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PHYSICS

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1. Some Conversion Factors

1. Mass and Density :

1 kg = 1000 g

1 u = 1.66×10^{-27} kg

1 kg/m^3 = 10^{-3} g/cm^3

2. Length and Volume :

1 m = 100 cm = 39.4 in. = 3.28 ft

1 mi. = 1.61 km = 5280 ft

1 in. = 2.54 cm

1 nm = 10^{-9} m = 10 Å

1 pm = 10^{-12} m = 1000 fm

1 light-year = 9.46×10^{15} m

1 m^3 = 10^3 lit = 35.3 ft^3 = 264 gal

1 ml = 1 cm^3 = 10^{-3} lit = 10^{-3} dm^3
= 10^{-6} m^3

1 m^3 = 10^3 dm^3 = 10^3 lit = 10^6 ml
= 10^6 cm^3

1 lit = 10^3 ml = 10^3 cm^3 = 1 dm^3
= 10^{-3} m^3

The most common unit of volume used in Chemistry is cubic decimetre (dm^3). The advantage is that 1 lit = 1 dm^3.

3. Time :

1 d = 86 400 s

1 y = $365\frac{1}{4}$ d = 3.16×10^7 s

4. Angular Measure :

1 rad = 57.3° = 0.159 rev

π rad = 180° = $\frac{1}{2}$ rev

5. Speed :

1 m/s = 3.28 ft/s = 2.24 mi/h

1 km/h = 0.621 mi/h = 0.278 m/s

6. Force and Pressure :

1 N = 10^5 dyne = 0.225 lb

1 lb = 4.45 N

1 ton = 1000 kg

1 Pa = 1 N/m^2 = 10 $dyne/cm^2$

1 atm = 1.013×10^5 Pa
= 1.013×10^5 Nm^{-2}
= 1.013×10^2 kNm^{-2} = 76 cm Hg

7. Energy and Power :

1 J = 10^7 erg = 0.239 cal

1 kWh = 3.6×10^6 J

1 cal = 4.19 J

1 eV = 1.60×10^{-19} J

1 horsepower = 746 W

8. Magnetism :

1 T = 1 Wb/m^2 = 10^4 gauss

2. Useful Data

Material	Young's modulus ($dynes/cm^2$) *(approximate value)*
(i) Aluminium	7.1×10^{11}
(ii) Brass	10×10^{11}
(iii) Copper	11.7×10^{11}
(iv) Iron (pure)	20.6×10^{11}

Element/Alloy	Specific resistance (ohm cm) *(approximate value)*
(i) Copper	1.7×10^{-6}
(ii) Aluminium	2.65×10^{-6}
(iii) Brass	8×10^{-6}
(iv) Iron (pure)	10×10^{-6}
(v) Tin	11×10^{-6}
(vi) Manganin	45×10^{-6}
(vii) Constantan	47×10^{-6}

Surface tension of water at 20°C = 72.75 dynes / cm

Coefficient of viscosity of glycerine at 20°C = 13.4 poise

1. Coefficient of linear expansion

Iron	12×10^{-6} per °C
Copper	17×10^{-6} per °C
Brass	18×10^{-6} per °C
Aluminium	23×10^{-6} per °C

2. Specific heat

Brass	0.092 cal / gram °C
Copper	0.093 cal / gram °C
Iron	0.120 cal / gram °C
Aluminium	0.220 cal / gram °C

3. Electrochemical equivalent of copper

3.3×10^{-4} gram / coulomb

4. Mechanical equivalent of heat, J

4.186 J / cal = 4186 J/kcal

3. Useful Formulae in Physics (XI-XII)

(1) MEASUREMENT, SYSTEMS OF UNITS, DIMENSIONS, VECTORS AND KINEMATICAL EQUATIONS

1. Percentage error in the determination of a quantity

$$= \frac{\text{average absolute error}}{\text{mean value}} \times 100\,\% = \frac{\sum_{i=1}^{n} |x_i - \bar{x}|/n}{\bar{x}} \times 100\,\%$$

2. If $\vec{R} = \vec{P} + \vec{Q}$, then, $R^2 = P^2 + Q^2 + 2PQ\cos\theta$ and $\tan\alpha = \dfrac{Q\sin\theta}{P + Q\cos\theta}$

3. $\vec{P} = P_x\vec{i} + P_y\vec{j} + P_z\vec{k}$, $\quad P = \sqrt{P_x^2 + P_y^2 + P_z^2}$

4. Scalar product : $\vec{P}\cdot\vec{Q} = PQ\cos\theta = P_xQ_x + P_yQ_y + P_zQ_z$

5. Vector product : If $\vec{R} = \vec{P} \times \vec{Q}$, then, $R = PQ\sin\theta$ and

$$\vec{R} = \vec{P} \times \vec{Q} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ P_x & P_y & P_z \\ Q_x & Q_y & Q_z \end{vmatrix}$$

6. Kinematical equations (uniformly accelerated motion of a particle)

Vector Form

(i) $\vec{v} = \vec{u} + \vec{a}\,t$ (ii) $\vec{s} = \vec{u}\,t + \frac{1}{2}\vec{a}\,t^2$ (iii) $v^2 = u^2 + 2\vec{a}\cdot\vec{s}$

(iv) Displacement of a particle in the nth second

$$= \vec{s}_n - \vec{s}_{n-1} = \vec{u} + \frac{\vec{a}}{2}(2n-1)$$

(2) PROJECTILE MOTION

1. $v_x = u_x = u\cos\theta$
2. $v_y = u_y - gt = u\sin\theta - gt$
3. $x = u\cos\theta\, t$
4. $y = u\sin\theta\, t - \frac{1}{2}gt^2$
5. $t' = \dfrac{u\sin\theta}{g}$
6. $T = 2t' = \dfrac{2u\sin\theta}{g}$
7. $h = \dfrac{u^2\sin^2\theta}{2g}$
8. $h_{max} = \dfrac{u^2}{2g}$ for $\theta = 90°$
9. $R = \dfrac{u^2\sin 2\theta}{g}$
10. $R_{max} = \dfrac{u^2}{g}$ for $\theta = 45°$

(3) NEWTON'S LAWS OF MOTION

1. Momentum, $\vec{P} = m\vec{v}$
2. Resultant external force, $\vec{F} = \dfrac{d\vec{P}}{dt} = m\vec{a}$

   If the acceleration $\vec{a}$ is uniform, $\vec{F} = m\left(\dfrac{\vec{v} - \vec{u}}{t}\right)$
3. Impulse of a force, $\vec{J} = \vec{F}\,t = m\vec{v} - m\vec{u}$
4. In a collision, the total momentum of the bodies is conserved in the absence of external forces. $\therefore\ m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$
5. In an elastic collision, the total kinetic energy of the bodies is conserved.

   $\therefore\ \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$
6. In an elastic collision in one dimension,

   $$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2 \text{ and}$$

   $$v_2 = \left(\frac{2m_1}{m_1 + m_2}\right)u_1 + \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2$$

   If $u_2 = 0$, then the fractional decrease in the kinetic energy of the first particle $= \dfrac{4m_1m_2}{(m_1 + m_2)^2}$ and the loss in the kinetic energy of the first particle $= \frac{1}{2}m_1u_1^2 \times \dfrac{4m_1m_2}{(m_1 + m_2)^2}$
7. In a completely inelastic collision, $m_1\vec{u}_1 + m_2\vec{u}_2 = (m_1 + m_2)\vec{v}$

   Loss of kinetic energy $= \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \frac{1}{2}(m_1 + m_2)v^2$

   $$= \frac{m_1m_2}{2(m_1 + m_2)}(u_1 - u_2)^2$$

If $u_2 = 0$, the loss of kinetic energy $= \frac{1}{2} m_1 u_1^2 \times \left(\frac{m_2}{m_1 + m_2}\right)$

8. Coefficient of restitution, $e = \dfrac{v_2 - v_1}{u_1 - u_2}$

(4) WORK, POWER AND ENERGY

1. Work done by a force acting on a body, $W = \vec{F} \cdot \vec{s} = Fs \cos \theta$

2. Power, $P =$ rate of doing work $= \dfrac{dW}{dt} = \vec{F} \cdot \vec{v} = Fv \cos \theta$

3. Kinetic energy of a body, $K = \frac{1}{2} mv^2$

4. Gravitational potential energy of a body, $U = mgh$

(5) CIRCULAR MOTION

1. Angular speed of a particle, $\omega = \dfrac{d\theta}{dt} = \dfrac{2\pi}{T} = 2\pi f$

2. Linear speed of a particle, $v = r\omega$

3. Centripetal acceleration of a particle, $a = \dfrac{v^2}{r} = r\omega^2$

4. Centripetal force acting on a particle, $F = \dfrac{mv^2}{r} = mr\omega^2$

5. Angular acceleration, $\vec{\alpha} = \dfrac{d\vec{\omega}}{dt}$

If the angular acceleration is constant,

(i) $\omega = \omega_0 + \alpha t$ (ii) $\theta = \omega_0 t + \dfrac{1}{2} \alpha t^2$ (iii) $\omega^2 = \omega_0^2 + 2\alpha\theta$

6. Tangential acceleration : $a_{tangential} = r\alpha$

7. Angle of banking (θ) is given by $\tan \theta = \dfrac{v^2}{rg}$

(6) GRAVITATION

1. Gravitational force of attraction between two particles,

$F = G \dfrac{m_1 m_2}{r^2}$ (by Newton's law of gravitation)

2. Acceleration due to gravity at the surface of the earth, $g = \dfrac{GM}{R^2}$

3. Acceleration due to gravity at a point at a distance r $(r \geqslant R)$ from the centre of the earth,

$g' = \dfrac{GM}{r^2} = \dfrac{GM}{(R + h)^2}$

4. Critical velocity or critical speed (or orbital speed) of a satellite,

$V_c = \sqrt{\dfrac{GM}{r}} = \sqrt{\dfrac{GM}{R + h}} = \sqrt{\dfrac{gR^2}{(R + h)}} = \sqrt{g'r} = \sqrt{g'(R + h)}$

5. Period of revolution of a satellite, $T = \frac{2\pi r}{V_c} = \frac{2\pi}{\sqrt{GM}} . r^{3/2}$

$$\therefore \; T^2 = \left(\frac{4\pi^2}{GM}\right) r^3 = \left(\frac{4\pi^2}{GM}\right)(R+h)^3 = \left(\frac{4\pi^2}{gR^2}\right)(R+h)^3$$

6. Escape velocity or escape speed of a body projected from the surface of the earth,

$$V_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$$

7. Binding energy of a body at rest on the surface of the earth $= \frac{GMm}{R}$

8. For a satellite performing uniform circular motion around the earth,

(i) potential energy of the satellite $= -\frac{GMm}{(R+h)}$

(ii) kinetic energy of the satellite $= \frac{GMm}{2(R+h)}$

(iii) total energy of the satellite $= -\frac{GMm}{2(R+h)}$

(iv) binding energy of the satellite $= \frac{GMm}{2(R+h)}$

(7) STATICS AND ROTATIONAL MOTION

1. Torque or moment of a force, $\vec{T} = \vec{r} \times \vec{F}$,

$T = rF \sin\theta = Fr \sin\theta$ = magnitude of the force × perpendicular distance between the axis of rotation and the line of action of

the force = magnitude of the force × moment arm

2. Moment of a couple, $T = F$ × perpendicular distance between the lines of action of the two forces

3. Position vector of the centre of mass of a system of n particles is

$$\vec{R} = \frac{m_1\vec{r_1} + m_2\vec{r_2} + \ldots + m_n\vec{r_n}}{m_1 + m_2 + \ldots + m_n} = \frac{\sum_{i=1}^{n} m_i\vec{r_i}}{\sum_{i=1}^{n} m_i} = \frac{\sum_{i=1}^{n} m_i\vec{r_i}}{M}$$

Coordinates of the centre of mass are

$$X_{c.m.} = \frac{\sum_{i=1}^{n} m_i x_i}{M}, \quad Y_{c.m.} = \frac{\sum_{i=1}^{n} m_i y_i}{M}, \quad Z_{c.m.} = \frac{\sum_{i=1}^{n} m_i z_i}{M}$$

4. Conditions of equilibrium of a rigid body under the action of forces :

(i) $\sum_i \vec{F_i} = 0$ (ii) $\sum_i \vec{T_i} = 0$ or $\sum_i \vec{r_i} \times \vec{F_i} = 0$

5. Moment of inertia of a system of n particles is given by $I = \sum_{i=1}^{n} m_i r_i^2$

6. Radius of gyration (k) of a body about an axis of rotation is given by $I = Mk^2$

7. Kinetic energy of rotation of a body $= \frac{1}{2} I\omega^2$

8. Angular momentum of a body. $\vec{L} = I\vec{\omega}$

9. Torque acting on a body. $\vec{\tau} = I\vec{\alpha}$

10. Principle of parallel axes : $I_o = I_c + Mh^2$

11. Principle of perpendicular axes : $I_z = I_x + I_y$

12. Kinetic energy of a rolling body $= \frac{1}{2} MV^2 + \frac{1}{2} I\omega^2$

13. For a body rotating with a constant angular acceleration $\vec{\alpha}$,

$$\omega = \omega_o + \alpha t,\ \theta = \omega_o t + \frac{1}{2} \alpha t^2,\ \omega^2 = \omega_o^2 + 2\alpha\theta$$

14. Work done by a constant torque acting on a body $= \tau\theta$

= change in the rotational kinetic energy of the body

$$= \frac{1}{2} I\omega_2{}^2 - \frac{1}{2} I\omega_1{}^2$$

15. Power $= \tau\omega$

16. When $\vec{\tau}_{ext}$ = zero, the angular momentum of the body is conserved.

$\therefore\ I_1\vec{\omega_1} = I_2\vec{\omega_2}$

(8) OSCILLATIONS

1. In linear S.H.M., restoring force acting on a particle, $F = -kx$

2. Acceleration, $a = -\frac{k}{m}x = -\omega^2 x$

3. Period of S.H.M., $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$

4. Frequency of S.H.M., $f = \frac{1}{T} = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

5. Displacement of a particle in S.H.M. (from its mean position),

$x = A \sin (\omega t + \alpha)$

6. Velocity of a particle in S.H.M., $v = A\omega \cos (\omega t + \alpha)$

$= \pm\, \omega \sqrt{A^2 - x^2}$

7. Maximum velocity of a particle in S.H.M. $= A\omega$

8. Maximum acceleration of a particle in S.H.M. $= A\omega^2$

9. For a particle performing S.H.M.,

(i) potential energy (P.E.) $= \frac{1}{2} kx^2 = \frac{1}{2} m\omega^2 x^2$

(ii) kinetic energy (K.E.) $= \frac{1}{2} k(A^2 - x^2) = \frac{1}{2} m\omega^2(A^2 - x^2)$

(iii) total energy (E) $= \frac{1}{2} kA^2 = \frac{1}{2} m\omega^2 A^2 = 2\pi^2 mf^2 A^2$

10. $x_1 = A \sin(\omega t + \alpha_1)$ and $x_2 = B \sin(\omega t + \alpha_2)$

$x = x_1 + x_2 = C \sin(\omega t + \in)$, where

$C = \sqrt{A^2 + B^2 + 2AB \cos(\alpha_1 - \alpha_2)}$

and $\tan \in = \dfrac{A \sin \alpha_1 + B \sin \alpha_2}{A \cos \alpha_1 + B \cos \alpha_2}$

11. Period of S.H.M. of a simple pendulum, $T = 2\pi \sqrt{\dfrac{l}{g}}$

12. Period of angular S.H.M. of a magnet suspended in a uniform magnetic induction $\vec{B}$ is

$T = 2\pi \sqrt{\dfrac{I}{MB}}$

(9) ELASTICITY

1. Young's modulus, $Y = \dfrac{\text{longitudinal stress}}{\text{longitudinal strain}} = \dfrac{(F/A)}{(e/L)} = \dfrac{(Mg/\pi r^2)}{(e/L)}$

2. Bulk modulus, $K = \dfrac{\text{normal stress}}{\text{volume strain}} = \dfrac{\delta P}{(\delta V/V)}$

3. Modulus of rigidity, $\eta = \dfrac{\text{shearing stress}}{\text{shearing strain}} = \dfrac{F_t/A}{x/h}$

4. Poisson's ratio, $\sigma = \dfrac{\text{lateral contraction strain}}{\text{longitudinal elongation strain}}$

$= \dfrac{(\delta D/D)}{e/L} = \dfrac{(\delta r/r)}{(e/L)}$

5. Work done in stretching a wire, or strain energy,

$W = \frac{1}{2} \times \text{load} \times \text{elongation}$

$= \dfrac{1}{2} Fe = \dfrac{1}{2} \times Mg \times e = \dfrac{1}{2} \times \dfrac{YA}{L} \times e^2$

6. Work done (or strain energy) per unit volume of a stretched wire

$= \frac{1}{2}$ longitudinal stress $\times$ longitudinal strain

(10) FRICTION AND VISCOSITY

1. Coefficient of static friction, $\mu_S = \dfrac{F_S}{R}$

2. Coefficient of kinetic friction, $\mu_K = \dfrac{F_K}{R}$

3. $\mu_s = \tan \theta_r$, where θ_r = angle of repose

4. Newton's formula for the force due to viscosity of a liquid : $F = \eta A \dfrac{dv}{dx}$

5. Stokes' law : $F = 6\pi\eta r v$

6. The terminal speed (or terminal velocity), $v = \dfrac{2r^2(\rho - \sigma)g}{9\eta}$

(11) PROPERTIES OF FLUIDS

1. Determination of the surface tension of a liquid by capillary rise method :

$$T = \frac{h r \rho g}{2 \cos \theta}$$

2. Work done in blowing a soap bubble, $W = T \times 2 \times (4\pi r_2^{\,2} - 4\pi r_1^{\,2})$

(12) WAVE MOTION

1. Frequency $(n) = \dfrac{1}{\text{period } (T)}$

2. Wave velocity [or speed] $(V) = \dfrac{\lambda}{T} = n\lambda$

3. Distance covered by a wave in time t is $s = Vt$

4. $V_1 = n\lambda_1$ (in medium 1) and $V_2 = n\lambda_2$ (in medium 2) $\therefore \dfrac{V_1}{V_2} = \dfrac{\lambda_1}{\lambda_2}$

5. Newton's formula for the velocity [or speed] of sound in a medium : $V = \sqrt{\dfrac{E}{\rho}}$

6. Newton's formula for the velocity [or speed] of sound in a gas : $V = \sqrt{\dfrac{P}{\rho}}$

7. Laplace's formula for the velocity [or speed] of sound in a gas :

$$V = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$$

8. Phase difference (α) between the oscillatory motions of two particles separated by a distance x along the direction of propagation of the wave (X-axis) is $\alpha = \dfrac{2\pi x}{\lambda}$

9. The change in phase at a given point in time interval t is $\beta = \dfrac{2\pi t}{T}$

10. Equation of a simple harmonic progressive wave travelling along positive X-axis is

$$y = A \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda} \right)$$

11. If n_1 and n_2 are the frequencies of two notes producing the beats, then the beat frequency $= |n_1 - n_2|$

(13) STATIONARY WAVES

1. (i) Two simple harmonic progressive waves, travelling in opposite directions through the same part of the medium, are represented by

$$y_1 = A \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda} \right) \text{ and } y_2 = A \sin 2\pi \left(\frac{t}{T} + \frac{x}{\lambda} \right)$$

(ii) These waves combine to form a stationary wave represented by

$$y = y_1 + y_2 = 2A \sin \left(\frac{2\pi t}{T} \right) \cos \left(\frac{2\pi x}{\lambda} \right) = R \sin \left(\frac{2\pi t}{T} \right)$$

2. Distance between two adjacent nodes (or antinodes) $= \frac{\lambda}{2}$ = length of one loop

3. Distance between a node and the adjacent antinode $= \frac{\lambda}{4}$

4. (i) Speed of a transverse wave on a string (or wire) is $V = \sqrt{\frac{T}{m}}$

(ii) Fundamental frequency of vibration of a string (or wire) is $n = \frac{1}{2l}\sqrt{\frac{T}{m}}$

$OR \quad n = \frac{1}{2lr}\sqrt{\frac{T}{\pi\rho}} \qquad (\because\ m = \pi r^2 \rho)$

(iii) Frequency of the p^{th} harmonic $= \frac{p}{2l}\sqrt{\frac{T}{m}}$

(iv) Frequency of the p^{th} overtone $= \frac{(p+1)}{2l}\sqrt{\frac{T}{m}}$

5. Melde's Experiment : Parallel position : $\frac{N}{2} = n = \frac{p}{2l}\sqrt{\frac{T}{m}}$

Perpendicular position : $N = n' = \frac{p'}{2l}\sqrt{\frac{T}{m}}$

6. In the case of a tube (or a pipe) open at one end, the fundamental frequency of vibration of the air column in the tube is $n = \frac{V}{4L}$

$L = l + e$, where l = length of the tube and e = end correction

$e = 0.3\ d$, where d = inner diameter of the tube

In the resonance tube experiment, if l' is the length of the tube above the water level when the resonance is obtained again, $e = \frac{l' - 3l}{2}$

For a tube open at one end, only odd harmonics are present. The frequencies of the first, third, fifth, ..., harmonics are

$\frac{V}{4L}, \frac{3V}{4L}, \frac{5V}{4L}, \ldots$, respectively (neglecting the end correction).

7. In the case of a tube open at both ends, the fundamental frequency of vibration of the air column in the tube is $n = \frac{V}{2L}$. In this case, the end correction (e) is applied at each of the open ends. Hence, $L = l + 2e$, where l = length of the tube and e = end correction = $0.3\ d$

In this case, all harmonics are present. The frequencies of the first, second, third, ..., harmonics are

$\frac{V}{2L}, \frac{2V}{2L}, \frac{3V}{2L}, \ldots$, respectively (neglecting the end correction).

(14) HEAT AND THERMODYNAMICS

1. Coefficient of linear expansion of the material of a rod, $\alpha = \dfrac{l - l_0}{l_0 t}$

2. Coefficient of superficial expansion (surface expansion), $\beta = \dfrac{A - A_0}{A_0 t}$

3. Coefficient of cubical expansion, $\gamma = \dfrac{V - V_0}{V_0 t}$

4. $\beta = 2\alpha,\ \gamma = 3\alpha = \frac{3}{2}\beta$ **5.** Density, $\rho = \dfrac{\rho_0}{1 + \gamma t}$ **6.** $\gamma_r = \gamma_a + \gamma_g$

7. For a gas, (i) $\gamma_V = \dfrac{P - P_0}{P_0 t}$ (ii) $\gamma_P = \dfrac{V - V_0}{V_0 t}$

8. For a fixed mass of ideal gas,

(i) $\dfrac{P_1 V_1}{T_1} = \dfrac{P_2 V_2}{T_2}$ (ii) $PV = nRT$

9. Joule's law : $\dfrac{W}{Q} = J$

10. First law of thermodynamics, $dQ = dU + dW = dU + PdV$

11. Determination of J by electrical method :

$$J = \frac{VIt}{Q} = \frac{VIt}{(m_c c_c + m_w c_w)(\theta_2 - \theta_1)}$$

(15) HEAT TRANSFER

1. $\dfrac{Q}{t} = KA\dfrac{(\theta_1 - \theta_2)}{x}$

2. Searle's method to find thermal conductivity : $K = \dfrac{mc(\theta_4 - \theta_3)}{A\left(\dfrac{\theta_1 - \theta_2}{x}\right)t}$

(16) KINETIC THEORY OF GASES

1. (i) Mean speed, $\overline{C} = \dfrac{C_1 + C_2 + \dots + C_N}{N}$

(ii) Mean square speed *OR* Mean square velocity,

$$\overline{C^2} = \frac{C_1^2 + C_2^2 + \dots + C_N^2}{N}$$

(iii) Root mean square (R.M.S.) speed *OR* Root mean square velocity,

$$C = \sqrt{\frac{C_1^2 + C_2^2 + \dots + C_N^2}{N}}$$

2. (i) Pressure exerted by a gas is $P = \dfrac{1}{3}\dfrac{mN}{V}C^2$ (ii) $P = \dfrac{1}{3}\rho C^2$

3. (i) Average kinetic energy (K.E.) of a gas molecule $= \frac{1}{2} mC^2$

$$= \frac{3PV}{2N} = \frac{3}{2}\left(\frac{R}{N_0}\right)T = \frac{3}{2}kT \quad (N_0 : \text{Avogadro's number})$$

(ii) K.E. per unit volume of the gas $= \frac{(\frac{1}{2}mNC^2)}{V} = \frac{3}{2}P$

(iii) K.E. per unit mass of the gas $= \frac{3}{2}\frac{RT}{M} = \frac{3}{2}\frac{P}{\rho}$

(iv) K.E. per mole of the gas $= \frac{3}{2}RT$

4. R.M.S. speed, $C = \sqrt{\frac{3p}{\rho}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3RT}{N_0 m}} = \sqrt{\frac{3kT}{m}}$

(k : Boltzmann's constant)

5. Number of molecules per unit volume of the gas is

$$\frac{N}{V} = \frac{3P}{mC^2} = \frac{3PN_0}{MC^2} = \frac{PN_0}{RT} = \frac{P}{kT}$$

6. Van der Waals' equation of state for one mole of a real gas is

$\left(P + \frac{a}{V^2}\right)(V - b) = RT$ ...(a and b constants for a particular gas)

7. (i) Specific heat of a gas at constant volume, $c_v = \frac{(dQ)_v}{mdT} = \frac{dU}{mdT}$

(ii) Specific heat of a gas at constant pressure,

$$c_p = \frac{(dQ)_p}{mdT} = \frac{dU + dW}{mdT} = \frac{dU + PdV}{mdT}$$

8. Mayer's relation : (i) $c_p - c_v = r$ (ii) $c_p - c_v = \frac{r}{J}$

9. $c_p - c_v = \frac{R}{M}$ *or* $c_p - c_v = \frac{R}{MJ}$ depending upon the units used

10. (i) If C_p = molar specific heat of a gas at constant pressure and

C_v = molar specific heat of a gas at constant volume, then,

$C_p - C_v = R$ (all quantities in the same unit)

[$C_p = \frac{(dQ)_p}{n\,dT}$ and $C_v = \frac{(dQ)_v}{n\,dT}$, where n = number of moles of the gas]

(ii) If C_p and C_v are expressed in the heat unit and R in the mechanical unit, then,

$$C_p - C_v = \frac{R}{J}$$

(iii) $c_p = \frac{C_p}{M}$, $c_v = \frac{C_v}{M}$

11. Adiabatic constant, $\gamma = \frac{c_p}{c_v} = \frac{C_p}{C_v}$

12. Latent heat, $L = L_{internal} + L_{external} = L_i + \frac{P(v_2 - v_1)}{J}$

$L = L_i + \frac{P(V_2 - V_1)}{mJ}$, where m = mass of the substance

(17) RADIATION

1. (i) Absorption coefficient of a body, $a = \frac{Q_a}{Q}$

(ii) Reflection coefficient of a body, $r = \frac{Q_r}{Q}$

(iii) Transmission coefficient of a body, $t = \frac{Q_t}{Q}$

(iv) $a + r + t = 1$

2. (i) Emissive power of a body, $E = \frac{dQ(\text{radiated})}{Adt}$

(ii) If the temperature of the body is kept constant, $E = \frac{Q(\text{radiated})}{At}$

3. Emissivity *or* coefficient of emission of a body, $e = \frac{E}{E_b}$

$a = e$ at a given temperature, by Kirchhoff's law of radiation

4. (i) For a perfectly black body,

$E_b = \sigma T^4$ by Stefan's law of radiation

(ii) For an ordinary body, $E = \sigma e T^4$

5. Rate of loss of heat (by radiation) by a perfectly black body,

$$\frac{dQ}{dt} = \sigma A(T^4 - T_0^{\ 4})$$

6. (i) $\frac{dQ}{dt} \propto (\theta - \theta_0)$ by Newton's law of cooling $\therefore \frac{dQ}{dt} = K(\theta - \theta_0)$

(ii) $\frac{dQ}{dt} = mc\frac{d\theta}{dt} \quad \therefore \frac{d\theta}{dt} \propto (\theta - \theta_0)$ *or* $\frac{d\theta}{dt} = k(\theta - \theta_0)$

(18) DISPERSION OF LIGHT

1. Refractive index (n) of a medium

$$= \frac{\text{speed of light in vacuum } (c)}{\text{speed of light in the medium } (v)}$$

2. Refractive index of medium 2 with respect to medium 1,

$${}_1n_2 = \frac{\text{speed of light in medium } 1\,(v_1)}{\text{speed of light in medium } 2\,(v_2)} = \frac{n_2}{n_1}$$

${}_1n_2 = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$ (for the same frequency of light)

3. ${}_1n_2 = \dfrac{\sin i}{\sin r}$ = constant for a given pair of media and given frequency of light by Snell's law of refraction

4. Wave number $\bar{\nu}$ (number of waves per unit length) $= \dfrac{1}{\lambda} = \dfrac{\nu}{c}$

5. In the case of refraction of light through a prism,

(i) $A = r_1 + r_2$ (ii) $i + e = A + \delta$ (iii) ${}_1n_2 = \dfrac{\sin i}{\sin r_1} = \dfrac{\sin e}{\sin r_2}$

(iv) $i_1 + e_1 = A + \delta = i_2 + e_2$

(v) For $\delta = \delta_m$ (angle of minimum deviation), $i = e$

$$\therefore\ i = \frac{A + \delta_m}{2},\ r_1 = r_2 = \frac{A}{2} \text{ and } {}_1n_2 = \frac{\sin\left(\dfrac{A + \delta_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$$

6. For a thin prism and small angle of incidence,

$${}_1n_2 = \frac{i}{r_1} = \frac{e}{r_2},\ \delta = A\,({}_1n_2 - 1)$$

7. Dispersive power, $\omega = \dfrac{\text{angular dispersion}}{\text{mean deviation}}$

$$\therefore\ \omega_{VR} = \frac{\delta_V - \delta_R}{\left(\dfrac{\delta_V + \delta_R}{2}\right)} = \frac{n_V - n_R}{\left(\dfrac{n_V + n_R}{2}\right) - 1} \text{ (for a thin prism)}$$

(19) LENSES

1. In the case of refraction at a spherical surface, $\dfrac{n_2}{v} - \dfrac{n_1}{u} = \dfrac{n_2 - n_1}{R}$

2. In the case of a thin lens, $\dfrac{1}{v} - \dfrac{1}{u} = (n-1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$, where $n \equiv {}_1n_2 = \dfrac{n_2}{n_1}$

3. Lens maker's formula : $\dfrac{1}{f} = (n-1)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

4. Linear magnification $(M) = \dfrac{\text{linear size of the image}}{\text{linear size of the object}} = \dfrac{\text{image distance}}{\text{object distance}}$

M is negative for an inverted image and positive for an erect image.

5. Power of a lens $(P) = \dfrac{1}{\text{focal length } (f)}$

Power in dioptre $(D) = \dfrac{1}{f \text{ (in metre)}}$

6. When two lenses of focal lengths f_1 and f_2 are kept in contact with each other, the focal length (f) of the combination is given by $\dfrac{1}{f} = \dfrac{1}{f_1} + \dfrac{1}{f_2}$

Power (P) of the combination is given by $P = P_1 + P_2$

7. Simple microscope :

(i) Magnifying power of a simple microscope, M.P. $= \frac{\beta}{\alpha} = \frac{D}{u}$

(ii) M.P. $= \frac{D}{f}$ if the image is formed at ∞

(iii) M.P. $= 1 + \frac{D}{f}$ if the image is formed at the least distance of distinct vision, D

8. Compound microscope :

(i) When the final image is formed at D, M.P. $= \left(\frac{-f_0}{f_0 + u_0}\right)\left(1 + \frac{D}{f_e}\right)$

(ii) When the final image is formed at ∞, M.P. $= \left(\frac{-f_0}{f_0 + u_0}\right)\left(\frac{D}{f_e}\right)$

where f_0 = focal length of the objective and f_e = focal length of the eyepiece of the microscope

(20) INTERFERENCE OF LIGHT

1. (i) In Young's experiment (or in Fresnel's biprism experiment), the distance between the centre of the interference pattern and the nth bright band is $x_n = n\lambda\frac{D}{d}$, $n = 0, 1, 2, 3, 4, \ldots$.

Similarly, the distance between the centre of the interference pattern and the nth dark band is

$$x'_n = (2n-1)\frac{\lambda}{2}\cdot\frac{D}{d}, \quad n = 1, 2, 3, 4, 5, \ldots$$

(ii) Band width or fringe width, $X = \frac{\lambda D}{d}$

2. In Fresnel's biprism experiment, $\frac{d_1}{d} = \frac{v_1}{u_1}, \frac{d_2}{d} = \frac{v_2}{u_2}, d = \sqrt{d_1 d_2}$

(21) ELECTROSTATICS

1. According to Coulomb's law, $F = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r^2}$ (charges placed in vacuum)

2. If the charges are placed in a dielectric medium,

$F = \frac{1}{4\pi\epsilon_0 k}\cdot\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon}\cdot\frac{q_1 q_2}{r^2}$, where k = dielectric constant of the medium and $\epsilon = \epsilon_0 k$ = permittivity of the medium

3. Electric field (or electric field intensity or electric field strength) $\vec{E} = \frac{q}{4\pi\epsilon r^2}\hat{r}$

4. Force due to action of electric field is $\vec{F} = q\vec{E}$

5. Electric field between two parallel plates separated by a very small distance d is given by $E = \frac{V}{d}$

6. Electric potential at a point at a distance r from a point charge q is $V=\frac{q}{4\pi\epsilon r}$

7. When a point charge q is accelerated through a potential difference V, the work done on the charge is $W=qV=\frac{1}{2}mv^2-\frac{1}{2}mu^2$

8. Electric dipole moment, $\vec{p}=2\,q\vec{l}$, $|\vec{p}|=p=2\,ql$, where $2l$ is the distance between the two point charges, $+q$ and $-q$, forming the dipole

9. If a plane surface of area S is in a region of uniform electric field $\vec{E}$, the flux of the electric field through the area S is $\Phi=\vec{E}\cdot\vec{S}=ES\cos\theta$

10. A charged sphere behaves as a point charge (at the centre of the sphere), for points outside the sphere. In that case, the electric field intensity E (in magnitude) at distance r from the centre of the sphere is $E=\frac{1}{4\pi\epsilon_0 k}\cdot\frac{q}{r^2}$

If R is the radius of the charged sphere in the above case, the surface charge density,

$$\sigma=\frac{q}{4\pi R^2}\quad\therefore\ q=4\pi R^2\sigma\ \therefore\ E=\frac{1}{4\pi\epsilon_0 k}\cdot\frac{4\pi R^2\sigma}{r^2}=\frac{R^2\sigma}{\epsilon_0 k r^2}$$

11. Electric field intensity, E (in magnitude) due to a charged conducting cylinder (with radius R and surface charge density σ) at a point outside the cylinder and at a distance r from the axis of the cylinder is

$$E=\frac{\sigma R}{k\epsilon_0 r}.$$ (The cylinder is assumed to be infinitely long.)

If λ denotes the linear charge density (change per unit length) of the cylinder,

$$\lambda=\sigma 2\pi R.\quad\therefore\ E=\frac{\lambda}{2\pi\epsilon_0 kr}$$

12. Electric field intensity, E (in magnitude) at a point just outside a charged conductor is

$$E=\frac{\sigma}{k\epsilon_0}=\frac{\sigma}{\epsilon}$$

13. The magnitude of the mechanical force per unit area of a charged conductor is $f=\frac{F}{A}=\frac{\sigma^2}{2\epsilon_0 k}=\frac{\epsilon_0 kE^2}{2}$, where E is the magnitude of the electric field intensity at a point just outside the charged conductor.

14. Energy density or energy per unit volume of a medium $=\frac{\sigma^2}{2\epsilon_0 k}=\frac{\epsilon_0 kE^2}{2}$

15. Capacitance (capacity) of a conductor, $C=\frac{Q\,(\text{charge})}{V\,(\text{potential})}$

16. Capacitance (capacity) of a parallel plate capacitor (condenser),

$$C=\frac{k\epsilon_0 A}{d}=\frac{\epsilon A}{d}$$

17. Energy of a charged capacitor (condenser) (energy stored in the electric field in the medium between the plates of the condenser) or work done in charging a capacitor is

$$U=\frac{1}{2}CV^2=\frac{1}{2}QV=\frac{1}{2}\frac{Q^2}{C}$$

18. $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$ (series combination of n capacitors)

19. $C = C_1 + C_2 + C_3 + \dots + C_n$ (parallel combination of n capacitors)

(22) CURRENT ELECTRICITY

1. Electric current, I = rate of flow of electric charge with time

$= \frac{dQ}{dt}$ or $\frac{Q}{t}$ (for a steady current)

2. Resistance, $R = \frac{\text{potential difference}}{\text{current}} = \frac{V}{I}$; Conductance, $K = \frac{1}{R} = \frac{I}{V}$

3. $R = \rho \frac{l}{A}$ Conductivity, $k = \frac{1}{\rho}$

4. Temperature coefficient of resistance of a material, $\alpha = \frac{R - R_0}{R_0 t}$

5. (i) Resistances in series : $R = R_1 + R_2 + R_3 + \dots$.

(ii) Resistances in parallel : $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$

6. $I = \frac{E}{R + r} = \frac{V}{R}$ 7. Power $= VI = RI^2 = \frac{V^2}{R}$

8. (i) Heat produced in time $t = VIt = I^2Rt$

(ii) Heat produced in time $t = \frac{VIt}{J} = \frac{I^2Rt}{J}$

9. (i) In a balanced Wheatstone network, $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

(ii) In a Wheatstone metre bridge, $\frac{R_1}{R_2} = \frac{l_1}{l_2}$ or $\frac{X}{R} = \frac{l_x}{l_R}$

10. **Potentiometer :**

(i) Potential gradient along the wire, $k = \frac{V_A - V_B}{L}$

(ii) $k = \left(\frac{Er}{R + r}\right)\frac{1}{L}$ (iii) $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

(iv) In the sum and difference method to compare the e.m.f.s of two cells,

$\frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2}$

(v) Internal resistance of a cell, $r' = R\left(\frac{l_1 - l_2}{l_2}\right)$

(23) CHEMICAL EFFECT OF ELECTRIC CURRENT

1. $m = zq = zIt$

2. Chemical equivalent (c) in the case of atomic ions $= \frac{\text{atomic weight } (A)}{\text{valency } (V)}$

3. Chemical equivalent in the case of molecular ions $= \dfrac{\text{molecular weight}}{\text{valency}}$

(24) MAGNETIC EFFECT OF ELECTRIC CURRENT

1. Biot-Savart's law : $\overrightarrow{dB} = \dfrac{\mu_0}{4\pi} \cdot \dfrac{I\, \overrightarrow{dl} \times \vec{r}}{r^3}$, $dB = \dfrac{\mu_0}{4\pi} \cdot \dfrac{I\ dl\ \sin\theta}{r^2}$

2. Magnetic induction (B) at a point near an infinitely long thin straight conductor is
$$B = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r} = \frac{\mu_0 I}{2\pi r}$$

3. Magnetic induction (B) at a point along the axis of a circular coil is
$$B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi n I R^2}{(R^2 + x^2)^{3/2}}, \quad B = \frac{\mu_0}{4\pi} \cdot \frac{2M}{(R^2 + x^2)^{3/2}}$$

4. If a thin conductor of length l is bent in the form of an arc of radius r, the magnitude of the magnetic induction (B) at the centre (of curvature) of the arc is $B = \dfrac{\mu_0}{4\pi} \cdot \dfrac{Il}{r^2}$

5. The force $(\vec{F})$ acting on a charged particle (charge $= q$) due to the action of magnetic induction $(\vec{B})$ is $\vec{F} = q\vec{v} \times \vec{B}$, $F = qvB \sin\theta$

6. The force $(\vec{F})$ acting on a straight conductor (of length l and carrying current I) due to the action of magnetic induction $(\vec{B})$ is $\vec{F} = I\vec{l} \times \vec{B}$, $F = IlB \sin\theta$

7. The force per unit length of each conductor between two thin infinitely long straight conductors placed parallel to each other in vacuum is $\dfrac{F}{l} = \dfrac{\mu_0}{4\pi} \cdot \dfrac{2I_1I_2}{r}$

8. When a current carrying coil is suspended freely in a uniform magnetic field of induction $\vec{B}$ with its axis of rotation perpendicular to the magnetic field, the coil experiences a torque
$$\vec{\tau} = \vec{M} \times \vec{B} = nI\vec{A} \times \vec{B}, \ \tau = MB \sin\theta = nIAB \sin\theta$$

9. For a moving coil galvanometer, $nIAB = c\,\theta$

10. For a tangent galvanometer (T.G.), $I = \left(\dfrac{2rB_H}{\mu_0 n}\right) \tan\theta = k \tan\theta$

11. Current sensitivity of a galvanometer, $S_I = \dfrac{d\theta}{dI}$

    For a moving coil galvanometer, $S_I = \dfrac{nAB}{c}$

    For a tangent galvanometer, $S_I = \left(\dfrac{\mu_0 n}{2rB_H}\right) \cos^2\theta$

12. Voltage sensitivity of a galvanometer, $S_V = \dfrac{d\theta}{dV}$

13. (i) When a galvanometer is converted into an ammeter,

    shunt resistance, $S = G\left(\dfrac{I_g}{I - I_g}\right)$

(ii) Current through the galvanometer, $I_g = \left(\frac{S}{S+G}\right)I$

(iii) Current through the shunt, $I_s = \left(\frac{G}{S+G}\right)I$

(iv) Equivalent resistance of the parallel combination of G and S is $R = \frac{GS}{S+G}$

14. When a galvanometer is converted into a voltmeter, series resistance,

$$R = \frac{V}{I_g} - G$$

(25) MAGNETISM

1. The magnetic moment of a current carrying plane coil, $\vec{M} = nI\vec{A}$

2. Magnetic moment of a bar magnet (or a magnetic dipole) is $\vec{M} = 2m\vec{l}$, where m = pole strength of the bar magnet and $2l$ = magnetic length of the bar magnet $= \frac{5}{6} \times$ geometric length of the bar magnet

3. When a bar magnet is placed in a uniform magnetic induction $\vec{B}$, it experiences a torque, $\vec{T} = \vec{M} \times \vec{B}$, $T = MB \sin\theta$

4. Suppose that a bar magnet is acted upon by two uniform magnetic inductions $\vec{B_1}$ and $\vec{B_2}$ at right angles to each other, and in the equilibrium position of the magnet, its axis makes an angle θ with $\vec{B_1}$. Then, $\tan\theta = \frac{B_2}{B_1}$

5. The magnitude of the magnetic induction due to a bar magnet :

(i) $B_{axis} = \frac{\mu_0}{4\pi} \cdot \frac{2Md}{(d^2 - l^2)^2}$

$B_{axis} \doteqdot \frac{\mu_0}{4\pi} \cdot \frac{2M}{d^3}$ (for a short magnetic dipole or a short bar magnet)

(ii) $B_{equator} = \frac{\mu_0}{4\pi} \cdot \frac{M}{(d^2 + l^2)^{3/2}}$

$B_{equator} \doteqdot \frac{\mu_0}{4\pi} \cdot \frac{M}{d^3}$ (for a short magnetic dipole or a short bar magnet)

6. (i) Magnetic induction (B) at a point due to a short dipole

$$B = \frac{\mu_0}{4\pi} \cdot \frac{M}{r^3} \cdot \sqrt{3\cos^2\theta + 1}, \qquad \tan\alpha = \frac{\tan\theta}{2}.$$

The angle made by $\vec{B}$ with the axis of the dipole $= \theta + \alpha$

(ii) $B_{axis} = \frac{\mu_0}{4\pi} \cdot \frac{2M}{r^3}$ (for $\theta = 0°, 180°$)

(iii) $B_{equator} = \frac{\mu_0}{4\pi} \cdot \frac{M}{r^3}$ (for $\theta = 90°$)

7. (i) Magnetic potential (V) at a point due to a short dipole,

$$V = \frac{\mu_0}{4\pi} \cdot \frac{M\cos\theta}{r^2}$$

(ii) $V_{axis} = \frac{\mu_0}{4\pi} \cdot \frac{M}{r^2}$ (for $\theta = 0°$)

(iii) $V_{equator} = \text{zero}$ (for $\theta = 90°$)

(26) ELECTROMAGNETIC INDUCTION

1. Magnetic flux through a plane coil, $\Phi = \vec{B} \cdot \vec{A} = BA \cos\theta$

2. Induced e.m.f., $e = -\frac{d\Phi}{dt}$. Numerically, $e = \left|\frac{d\Phi}{dt}\right|$

3. Particular cases : (i) $e = -\frac{d\Phi}{dt} = A\frac{\Delta B}{\Delta t}$ (ii) $e = -\frac{d\Phi}{dt} = B\frac{\Delta A}{\Delta t}$

4. If a straight conductor of length l moves with a uniform velocity $\vec{v}$ at right angles to a uniform magnetic field of induction $\vec{B}$, the e.m.f. induced between its ends, $e = Blv$

5. If a metal rod of length r rotates about one of its ends in a plane perpendicular to a uniform magnetic induction $\vec{B}$, the e.m.f. induced between its ends,

$$e = B \times \frac{\pi r^2}{T} = B \times \pi r^2 f$$

6. The charge induced in a rotating coil, $q = \frac{BnA(\cos\theta_1 - \cos\theta_2)}{R}$

7. Earth inductor or Earth coil :

(i) $q_1 = \frac{2nAB_H}{R} = \frac{2n\pi r^2 B_H}{R}$ (for rotation through 180°)

(ii) $q_2 = \frac{2nAB_V}{R} = \frac{2n\pi r^2 B_V}{R}$ (for rotation through 180°)

(iii) Angle of dip, $\theta = \tan^{-1}\left(\frac{B_V}{B_H}\right)$

(iv) $B = \sqrt{B_H^2 + B_V^2}$

8. For a plane coil rotating with a uniform angular velocity $\vec{\omega}$ in a uniform magnetic field of induction $\vec{B}$, with the axis of rotation in the plane of the coil and perpendicular to $\vec{B}$, the peak value of the induced e.m.f. is

$$e_{max} = e_o = nBA\omega = nB(\pi r^2)\, 2\pi f$$

9. (i) Alternating e.m.f., $e = e_o \sin\omega t = e_o \sin 2\pi f t$

Alternating current, $I = \frac{e}{R} = \frac{e_o}{R}\sin\omega t = \frac{e_o}{R}\sin 2\pi f t = I_o \sin 2\pi f t$

(ii) $I_{R.M.S.} = \frac{I_{peak}}{\sqrt{2}} = \frac{I_o}{\sqrt{2}} = 0.707\, I_o$, $e_{R.M.S.} = \frac{e_{peak}}{\sqrt{2}} = \frac{e_o}{\sqrt{2}} = 0.707\, e_o$

(iii) In the case of a purely resistive circuit, average power (over one cycle),

$$P = e_{R.M.S.} \times I_{R.M.S.} = \frac{e_o I_o}{2}$$

10. Induced e.m.f., $e = -L\frac{dI}{dt}$ and inductive reactance, $X_L = \omega L = 2\pi f L$

11. Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

12. When an inductance (L) and a resistance (R) are connected in series, the impedance

$$Z = \sqrt{X_L^2 + R^2} = \sqrt{\omega^2 L^2 + R^2}$$

13. When a capacitor of capacitance C and a resistance (R) are connected in series, the

impedance $Z = \sqrt{X_C^2 + R^2} = \sqrt{\frac{1}{\omega^2 C^2} + R^2}$

14. When a resistance and an inductance and/or capacitance are connected in series, average power (over one cycle), $P = V_{R.M.S.}\, I_{R.M.S.} \cos\varphi$

15. In an $L\ C\ R$ series circuit, $\tan\varphi = \frac{X_L - X_C}{R}$, $Z = \sqrt{(X_L - X_C)^2 + R^2}$

and $\cos\varphi = \frac{R}{Z}$

16. In $L\ C\ R$ resonance, the resonant frequency is $f = \frac{1}{2\pi\sqrt{LC}}$

(27) ELECTRONS AND PHOTONS

1. The force acting on a charged particle due to the action of the electric field $\vec{E}$ is $\vec{F} = q\vec{E}$

2. If $q\vec{E}$ is the only force acting on the particle, the acceleration of the particle is

$$\vec{a} = \frac{q\vec{E}}{m} \quad \therefore \vec{v} = \vec{u} + \vec{a}\,t = \vec{u} + \frac{q\vec{E}}{m}t$$

3. The force acting on a charged particle due to the action of the magnetic field $\vec{B}$ is, $\vec{F} = q\vec{v} \times \vec{B}$, $|\vec{F}| = qvB \sin\theta$

When $\vec{v}$ and $\vec{B}$ are mutually perpendicular, $F = qvB$

In this case, the particle performs uniform circular motion, $\frac{mv^2}{r} = qvB$

Radius of the circular path, $r = \frac{mv}{qB}$

4. In a velocity selector, $v = \frac{E}{B}$

5. When a charged particle is accelerated through a potential difference V, the increase in the kinetic energy of the particle is $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Vq$

6. Energy of a quantum of electromagnetic radiation (a photon) is $E = h\nu = \frac{hc}{\lambda}$

7. (i) Einstein's photoelectric equation : $h\nu = W_o + \frac{1}{2} mV^2_{max}$

(ii) $W_o = h\nu_o = h\dfrac{c}{\lambda_o}$

(iii) Stopping potential, $V_s = \left(\dfrac{\frac{1}{2} mV^2_{max}}{e}\right) = \left(\dfrac{h\nu - W_o}{e}\right)$

(28) ATOMS, MOLECULES AND NUCLEI

1. Angular momentum of the electron in a hydrogen atom is

$$I\omega = mr^2\omega = mvr = \frac{nh}{2\pi} \quad (h : \text{Planck's constant})$$

2. (Centripetal force acting on the electron) $\dfrac{mv^2}{r} = \dfrac{e^2}{4\pi\epsilon_o r^2}$

3. (i) Radius of the nth orbit of the electron, $r = \dfrac{\epsilon_o n^2 h^2}{\pi m e^2}$

(ii) Linear speed of the electron, $v = \dfrac{e^2}{2\epsilon_o n h}$

(iii) Angular speed of the electron, $\omega = \dfrac{\pi m e^4}{2\epsilon_o^2 n^3 h^3}$

(iv) Period of revolution of the electron, $T = \dfrac{4\epsilon_o^2 n^3 h^3}{me^4}$

(v) Frequency of revolution of the electron, $f = \dfrac{me^4}{4\epsilon_o^2 n^3 h^3}$

4. (i) Potential energy of the electron $= \dfrac{-e^2}{4\pi\epsilon_o r}$

(ii) Kinetic energy of the electron $= \dfrac{e^2}{8\pi\epsilon_o r}$

(iii) Total energy of the electron $= \dfrac{-e^2}{8\pi\epsilon_o r} = -\dfrac{me^4}{8\epsilon_o^2 n^2 h^2}$

5. Binding energy of the electron $= \dfrac{e^2}{8\pi\epsilon_o r} = \dfrac{me^4}{8\epsilon_o^2 n^2 h^2}$

6. Energy of the photon emitted/absorbed

$$= h\nu = E_{n_2} - E_{n_1} = \frac{me^4}{8\epsilon_o^2 h^2}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \text{[where } n_2 > n_1\text{]}$$

7. Frequency (ν) of the electromagnetic radiation emitted/absorbed

$$= \frac{E_{n_2} - E_{n_1}}{h} = \frac{me^4}{8\epsilon_o^2 h^3}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

8. Wave number ($\bar{v}$) of the electromagnetic radiation emitted/absorbed and the corresponding wavelength (λ) are given by

$$\bar{v} = \frac{1}{\lambda} = \frac{v}{c} = \frac{me^4}{8\epsilon_o^2 h^3 c}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where $R\left(= \frac{me^4}{8\epsilon_o^2 h^3 c}\right)$ is Rydberg's constant.

(i) For the Lyman series, $n_1 = 1$, $n_2 = 2, 3, 4, \ldots, \infty$

(ii) For the Balmer series, $n_1 = 2$, $n_2 = 3, 4, 5, \ldots, \infty$

(iii) For the Paschen series, $n_1 = 3$, $n_2 = 4, 5, 6, \ldots, \infty$

9. Law of radioactive decay : $N = N_o e^{-\lambda t}$

10. Decay constant, $\lambda = \frac{2.303}{t} \log_{10}\left(\frac{N_o}{N}\right)$

11. (i) Half-life, $T = \frac{0.693}{\lambda}$ (ii) For $t = nT$, $N = \frac{N_o}{2^n}$

12. According to Einstein's theory of relativity,

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \text{ and } E = mc^2 = \frac{m_0 c}{\sqrt{1 - \frac{v^2}{c^2}}} = m_0 c^2 + K$$

13. Energy of a photon, $E = hv = h\frac{c}{\lambda} = mc^2$.

~ Jhulia Chaudhary