand.

**#1.** used to determine the direction of the magnetic lines of force from a current-carrying conductor: imagine grasping a current-carrying conductor so that your thumb lies along the wire in the direction of the current and your fingers curl around it; then the magnetic lines of force encircle the wire in the direction of your fingers (16.1)

**#2.** used to indicate the direction of the magnetic lines of force in a solenoid: imagine grasping a solenoid so that your fingers point in the direction of the current, then your thumb points in the direction of the magnetic lines of force inside the coil (16.1)

**#3.** used to find the direction of the force exerted on a conductor by a magnet: with your hand flat, point your thumb along a conductor in the direction of the current and your fingers in the direction of the magnetic field (from the magnet), then your palm faces in the direction of the force that the magnet's field exerts on the conductor (16.2)

**rotational motion** angular motion around one point (10.3)

**rotor** the rotating part of an electric motor, which consists of a coil with an iron core, also called *armature* (16.2)

**Rydberg constant** the constant of proportionality that relates the wavelength of a spectral line in the hydrogen atom and the difference of energy level numbers that produce it:  
 $R = 1.097\,373\,15 \times 10^7 \text{ m}^{-1}$  (19.1)

**S**

**scalar** a physical quantity that has only a magnitude or size; compare to *vector* (2.2)

**Schrödinger wave equation** the basic quantum mechanical equation whose solutions produce detailed information about matter waves and the atom (19.2)

**scientific inquiry** the systematic process of gathering data through observation,

experimentation, organizing the data, and drawing conclusions (1.1)

**series** a connection in a circuit in which there is only one path for the current to follow (15.2)

**simple harmonic motion** a periodic motion generated by a linear restoring force (13.1)

**simultaneity** a concept that describes events that occur at the same time and in the same inertial reference frame (17.2)

**slip-ring commutator** a device that allows the continuous connection of the rotating rotor (or armature) to the rest of the circuit in a generator; used in an AC generator to transmit alternating current (16.3)

**Snell's law** for any two media, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant and is equal to the inverse ratio of the indices of refraction for the two media (9.2)

**solenoid** a closely wound helix of wire that acts as a magnet when current runs through the wire (16.1)

**sonic boom** an acoustic pressure wave caused by an object moving faster than the speed of sound (9.2)

**sound spectrum** a plot of relative intensity versus frequency for the various frequencies that make up a sound (9.3)

**south-seeking pole** the end of a magnet that points toward the south; commonly known as the south pole (16.1)

**speed** the distance an object travels divided by the time the object was travelling; speed is a scalar quantity (2.2)

**spin quantum number** specifies the orientation, up or down, of the electron's "spin"; has values  $+\frac{1}{2}$  or  $-\frac{1}{2}$  when placed in a magnetic field (19.2)

**split-ring commutator** a device which allows continuous connection of the rotating rotor (or armature) to the rest of the circuit in a motor or generator; used in DC motors and generators to reverse the current direction (16.2, 16.3)

**spring constant** the amount of force a spring can exert per unit distance of extension or compression (6.3)

**standing wave** a stationary wave consisting of nodes and antinodes, formed when two equal waves travelling in opposite directions in a linear medium such as a rope or string pass through one another (8.3)

**static equilibrium** the state of an object when the vector sum of all of the forces acting on it is zero

and the sum of all of the torques acting on it is zero (10.3)

**static frictional force** a frictional force that acts to keep an object at rest; measured as the force required to move an object from rest (4.2)

**stopping potential** in the photoelectric effect, the potential difference required to stop the emission of photoelectrons from the surface of a metal (18.1)

**strong nuclear force** the fundamental force that holds the parts of the nucleus together (20.1)

**subcritical** the condition that fewer than one neutron from each fission event causes another fission: the reactions will eventually cease (21.2)

**supercritical** the condition that more than one neutron from each fission event causes another fission: the reactions rate will rise in a cascade of fissions (21.2)

**system** an arbitrarily assigned group of objects (7.2, 10.2)

**systematic error** results from bias in observation that will not be reduced by repeating the measurement (Skill Set 1)

## T

**tangent** a line that intersects a curve at only one particular point (2.3)

**temporary magnet** a magnet that loses its magnetic properties when removed from an external magnetic field (16.1)

**tension** the magnitude of the force exerted on and by a cable, rope, or string (10.2)

**terminal velocity** the velocity of a falling object at which the force of friction is equal in magnitude to the force of gravity (5.3)

**terminal voltage** the potential difference across the anode and cathode of a battery (15.4)

**tesla (T)** unit of magnetic field strength, equivalent to the magnetic field that exerts a force of one newton (1 N) on a one-metre-long (1 m) conductor carrying a current of one ampere (1 A) (16.2)

**test charge** a charge of small enough magnitude that will not affect the field being measured; it is used to determine the strength of an electric field (14.2)

**theory** a collection of ideas, validated by many scientists, that fit together to explain and predict a natural phenomenon (1.1)

**thermal neutrons** slow neutrons that have an energy of about 0.03 eV (21.2)

**threshold frequency** the lowest frequency of light (smallest photon energy) that can eject a photoelectron from a particular metal (18.1)

**time dilation** a consequence of special relativity in which two observers moving at constant velocity relative to each other will each observe the other's clock to have slowed down (17.2)

**time interval** the amount of time that passes between two instants of time (2.2)

**torque** a force that acts to produce a rotation (10.3, 16.2)

**torsion balance** a sensitive instrument for measuring the twisting forces in metal wires, consisting of an arm suspended from a fibre (14.1)

**total energy** the sum of the rest energy of a particle and its kinetic energy (17.3)

**total internal reflection** phenomenon in which light incident on the boundary of an optically less dense medium is not refracted at all but is totally reflected back from the boundary into the optically more dense medium; occurs when the angle of incidence is greater than the critical angle (9.4)

**trajectory** the path described by an object moving due to a force or forces (11.1)

**translational motion** linear motion along a straight line or across a surface (10.3)

**transmutation** the conversion of one element into a different element, usually as a result of radioactive decay (20.2)

**transverse wave** a wave in which the particles of a medium vibrate at right angles to the direction of motion; for example, water waves (8.2)

**trough** the lowest point on a wave (8.2)

**Tychonic system** a planetary model in which the Sun and Moon revolve around Earth, but the other planets revolve around the Sun (12.1)

## U

**ultraviolet catastrophe** the significant discrepancy at ultraviolet and higher frequencies between the predictions based on classical physics and observations of blackbody radiation (18.1)

**uniform acceleration** acceleration that is not changing over a certain time interval; also known as *constant acceleration* (2.4)

**uniform circular motion** motion with constant speed in a circle (11.2)

**uniform motion** moving at constant velocity (2.3)

## V

**vector** a physical quantity that has a magnitude and a direction; vectors must be defined in terms of a frame of reference; compare to scalar (2.2)

**vector components** parts of a vector that lie on the axes of a coordinate system, into which a vector can be resolved; they are scalar quantities (10.1)

**vector diagram** a diagram, with a coordinate system, in which all quantities are represented by vectors (3.2)

**velocity** the rate of change of position of an object in a particular direction; velocity is a vector quantity; also known as *average velocity* (2.2)

**voltage** the potential difference between two points in a circuit (15.1)

**voltaic cell** a cell consisting of two different metals, called electrodes, placed in an electrolytic solution that produces an electric charge on the electrodes (15.1)

**voltmeter** a device that measures the potential difference across a circuit element (15.2)

## W

**wave** a disturbance that transfers energy through a medium (8.2)

**wave equation** the fundamental equation governing the motion of waves that relates the velocity of the wave to its frequency and wavelength (8.2)

**wave function** a mathematical expression that is a solution of the Schrödinger wave equation; provides information about the allowed orbits and energy levels of electrons in the atom (19.2)

**wave-particle duality** both matter and electromagnetic radiation exhibit some properties of waves and some properties of particles (18.2)

**wavefront** a group of adjacent points in a two-dimensional wave that all have the same phase, usually indicated by a curved line drawn across the crests (8.2)

**wavelength** the shortest distance between any two points in a medium that are in phase; commonly measured from one trough to the next trough, or one crest to the next crest (8.2)

**weight** the force that gravity exerts on an object because of its mass; an object's weight may change because the force of gravity acting on it may change, even though its mass remains the same (4.2)

**work** the transfer of mechanical energy; calculated as the product of the force and the displacement when the force and displacement vectors are in the same direction (6.1)

**work function** in the photoelectric effect, the minimum amount of energy necessary to remove an electron from a metal surface (18.1)

**work-energy theorem** the relationship between the work done on an object and the resulting change in any form of energy of the object,  $W = \Delta E$  (6.2)

**work-kinetic energy theorem** the relationship between the work done on an object and the resulting change in kinetic energy,  $W = \Delta E_k$  (6.2)

## Z

**Zeeman effect** the splitting of the spectral lines of an atom when it is placed in a magnetic field (19.2)