A2 level. Definitions, laws & principles.

7. Motion in a Circle

7.1 Angular displacement = Angular turned through from a reference point in a specific direction.

7.2 Angular velocity = rate of change in angular displacement *or* angle turned through per unit time.

$\omega = \dfrac{d\theta}{dt}$; $\omega = \dfrac{\theta}{t}$

7.3 Period = time taken for 1 complete revolution. $T = \dfrac{t}{N}$. $T = \dfrac{2\pi}{\omega}$. $T = \dfrac{1}{f}$

7.4 Frequency = number of complete revolutions per unit time.

$f = \dfrac{N}{t}$. $f = \dfrac{1}{T}$. $\omega = 2\pi f$

7.5 Centripetal acceleration (radial acceleration) = The acceleration towards the centre of a circle for an object moving in circular motion. $a = \dfrac{v^2}{r}$; $a = r\omega^2$

7.6 Centripetal force = the resultant force which causes an object to move in a circle, and its direction is towards the centre of the circle.

$F = \dfrac{mv^2}{r}$; $F = mr\omega^2$

7.5 Additional formulae: $\omega = \dfrac{\theta}{t}$; $s = r\theta$; $v = r\,\omega$; $a = \dfrac{v^2}{r}$, $a = r\,\omega^2$; $F = \dfrac{mv^2}{r}$,

$F = m\,r\,w^2$, $T = \dfrac{2\pi}{\omega}$ $\omega = \dfrac{2\pi}{T}$. $f = \dfrac{1}{T}$ $\omega = 2\pi\,f$

8. Gravitational Field

8.1 *Newton's law of gravitation* states that the gravitational force between 2 point masses is directly proportional to the product of their masses, and is inversely proportional to the square of the distance between them.

The gravitational force is an attractive force.

$F = -\,G\dfrac{Mm}{r^2}$

8.2 Gravitational field = region in which a force is experienced by a mass.

8.3 Gravitational field strength = force per unit mass acting on a mass in a gravitational field. $g = \dfrac{F}{m}$. $g = -\,G\dfrac{M}{r^2}$

8.4 Gravitational potential at a point = work done per unit mass in bringing the mass from infinity to the point *or* work done in bringing unit mass from infinity to that point.

$\phi = -\,G\dfrac{M}{r}$

8.5 Gravitational potential energy = Work done in bringing a mass from infinity to that point.

$E_k = m\phi = -G\dfrac{Mm}{r}$

8.6 Velocity of escape = minimum velocity of a body at the surface of the Earth so that it can escape from the gravitational field to infinity.

8.7 Geosynchronous/Geostationary orbit = orbit of a geostationary satellite which results in the satellite always remaining over the same point on the earth.

8.8 Geostationary satellite = The satellite always remains over the same point on the earth. The satellite moves from west to east and has a period of 24 hours.

8.9 Additional formulae: F = $-G\dfrac{Mm}{r^2}$; g = $-G\dfrac{M}{r^2}$; V = $-G\dfrac{M}{r}$; $E_p = -G\dfrac{Mm}{r}$;

g = $-\dfrac{dV}{dr}$; $v_e = \sqrt{2gr}$ GM = g $R_E^{\ 2}$

11. Ideal Gases

11.1 Ideal gas = a gas which always obeys the equation $pV = nRT$ for all values of pressure, p, volume, V and temperature, T.
The gas also obeys the assumptions of the kinetic theory.

11.2 Ideal Gas equation : pV = nRT

General Gas law: $\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}$

11.3 Brownian motion = Haphazard motion of the smoke particles when knocked around by the gas molecules which are moving randomly..

11.4 Additional formulae: p = $\dfrac{1}{3}m\dfrac{N}{V}<c^2>$, p = $\dfrac{1}{3}\rho < c^2 >$; n = $\dfrac{M}{M_{molar}}$ or n = $\dfrac{N}{N_A}$;

Average translational k.e. of a molecule, $E_k = 3\left(\dfrac{1}{2}kT\right)$ where $k = \dfrac{R}{N_A}$,

Internal energy of ideal gas (mono-atomic), U = N (3 x $\dfrac{1}{2}$ k T) where N = total number of molecules

12. Temperature

12.1 Temperature = The property of a body which determines which way heat will flow between it and another body.

12.2 Thermal equilibrium = 2 bodies in thermal contact are in thermal equilibrium when there is no net transfer of heat between them.

12.3 Heat energy = energy which transfers from a region of higher temperature to a region of lower temperature due to a difference in temperature.

12.4 Thermometric property = physical property of a substance which varies significantly with temperature.

12.5 Absolute temperature scale (thermodynamic temperature scale) = the temperature scale which does not depend on the thermometric property of a substance.

12.6 Absolute zero = 0 K, the lowest possible temperature that can be attained by a body.

12.7 Triple point of water = temperature at which pure ice, water and water vapour co-exist in equilibrium.

12.8 Additional formulae:

$$\theta\ °\ C\ \text{(Centigrade)} = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100$$

$$T/K = \frac{P_T}{P_{tr}} \times 273.16$$

$T/^oC = T/K - 273.15$

13. Thermal Properties of Materials

13.1 Specific heat capacity = Amount of heat per unit mass required to raise the temperature of a substance by one degree. $Q = mc\,\Delta\theta$

13.2 Specific latent heat = Amount of heat per unit mass required to change a substance from one phase to another without change in temperature. $Q = ml$

13.3 Specific latent heat of vaporisation = Amount of heat per unit mass required to change the phase of a substance from liquid to vapour without change in temperature.

13.4 Specific latent heat of fusion = Amount of heat per unit mass required to change the phase of a substance from solid to liquid without change in temperature.

13.5 Internal energy (thermal energy) = the sum of the potential energy and kinetic energy of all the molecules.

13.6 *First law of thermodynamics* states that the increase in internal energy of a system is the sum of the heat energy supplied to the system and the work done on the system. $\Delta U = \Delta Q + \Delta W$

13.7 Additional formulae: $\Delta U = \Delta Q + \Delta W$; $\delta W = p\,\delta V$; $W = \int p dV$ = area under the p-V graph. At constant volume, W = 0. At constant pressure, $W = p\,\Delta V$

$Q = m\,c\,\Delta\theta$. $Q = ml$

14. Oscillations

14.1 Oscillation = A repeated back and forth motion on either side of a fixed position.

Free oscillation = oscillation experienced by an oscillating system when given an initial disturbance.

14.2 Simple harmonic motion = a periodic motion in which the acceleration of the body is directly proportional to its displacement from a fixed point, and the acceleration is always directed towards that fixed point. $a = -\omega^2 x$

14.3 Amplitude = magnitude of the maximum displacement.

14.4 Period = time taken for 1 complete oscillation. $T = \frac{t}{N}$

14.5 Frequency = number of oscillations per unit time. f = $\frac{N}{t}$

14.6 Angular frequency = Frequency expressed in radians per second.
= $2\pi f$ where f is the number of oscillations per unit time.

$$\omega = 2\pi f; \quad \omega = \frac{2\pi}{T}$$

14.7 Damped oscillations = oscillations in which the amplitude, and hence the energy, decreases exponentially with time due to an opposing force.

14.8 Critical damping = a damped oscillation in which the displaced body returns to the equilibrium position without passing through it in the shortest time possible.

14.9 Forced oscillations = An oscillation which is forced into motion by an external periodic force; it has the same frequency as that of the external periodic force.

14.10 Resonance = A phenomenon in which a system responds at maximum amplitude to an external driving force when the driving force frequency is equal to the natural frequency of the driven system.

14.11 Additional formulae: T = $\frac{t}{N}$, f = $\frac{N}{t}$, f = $\frac{1}{T}$, $\omega = 2\pi f$, $\omega = \frac{2\pi}{T}$

$x = x_o \sin \omega t$ or $x = x_o \cos \omega t$. $v = x_o \omega \cos \omega t$, $v = \omega \sqrt{(x_o^2 - x^2)}$, $v_{max} = \omega x_o$

$a = - x_o \omega^2 \sin \omega t$, $a = - \omega^2 x$

$E_k = ½ m x_o^2 \omega^2 \cos^2 \omega t$, $E_k = ½ m \omega^2 (x_o^2 - x^2)$, Maximum $E_k = ½ m \omega^2 x_o^2$

Total energy, $E = ½ m \omega^2 x_o^2$; $E_p = ½ m \omega^2 x_o^2 \sin^2 \omega t$, $Ep = ½ m \omega^2 x^2$

17. Electric Fields (A2 level only)

17.1 *Coulomb's law* states that the electric force between 2 point charges is directly proportional to the product of their charges, and is inversely proportional to the square of the distance between them. F = $\frac{1}{4\pi\varepsilon_o}\frac{Q_1Q_2}{r^2}$

17.2 Electric potential at a point = work done per unit charge in bringing the charge from infinity to the point *or* Work done in moving unit charge from infinity to that point. V = $\frac{1}{4\pi\varepsilon_o}\frac{Q}{r}$

17.3 Electric potential energy at a point = work done in bringing a charge from infinity to that point.

$E_p = q V$, $E_p = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r}$

17.4 Electric field = negative of the potential gradient at any point

17.5 Additional formulae: $E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$, $E = -\frac{dV}{dr}$

18. Capacitance

18.1 Capacitance = Charge stored on either plate of the capacitor per unit potential difference applied across it. C = $\frac{Q}{V}$

18.2 Farad = 1 farad is the value of capacitance when a charge of 1 coulomb is stored in the capacitor when a potential difference of 1V is applied across it.

18.3 Additional formulae: Capacitors in series: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$,

N identical capacitors in series , C' = $\frac{C}{N}$,

capacitors in parallel: $C = C_1 + C_2 + C_3$

Energy stored in capacitor: W = $\frac{1}{2}QV$, W = $\frac{1}{2}\frac{Q^2}{C}$, W = $\frac{1}{2}CV^2$

Energy supplied by source of e.m.f. *E*. Energy = *QE* (compared with energy, W = QV)

21. Magnetic fields

22. Electromagnetism

22.1 Magnetic flux density (magnetic field intensity / magnetic field strength) = force per unit current in a conductor of unit length when the conductor is placed perpendicular to the magnetic field. $F = BIl \sin\theta = BIl$

22.2 Tesla = 1 tesla is the value of the magnetic flux density when a force of 1 N acts on 1 m of the conductor which carries a current of 1 A, when the conductor is placed at right angle to the magnetic field.

22.3 Additional formulae:; $F = BIl \sin\theta$, $F = Bqv \sin\theta$

23. Laws of Electromagnetic Induction

23.1 Magnetic flux = the product of flux density and the area, when the flux is at right angles to the area. $\phi = BA$

23.2 Weber = 1 weber is the value of magnetic flux when a magnetic flux density of 1 tesla passes normally through an area of 1 m^2.

23.3 Magnetic flux linkage = the total magnetic flux passing normally through the area of a coil of N turns. $\Phi = N\phi$; $\Phi = NBA$

23.4 *Faraday's law* states that the magnitude of induced e.m.f. is directly proportional to the rate of change of flux linkage. $E = -\frac{d\Phi}{dt}$

23.5 *Lenz's law* states that the direction of any induced current is such as to oppose the flux change that causes it.
(Effect: another magnetic field produced by the induced current, and this second magnetic field opposes the change of the original magnetic flux)

23.6 Additional formulae: $\phi = BA \sin\theta$. For straight conductor: E.m.f = Blv

24. Alternating Currents

24.1 Period of a.c. = time taken for 1 complete cycle of the alternating current $T = \dfrac{t}{N}$

24.2 Frequency of a.c. = number of cycles per unit time of the alternating current. $f = \dfrac{N}{t}$

24.3 r.m.s value of an alternating current (or voltage) is defined as the equivalent value of the steady direct current (or voltage) which would dissipate heat at the same average rate as the alternating current (or voltage) in a given resistance.

24.4 peak value = the greatest value of the potential difference or current in a cycle. $V_{rms} = \dfrac{V_o}{\sqrt{2}}$

24.5 Half-wave rectification = the conversion of a.c. to d.c. with only half of a cycle of the a.c. passing through the load in one direction.

24.6 Full-wave rectification = the conversion of a.c. to d.c. when both the positive and negative portion of a cycle of the a.c. pass through the load in the same direction.

24.6 Additional formulae: For transformer, $\dfrac{V_S}{V_P} = \dfrac{N_S}{N_P} = \dfrac{I_P}{I_S}$

25. Charged Particles

Charge is quantised = All value of charges are either equal to a certain minimum value or whole number multiples of this minimum value.

26. Quantum Physics

26.1 Photoelectric effect = the emission of electrons from a clean metal surface when electromagnetic radiation of sufficiently high frequency is incident on it.

26.2 Photon = discrete packet of energy of e.m. radiation. It has the behaviour of a particle. It's energy is directly proportional to the frequency of the e.m. radiation. E=hf.

26.3 Threshold frequency = the minimum frequency of the e.m. radiation which can produce photoelectric emission.

26.4 Threshold wavelength = the maximum wavelength of the e.m. radiation which can produce photoelectric emission.

26.5 Work function = the minimum energy needed to emit to remove an electron from the surface of the metal.

26.6 Emission line spectra = bright spectra lines on a dark background.
The bright lines correspond to certain discrete values of wavelengths of lights emitted by luminous gases and vapours at low pressure. Each line is the image of the slit of the spectrometer on which the light falls.

26.7 Absorption line spectra = Dark lines observed against a bright continuous spectrum of white light. It occurs when light passes through a cooler gas or vapour before it enters the slit of the spectrometer.

26.8 Additional formulae: $E = hf$, $hf = \Phi + \frac{1}{2} m v^2_{max}$, $hf_{min} = \Phi + 0$, $E_{max} = eV_o$ joule,

E_{max} = V_o eV, 1 eV = e joule, I = $\frac{1}{A}.\frac{E}{t} = \frac{1}{A}.\frac{N(hf)}{t}$.

Line spectrum: hf = $E_1 - E_2$. de Broglie wavelength: $\lambda = \frac{h}{p}$, $p = \frac{h}{\lambda}$; where p = momentum

27. Nuclear Physics (A2 level only)

27.1 Binding energy of a nucleus = <u>minimum</u> energy needed to separate the nucleus into its individual nucleons completely to infinity.

27.2 Binding energy per nucleon = <u>minimum</u> energy <u>per nucleon</u> needed to separate the nucleus into its individual nucleons completely to infinity.

27.3 Radioactivity = the spontaneous and random decay of unstable nucleus to a more stable daughter nucleus with the emission of radiations such as α, β and γ radiation.

27.4 Activity = number of radioactive disintegrations per unit time. (Rate at which nuclei decay).

$A = \frac{dN}{dt}$

27.5 Decay constant = the probability that an individual nucleus will decay per unit time interval.

27.6 Half-life = <u>Average time taken</u> for half of the nuclei in the sample to decay or the average time taken for the activity of a sample to decrease to half of some initial value.

$t_{½} = \frac{\ln 2}{\lambda}$

27.6 Additional formulae: $N = N_o\, e^{-\lambda t}$, $m = m_o\, e^{-\lambda t}$. $A = A_o\, e^{-\lambda t}$, $E = mc^2$