GENERAL PHYSICS

Units

1. $N \propto \frac{1}{u}, N_1U_1 = N_2U_2$ where N – Numerical value, u – Units

2. **Fundamental or basic S.I. units :** (i) **metre** (m) ⟶ *length,* (ii) *Kg* ⟶ *mass*, (iii) **second** (s) ⟶ *time*, (iv) **Kelvin** (***K***) ⟶ *temperature,* (v) **ampere** (A) ⟶ *electric current*, (vi) **candela** (Cd) ⟶ luminous intensity and (vii) **mole** (mol) ⟶ amount of substance.

3. **Supplementary S.I. units :** (i) plane angle : radian (rad); (ii) solid angle : steradian (Sr).

4. **Prefixes used for multiples and sub-multiples:**

MULTIPLES

10^1 = *deca* (D)	10^2 = *hecto* (H)	10^3 = *kilo* (K)	10^6 = *mega* (M)
10^9 = *giga* (G)	10^{12} = *tera* (T)	10^{15} = *peta* (P)	10^{18} = *exa* (E)

5. **Sub-Multiples**

10^{-1} = *deci* (d)	10^{-2} = *centi* (c)	10^{-3} = *milli* (m)	10^{-6} = *micro* (μ)
10^{-9} = *nano* (n)	10^{-12} = *pico* (p)	10^{-15} = *femto* (f)	10^{-18} = *atto* (at)

Some other important units :

(i) 1 *micron* (μ) = 10^6 m.

(ii) 1 *millimicron* ($m\mu$) = 10^{-9} m.

(iii) 1 *angstrom unit* ($\mathring{A}$) = 10^{-10} m.

(iv) 1 *X– ray unit* ($X.U.$) = 10^{-13} m.

(v) *1 fermi* = 10^{-15} m (*used in nuclear physics*).

(vi) 1 *light year* = 10^{16} m (*approximately*) = 9.46×10^{15} m.

(vii) 1 per second = 3.26 light years.

(viii) 1 sea mile = 6020 *ft*.

(ix) 1 cable = 182.5 *m*.

(x) 1 knot = 1 *sea mile/hr* or 1 nautical *mile/hr.*

(xi) 1 *slug* = 14.59 *kg*.

(xii) 1 *bar* = 10^5 N/m^2.

(xiii) 1 *foot* = 0.3048 *m*.

(xiv) 1 *A.U.* = 1.496 × 1011 *m* (astronomical unit).

6. **Dimensional formula :**

$M^a L^b T^c \theta^d$

a, b, c, d – Dimensions, *M* – Mass, *L* – Length, *T* – Time, θ – Temperature.

7. To change one system of units into another :

$$N_2 = N_1\left(\frac{M_1}{M_2}\right)^x \cdot \left(\frac{L_1}{L_2}\right)^y \cdot \left(\frac{T_1}{T_2}\right)^z.$$

Where N_1 = numerical value in one system and N_2 = numerical value in another system.

Vectors and Scalars, Velocity and Acceleration

1. (i) $\vec{v} \times s = \vec{v}$ (ii) $\frac{\vec{v}}{s} = \vec{v}$ (iii) $\vec{v}.\vec{v} = s$ (iv) $\vec{v} \times \vec{v} = \vec{v}$ Here $\vec{v}$ = vector, s = scalar

2. $\vec{A} = K\vec{a}, K = \text{constant}$

3. $\vec{A} = A_x\vec{i} + A_y\vec{j} + A_z\vec{k}$, then $|\vec{A}| = \sqrt{(A_x^2) + (A_y^2) + (A_z^2)}$

4. **Dot or Scalar product :** $\vec{A}.\vec{B} = |A|.|B|\cos\theta$.

Where θ is angle between $\vec{A}$ & $\vec{B}$ measured from A to B.

$|A| =$ modulus of $\vec{A}$, $|B| =$ modulus of $\vec{B}$

5. **Vector or cross product :** $\vec{C} = \vec{A} \times \vec{B} = |A|.|B| \sin\theta$.

6. **Instantaneous velocity** $(v_i) = \frac{dy}{dt}$, $y =$ displacement

7. **Average velocity**

$$(\vec{v}_{av}) = \frac{\text{total displacement}}{\text{total time taken}} = \frac{y_2 - y_1}{t_2 - t_1} = \frac{\Delta \vec{y}}{\Delta t}$$

8. **Average speed =** $\frac{\text{total distance travelled}}{\text{total time taken}}$

9. **Change in velocity** $(\Delta\vec{v}) =$ final velocity $(\vec{v}_2) -$ initial velocity $(\vec{v}_1)$.

10. **Average acceleration**

$$(\vec{f}_a) = \frac{\text{change in velocity}}{\text{time interval}} = \frac{\Delta\vec{v}}{\Delta t}$$

11. **Instantaneous acceleration** $(f_i) = \frac{dv}{dt}$.

12. $(\Delta\vec{v})^2 = \vec{v}_2^2 + \vec{v}_1^2 - 2\vec{v}_2\vec{v}_1 \cos\theta$. Where : $\theta =$ angle between v_2 and v_1 .

13. Relative velocity of A with respect to ***B*** $(\vec{v}_{AB}) = \vec{v}_A - \vec{v}_B$.

14. **Composition and resolution of velocity and forces:**

$R^2 = v_1^2 + v_2^2 + 2v_1v_2 \cos\theta$ and

$\tan\alpha = \frac{v_2 \sin\theta}{v_1 + v_2\cos\theta}$. $R_{max} = v_1 + v_2$, When $\theta = 0°$; $R_{min} = v_1 - v_2$, When $\theta = 180°$;.

$$v_1 = \frac{R\sin\beta}{\sin(\alpha+\beta)}, v_2 = \frac{R\sin\alpha}{\sin(\alpha+\beta)}$$. where $= \theta = \alpha + \beta$.

Components at right angle : $v_1 = R\cos\alpha$ and $v_2 = R\sin\alpha$.

For forces, replace v_1 by p and v_2 by Q.

Equation of Motion Along a Stright Line

1. (i) $v = \dfrac{ds}{dt} = \dfrac{\Delta s}{\Delta t}$ (ii) $f = \dfrac{dv}{dt} = \dfrac{\Delta v}{\Delta t}$

(iii) Gradient of time –displacement graph is $\dfrac{\Delta s}{\Delta t} = v$ (velocity). In mathematic, gradient = tan θ [θ = angle of inclination].

So that $v = \tan\theta$, $\dfrac{v_1}{v_2} = \dfrac{\tan\theta_1}{\tan\theta_2}$

(iv) Gradient of time–velocity graph is $\dfrac{\Delta v}{\Delta t} = f$ (acceleration) $a = \tan$ $\theta, \dfrac{a_1}{a_2} = \dfrac{\tan\theta_1}{\tan\theta_2}$

2. **In horizontal plane, with uniform velocity and retardation/acceleration:**

(i) $s = ut$, $[f = 0]$ (ii) $v = u \pm ft$. (iii) $v^2 = u^2 \pm 2fs$

(iv) $s = ut \pm \frac{1}{2}ft^2$ (v) The distance travelled in n^{th} second,

$$s_n = u \pm \frac{1}{2}(2n - 1)f$$

Here (–*ve*) sign is used for retardation. For rotational motion, replace u, v, s & f by ω_0, ω, θ and α respectively.

3. **For motion under gravity :** (i) $g = 9.8\ m/sec^2$. (ii) $s = h$. (iii) Replace $f = \pm g$, (+*ve*) for downward motion (–*ve*) for upward motion

(a) $v = u \pm gt$ (b) $h = ut \pm \frac{1}{2}gt^2$ (c) $v^2 = u^2 \pm 2gs$

(iv) $h_{max} = \frac{u^2}{2g}$ (for upward). (v) The time taken to reach the highest point $= \frac{u}{g}$. (vi) $\frac{2u}{g}$ = total time of flight = time to ascend + time to descend.

4. For motion on an inclined plane making an angle α with the horizontal plane, replace g by $\pm g \sin \alpha$, for downward and upward motion respectively.

Here v = velocity, u = initial velocity, s distance, f = acceleration, t = time, h = height, g = acceleration due to gravity.

5. **Readymade formula—**

(i) When any particle is acceleration inside a pipe, then $t = \frac{2s}{u+v}$

Here t = time, s = distance [length of a pipe], u = initial velocity, v = final velocity.

(ii) A ball is dropped on the floor from a height h_1. It rebounds to a height oif h_2. If the ball is in contact with the floor for Δt *sec*, the average acceleration during contact is $f = \frac{\sqrt{2g}}{\Delta t}(\sqrt{h_1} + \sqrt{h_2})$

(iii) If a is related to b from $a \propto b^n$, then if increasing percentage of b, then percentage increases of a is given by

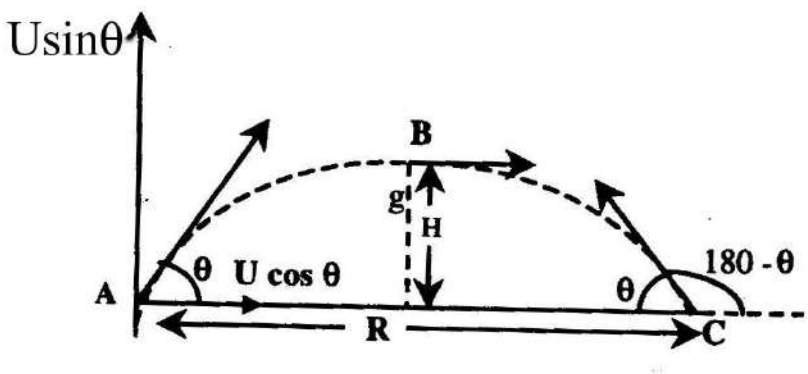
$a\% = [(b\% + 1)^n - 1] \times 100$. If decreases, then replace (b) by ($-b$).

Projectile Motion

When angle of projection = θ, u = initial velocity, g = acceleration due to gravity.

1. $Y - X$ Plane

Case – I : When projectile thrown from the ground level.



(i) Horizontal velocity $V_H = u\cos\theta$ (0) (ii) Vertical velocity $V_v = u \sin\theta$

(iii) In any time interval t, the horizontal distance travelled by the projectile

$X = (u\cos\theta).\,t$ [∵ =Horizontal acceleration = 0] (iv) Vertical acceleration (upwards) = –g] (v) Projectile moves in parabolic path. Its equation is given by

$$y = x\tan\theta - \left(\frac{g}{2u^2\cos^2\theta}\right)x^2.$$

2. **Time of flight** $(T) = \dfrac{2u\sin\theta}{g}, T_{max} = \dfrac{2u}{g}$.

3. **Maximum vertical height** $(H) = \dfrac{u^2\sin^2\theta}{2g}$; $H_{max} = \dfrac{u^2}{2g}$, when $\theta = 90°$.

4. **Horizontal range** (R) = Horizontal distance × Time of flight = $u\cos\theta \times T$

$$= \frac{u^2\sin 2\theta}{g}; R_{max} = \frac{u^2}{g}, \text{ when } \theta = 45°, R = 4H\cos\theta = 4H.$$

5. Range for θ = Range for $(90° - \theta)$ for the same velocity.

6. At maximum height $K.E. = \dfrac{1}{2}mv^2\cos^2\theta$ and at lowest point $K.E. =$

$\frac{1}{2}mv^2$, hence their ratio = $\cos^2\theta$.

7. Horizontal projection from height (h) : time to reach the ground $(t) = \frac{\sqrt{2h}}{g}$.

8. **Velocity at any point :**

After time t from the start,

Vertical velocity $v_1 = u \sin\theta - gt$, Horizontal velocity $v_2 = u\cos\theta$

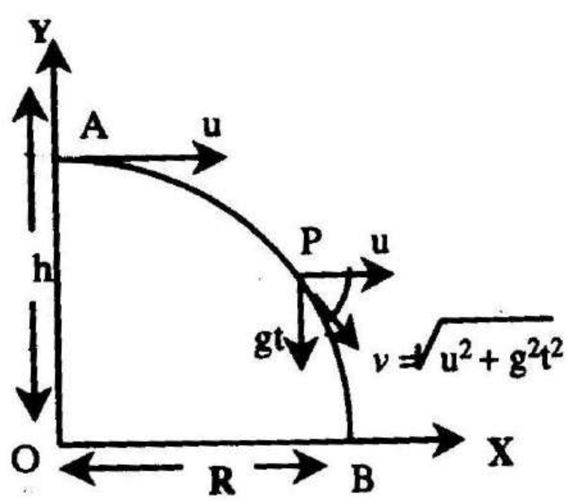
Total velocity $v = \sqrt{v_1^2 + v_2^2}$

$= [(u \sin\theta - gt)^2 + (u\cos\theta)^2]^{1/2}$

$= [u^2 + g^2t^2 - 2ugt \sin\theta]^{-1/2}$

And direction from horizontal $\beta = \tan^{-1}\left(\tan\theta - \frac{gt}{u\cos\theta}\right)$ [where $v_1 = v\sin\beta$, $v_2 = v\cos\beta$]

Case - II : When projectile thrown from a height



(i) Projectile moves in parabolic path. Its equation is $y = \left(-\frac{g}{2u^2}\right)x^2$.

(ii) Velocity at any point $v = \sqrt{u^2 + g^2 t^2}$ and direction $\beta = \tan^{-1}\left(\frac{gt}{u}\right)$

(iii) Horizontal range $R = u\sqrt{\frac{2h}{g}}$

Newton's Laws of Motion

1. **Momentum (*P*)** $= mv$.

2. (i) Force (F) $= \frac{dP}{dt} = \frac{d}{dt}(mv) = m\frac{dv}{dt} + v\frac{dm}{dt}$ (for variable *m*)

   (ii) $F = \frac{mdv}{dt}$ (iii) $F = \frac{m(v-u)}{t} = \frac{m\Delta v}{\Delta t}$

   For rotational motion replace *m*. *F* and *P* by *I*. τ & *L* respectively.

3. **Impulse** $= F.\ \Delta t = P_2 - P_1$ = change in momentum.

4. **Inertial mass :** $m = \frac{F}{f} \Rightarrow \frac{m_1}{m_2} = \frac{f_2}{f_1}$ [F is same]

5. **Gravitational mass :**

   $\frac{m_A}{m_B} = \frac{\Delta l_A}{\Delta l_B}$ m = mass, f = acceleration, v = Final velocity, u = initial velocity, t = time, Δl_A and Δl_B are extensions produced in the same string, n = frequency. Numerically, inertial and gravitational masses are equivalent.

6. **Units of force :** Absolute $\rightarrow$ 1 Newton (S.I.) = 10^5 dyne (C.G.S.).
   1 gravitational unit = $g \times$ absolute unit.

7. $R = m\,(g \pm f)$ are reactions of mass *m*, moving on a lift upward and downward respectively.

8. **Rocket propulsion :** It is based on the principle of conservation of momentum. Its acceleration is given by

$a = \frac{\Delta v}{\Delta t} = \frac{v_r}{m}\left[\frac{\Delta m}{\Delta t}\right] - g$. Where $v_r\left[\frac{\Delta m}{\Delta t}\right]$ is called thrust of the rocket,

v_r = velocity of gas related to rocket, Δm = mass of the gas and m= mass of the rocket and unburnt fuel.

In outer space, acceleration due to gravity becomes negligibly small or $g = 0$ and we have $a = \frac{v_r}{m}\left[\frac{\Delta m}{\Delta t}\right]$.

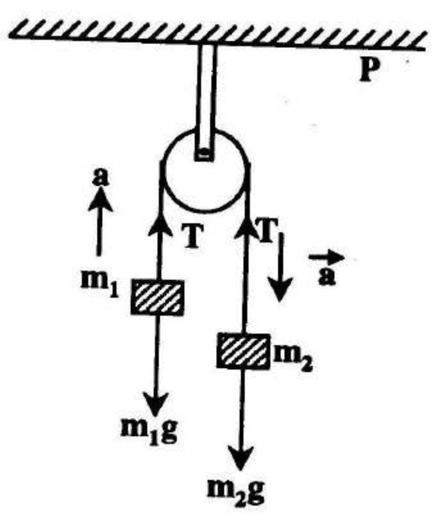
9. **Time period of a pendulum inside a moving lift:**

gT^2 (normal) = $(g + f)T_1^2$ (ascending) = $(g - f)\ T_2^2$ (descending).

$\frac{g}{n^2}$ (normal = $\frac{g+f}{n_1^2}$ (ascending) = $\frac{g-f}{n_2^2}$ (descending).

Motion of bodies on pulley—

Case 1 : Let two masses m_1 and m_2 ($m_2 > m_1$) are suspended on a pulley by means of an inextensible string.



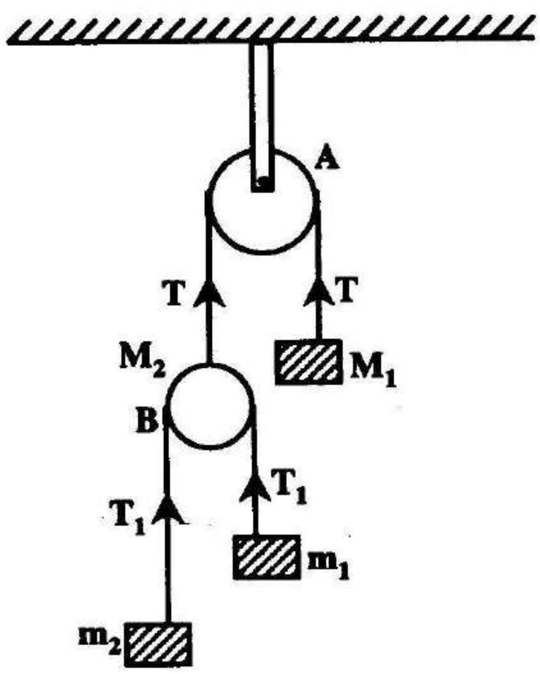
(i) Acceleration of the system $a = \frac{(m_2 - m_1)}{(m_1 + m_2)} g$

(ii) Tension in the string $T = \left(\dfrac{2m_1 m_2}{m_1 + m_2} \right) g$

(iii) The force at the point of suspension of the string

$$F = 2T = \left[\frac{4m_1 m_2}{m_1 + m_2} \right] g$$

Case 2 : Let the acceleration of pulley B and mass M_1 with respect to $A = a$ and the acceleration of masses m_1 and m_2 with respect to $A = a'$, then

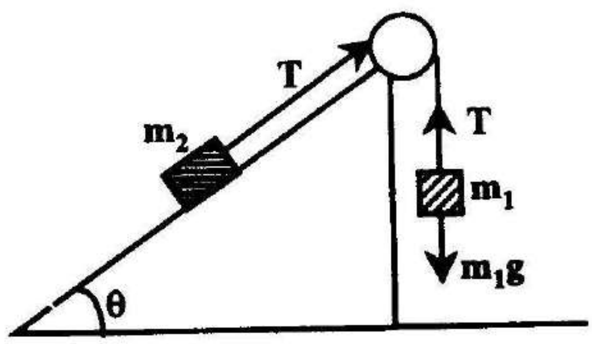


$$a = \left(\frac{M_1 - M_2}{M_1 + M_2} \right) g - \frac{2T_1}{M_1 + M_2}$$

and $a' = \dfrac{2M_1(m_2 - m_1)g}{4m_1 m_2 + (M_1 + M_2)(m_1 + m_2)}$

Case 3 : A body is raised on an inclined plane by means of another body, In this case, the acceleration of this system

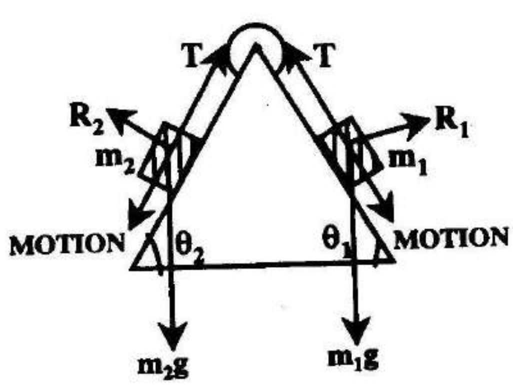
$$a = \frac{(m_1 - m_2 \sin\theta)g}{m_1 + m_2}$$



and tension $T = m_1 g\left[1 - \frac{m_1 - m_2 \sin\theta}{m_1 + m_2}\right]$

Case 4 : The bodies are on two inclined planes having angle of inclination θ_1 and θ_2 as shown. In this case, the acceleration of the system

$$a = \frac{g(m_2 \sin\theta_2 - m_1 \sin\theta_1)}{m_1 + m_2}$$

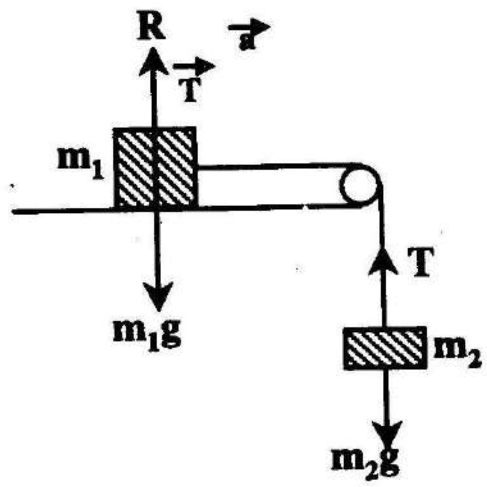


and tension, $T = \frac{m_1 m_2}{m_1 + m_2}(\sin\theta_2 + \sin\theta_1)g$

Some Special Cases of Motion –

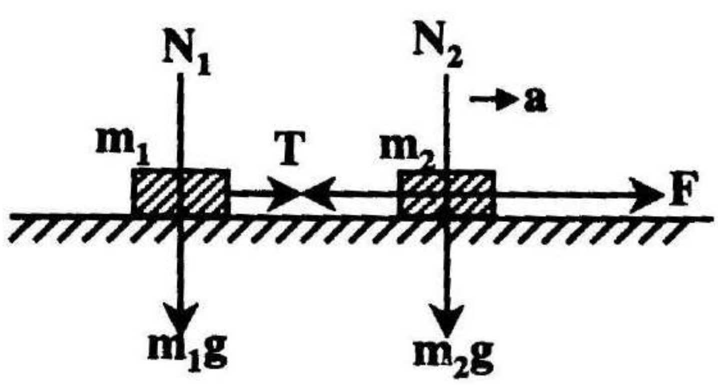
(1) **A** mass m_1 on a frictionless horizontal table is moved by connecting

it by a second mass m_2 by an inextensible string which passes over a frictionless pulley. The tension in the string and acceleration of the system is given by



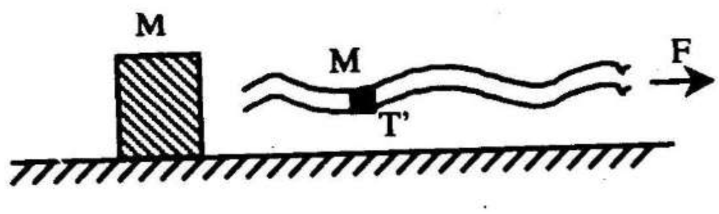
$$a = \frac{m_2 g}{m_1 + m_2} \text{ and } T = \left(\frac{m_1 m_2}{m_1 + m_2}\right) g$$

2. Two bodies of masses m_1 and m_2 placed on a horizontal frictionless table and are connected by a string and a force F is applied on a body.



The acceleration of the system $a = \dfrac{F}{m_1 + m_2}$ and the tension in the string $T = m_1 a$

3. A body of mass M is on the horizontal frictionless table and is moved by a string of mass m, then



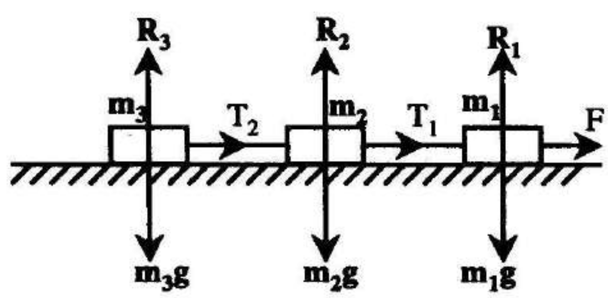
(i) Acceleration of the system $a = \dfrac{F}{M+m}$

(ii) The force exerted by the string on the body $= M\left[\dfrac{F}{M+m}\right]$

(iii) The tension at the centre of the string

$$T' = \left(M + \frac{m}{2}\right)\left(\frac{F}{m+M}\right) = \frac{(2M+m)F}{2(M+m)}$$

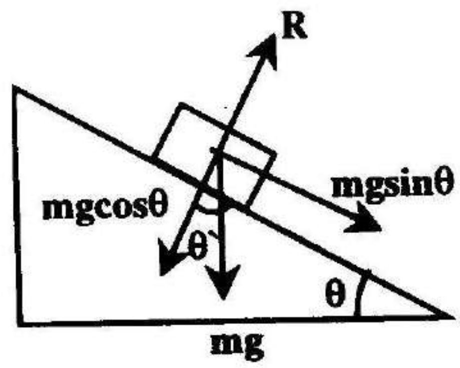
4. Three masses are connected by the string onthe horizontal friction-less table and are moved by a force F.



(i) The tension $T_1 = \dfrac{(m_2+m_3)F}{(m_1+m_2+m_3)}$

(ii) The tension $T_2 = \dfrac{m_3F}{(m_1+m_2+m_3)}$

5. Motion down on smooth inclined plane



In the position of equilibrium

$a = g \sin\theta$ and $R = mg\cos\theta$

6. Contact force when two bodies are in contact

(i) When the force acts on m_1

The acceleration of the system $a = \dfrac{F}{m_1 + m_2}$

If a portion of the force F_1 acts on m_1, the balance $(F - F_1)$ will necessarily be act on m_2.

Hence the force F_1 acting on $m_1 = m_1 a = \dfrac{m_1 F}{m_1 + m_2}$ and the force acting on $m_2 = F - m_1 a = \dfrac{m_2 F}{m_1 + m_2}$

(ii) When the force acts on m_2. The acceleration of the system $a = \dfrac{F}{m_1 + m_2}$. The portion F_2 of the force F acts on m_2 and the balance $(F - F_2)$ will act on m_1. Hence the force F_2 acting on $m_2 = m_2 a$ and the force acting on $m_1 = F - m_2 a = \dfrac{m_1 F}{m_1 + m_2}$

Work, Energy and Power

1. (a) Work $(W) = \vec{F}.\vec{d} = F\,d\cos\theta$

F = Force, d = displacement, θ = Angle between displacement to the direction on force

(b) $W = \int dW = -\int F.dr$

(c) $W = \Delta E_k$, ΔE_k = Kinetic energy

(c) $W = -\Delta U, \Delta U$ = Internal energy

When $\theta = 90°$, $W = 0$ and when $\theta = 180°$, W is $-ve$.

2. **Power (P)** $= \frac{W}{t} = \vec{F}.\vec{v} = F.v.\cos\theta = force \times velocity$.

3. **Kinetic energy (K.E.)**

$$E_K = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{1}{2}Pv$$

4. $P = \sqrt{2mE}, P =$ Momentum, m = Mass, E = Energy

5. **Work done by the resultant force** $(W) = F \times x = \frac{1}{2}m(v_2^2 - v_1^2)$.

6. **Stopping distance** $(d) = \frac{\frac{1}{2}mv2}{F} = \frac{initial\ K.E.}{retarding\ force}$.

7. In a frictionless gravitational field:

$$K.E.\left(\frac{1}{2}mv^2\right) + P.E.(mgh) = constant.$$

8. K.E. never be–ve but P.E. may be $-ve$ or $+ve$.

9. **Work done by a variable force** $(W) = \int F.dx$.

10. **Spring force** $(F) = \pm Kx$. where K = spring constnat and $\pm x$ = stretched or compressed distance respectively.

11. P.E. stored in a spring compressed through the distance $x = \frac{1}{2}Kx^2$.

12. **Gravitational potential energy:**

(i) $U_G = mgh$, m = Mass, g = Acceleration due to gravity, h = Height Potential energy at the height h from the earth $\Delta U = \frac{mgh}{l + \frac{h}{R}}$,

R = Radius of earth. (ii) $U_G = \frac{-GMm}{r}$, G = Gravitational constant, M = Mass of earth m = Mass of body, r = Distance from centre of earth

13. **Electric potential energy:** $U_E = \pm\frac{kq_1q_2}{r}$, $q_1 = q_2$ = Charge

14. **Gravitational kinetic energy :** $K.E. = \frac{GMm}{2r}$

15. When a ball is dropped, then total height h, h_1 = rebounded height

% Energy loss $= \frac{h - h_1}{h} \times 100$

16. **Units of work** Absolute, 1 *joule* (S.I.) = 10^7 erg (c.g.s.).

Gravitational S.I. ⟶ 1 J = 1 N-m, c.g.s. = *dyne–cm*.

In nuclear physics ⟶ Electron volt (eV).

17. **Units of power and relation :** Absolute, S.I. : *J/sec* = *watt,* c.g.s.: *erg/sec.* Special unit: Horse power (H.P.) = 550 *ft. lb/sec* = 746 *watt.*

Conservation of Linear Momentum and Collision

1. $\sum \vec{P}$ = constant, when external force = 0.

2. Total momentum before collision = total momentum after collision,

i.e. $P_1 + P_2 = P_1' + P_2'$

3. **For perfect elastic collision :** $m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$ and

$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$. $[e = 1]$.

4. The velocities of two masses after elastic collision are given by

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2} \text{ and } v_2 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$$

where m_1, m_2 are the masses of the particles and $\vec{u}_1, \vec{u}_2$ are their respective velocities before collision.

(i) If $m_1 = m_2$ then $v_1 = u_2$ and $v_2 = u_1$

5. **Co-efficient or restitution**

$$(e) = \frac{\text{relative velocity after collision}}{\text{relative velocity before collision}}$$

$= \frac{v_2 - v_1}{u_1 - u_2}$, When $u_1 > u_2$. The value of lies between 0 and 1.

6. (i) The velocities of two masses after inelastic collision are given by

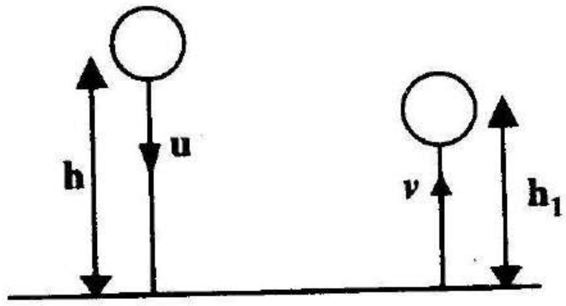
$$v_1 = \left(\frac{m_1 - em_2}{m_1 + m_2}\right)u_1 + \frac{m_2(1+e)u_2}{m_1 + m_2}$$

$$v_2 = \frac{m_1(1+e)}{m_1 + m_2}u_1 + \left(\frac{m_2 - em_1}{m_1 + m_2}\right)u_2$$

(ii) **Energy loss :**

$$\Delta E_k = \frac{1}{2}\frac{m_1m_2}{m_1 + m_2}(u_1 - u_2)^2(1 - e)^2$$

7. When any body is vertically falling on a horizontal plane from height h and after collision. It is rebound from height h_1, then



(i) Coefficient of restitution $= \frac{v}{u} = \sqrt{\frac{h_1}{h}}$ When body is strike on plane again and again and travel the distance h_1, h_2, h_3 ...... then

$e = \sqrt{\frac{h_1}{h}} = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{h_3}{h_2}} = \sqrt{\frac{h_n}{n_{n-1}}}$ (ii) After one rebound, $h_1 = e^2 h$

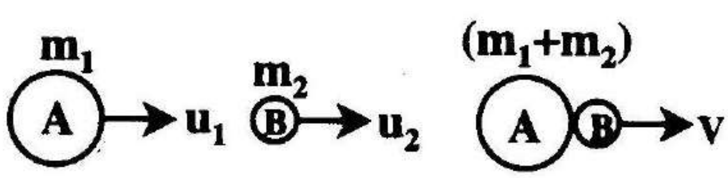
(iii) After second rebound, $h_2 = e^2 h_1 = e^2 e^2 h = e^4 h$

(iv) After n rebound, $h_n = e^{2n} h$.

(v) After n rebound, total distance $= h\left(\frac{1+e^2}{1-e^2}\right)$

8. **Perfectly inelastic collision:**

(i) When two bodies are joined, then after collision, velocity of combined body



$$v = \frac{m_1 u_1 + m_2 u_2}{m_1 + m_2}$$

When $u_2 = 0$ [second body is stationary]

$$v = \frac{m_1 u_1}{m_1 + m_2}$$

(ii) **Energy loss :** $\Delta E_k = \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(u_1 - u_2)^2$

(iii) The ratio of kinetic energy before and after collision is given by

$$\frac{K.K._1}{K.K._2} = \frac{(m_1 + m_2)m_1^2 u_1^2}{m_1 u_1^2 (m_1 + m_2)^2} = \frac{m_1}{m_1 + m_2}$$

Parallel Forces, Moment, Couple and Friction

1. $R = P \pm Q$. for like and (unlike unequal, $P > Q$) II forces respectively.
2. If P, Q & R act at points A, B,C respectively || to each other and A B C is a straight line then $\frac{P}{BC} = \frac{Q}{AC} = \frac{R}{AB}$.
3. **Moment of a couple** $(M) = F \times x$ = force×arm of the couple
4. **Moment of a force** $(\tau) = \vec{F} \times \vec{r}$
5. **Frictional force** $(F) = \mu R$, F_s - $\mu_s R \Rightarrow \mu_s \frac{F_s}{R}$

   where μ = co-efficient of friction, μ_s = coefficient of static friction, F_s = limiting frictional force, R = normal reaction, $F_k = \mu_k R \Rightarrow \mu_k \frac{F_k}{R}$

   μ_k = coefficient of sliding friction, μ is also equal to $= f/g$, f = Acceleration applied, g = Acceleration due to gravity.

   Readmade formula :

   v_0 = Initial velocity of car, μ = Coefficient of friction (between road and tires), when brakes is applied then total distance is, $s = \frac{v_0^2}{2\mu g}$

   and $\mu = \frac{v_0^2}{2sg}$

6. **For same surface :** $\mu_s > \mu_k > \mu_r$. Where μ_s, μ_k & μ_r are coefficients of limiting or static, kinetic & rolling friction respectively.

7. $\mu = \tan\lambda$. Where λ = anlge of friction.

8. $\mu = \tan\theta$. Where θ = angle of repose.

9. **Minimum force required to just slide a body over a rough horizontal surface** $(F) = \mu_s mg$.

10. $F = \mu_k mg$, for maintaining a body to slide with uniform speed over a rough horizontal surface.

11. **Motion on a rough inclined plane :**

(i) Minimum for required to prevent the body from sliding down $(F) = mg(\sin\theta - \mu_s \cos\theta)$.

(ii) Minimum force required to slide a body up the plane:

$F = mg(\sin\theta + \mu_k \cos\theta)$. Where θ = angle of inclination.

12. **Work done against friction:**

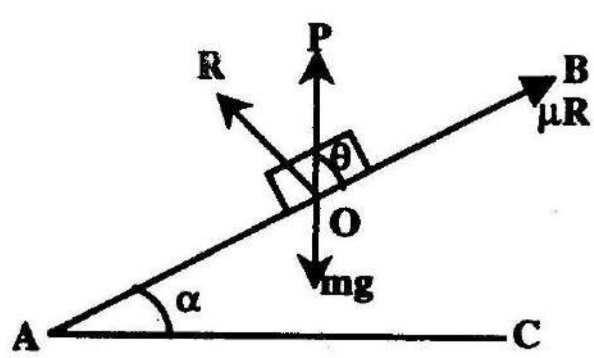
(i) (a) $W = F.d = \mu R.\, d = \mu \,.\, mg \,.\, d$, W = Work done, d = Distance.

(b) When angle of unclination is θ

(i) $W = [\mu R + mg \sin\theta]d$

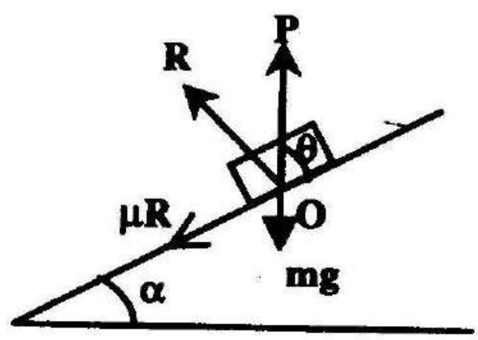
(ii) $W = [\mu\, mg \cos\theta + mg \sin\theta]\, d = mg[\mu \cos\theta + \sin\theta]\, d$

(ii) For downward motion



(a) $P = mg\dfrac{\sin(\alpha - \lambda)}{\cos(\theta + \lambda)}$ (b) $P_{\min} = mg \sin(\alpha - \lambda)$

(iii) For upward motion



(a) $P = mg\dfrac{\sin(\alpha+\lambda)}{\cos(\theta-\lambda)}$ (b) $P_{min} = mg\sin(\alpha+\lambda)$

Uniform Circular Motion

1. Angular velocity $\omega = \dfrac{\text{Angular displacement}}{\text{Total time}}$

$\omega = \dfrac{2\pi}{T} = 2\pi n$, T = Time, n = Frequency

2. $v = r\omega$, r = Radius, v = Velocity

3. **Radial or centripetal acceleration**

$(f_r) = -\dfrac{v^2}{r} = -r\omega^2 = v\omega$ (Numerically)

4. Tangential acceleration $(f_t) = \dfrac{dv}{dt} = r\dfrac{d\omega}{dt} = r\alpha$. Where α = angular acceleration.

5. **Instantaneous acceleration** $(f) = \sqrt{f_r^2 + f_t^2}$.

6. **Centripetal force** = $mf_r = \dfrac{mv^2}{r} = mr\omega^2 = mv\omega$ = **Centrifugal reaction** in opposite direction.

7. **Motion of a cyclist :** $\tan\theta = \frac{v^2}{rg} = \frac{fr_r}{g}$. Where θ = angle of inclination from vertical.

8. **Banking of track :** $\frac{\mu + \tan\theta}{1 - \mu\tan\theta} = \frac{v^2}{rg}$, μ = Coefficient of friction But generally considered μ = 0, then $\tan\theta = \frac{v^2}{rg}$.

9. **Maximum speed for safe driving :** $v = \sqrt{\mu rg}$.

10. **Motion in a vertical circle :** (i) Tension at the top $(T_1) = \frac{mv_1^2}{r} - mg$

(ii) **Tension at the bottom :** $(T_2) = \frac{mv_2^2}{r} + mg$. (iii) $T_2 - T_1 = 6$ mg. (iv) $v_2^2 - v_1^2 = 4rg$. (v) Minimum speed at the top for just performing complete revolution $(v_1) = \sqrt{rg}$. (vi) Minimum speed at the bottom for just performing complete revolution $(v_2) = \sqrt{5rg}$.

Surface Tension

1. **Surface tension** $(T) = \frac{F}{t}$. **S.I. unit = N × m^{-1}** F = force, l = length, ΔA = change in area, W = work done.

2. **Surface energy** $(E) = \frac{W}{\Delta A}$. **S.I. unit =** $Joule \times m^{-2}$.

3. Excess pressure (P) inside a liquid drop = $\frac{2T}{r}$. **Where** r = radius.

4. Excess pressure (P) inside a soap bubble = $\frac{4T}{r}$. For cylindrical

surface $P = \frac{T}{r}$.

5. Work done (W) in blowing a soap bubble = $8\pi r^2 \times S$. Where S is surface tension.

6. (i) $T = \frac{rh\rho g}{2\cos\theta}$. For pure water ($\theta = 0°$). $T = \frac{1}{2} rh\rho g$.

(ii) If the effective height (h) = $\frac{1}{3}r$, then $T = \frac{r\left(h + \frac{1}{3}r\right)\rho g}{2\cos\theta}$.

Where θ = angle of contact, h = rise of liquid, r = radius of the capillary tube & ρ = density of the liquid.

7. **Jurin's law :** $h \propto \frac{1}{r}$. ρ, g, θ and T are constant, *i.e.* hr = constant.

8. Work done in formation of a drop $W = T.\ \Delta A = T(A_2 - A_1) = 4\pi T$

$(R_2^2 - R_1^2) = 4\pi R^2 T \frac{W_1}{W_2} = \left(\frac{R_1}{R_2}\right)^2$, T = **Surface tension,** ΔA = Change in area.

9. **Work done in formation of a bubble**

$$W = 2T.\ \Delta A = 2T(A_2 - A_1) = 8\pi T(R_2^2 - R_1^2) = 8\pi R^2 T \frac{W_1}{W_2} = \left(\frac{R_1}{R_2}\right)^2.$$

10. $\frac{W_1}{W_2} = \left(\frac{V_1}{V_2}\right)^{2/3}$, V_1, V_2 = volume

11. Formation of bigger drop by a number of smaller drops (i) $R = n^{1/3} r$

R = Radius of big drop, r = Radius of small drop $W = 4\pi r^2 T n^{2/3} [n^{1/3} - 1]$.

(ii) Increase in temperature

$$\Delta T = \frac{3T}{J\rho S}\left[\frac{1}{r} - \frac{1}{R}\right], \Delta T = \frac{3T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

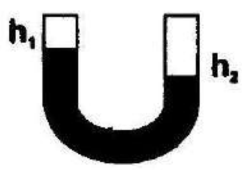
S = Specific heat of liquid, J = Mechanical equivalent of heat, ΔT= Temperature, ρ = Density of liquid

12. **Division of a bigger drop into smaller drops:**

$W = 4\pi TR^2 (n^{1/3} - 1)$,

Where $R = n^{1/3} r$, R = Radius of bigger drop, r = Radius of smaller drop, T = surface tension, n = Number of smaller drops.

13. **Height difference in a $'U'$ Shape tube**



$$h = h_1 - h_2,\ h = \frac{2T\cos\theta}{\rho g}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

Fluids in Motion and Viscosity

1. **Rate of flow** $(R) = A \times v$.

Where A = cross-sectional area and v = velocity of flow.

2. **Equation of continuity :** For stream line flow and incompressible fluid Av = constant, *i.e.* $A_1V_1 = A_2V_2$.

3. **Bernoulli's theorem :** (i) Pressure energy, P.E. and K.E. per unit volume are constant, *i.e.* $P + \rho gh + \frac{1}{2}\rho v^2$ = constant.

(ii) If $\frac{energy}{mass}$ is considered : $\frac{P}{\rho} + gh + \frac{1}{2}v^2$ = Constant.

Where h = height, ρ = density & P = pressure at any point.

(iii) $\frac{P}{\rho}+\frac{1}{2}v^2$ = constant ($\therefore P.E. = 0$) in a horizontal plane.

4. **Torricelli's theorem :** (i) $v=\sqrt{2gh}$. (ii) $t=\sqrt{\frac{2h_1}{g}}$. (iii) $x=2\sqrt{hh_1}$.

Where h = height of the liquid layer above the orfice, h_1 = height of the orfice above the ground, x = range, v = velocity of efflux and t = time to fall to the ground.

5. $F - \pm\eta A\frac{dv}{dx}$, where $\frac{dv}{dx}$ = velocity gradient, η = coefficient of viscosity, F = tangential force, A = area.

6. **Poiseculle's formula :** $V=\frac{\pi P r^4}{8\eta l}$, here P = Presure difference,

l = Length, V = *Volume/sec.*

7. **Stoke's law :** $F=6\pi\eta r v$.

8. $v_t=\frac{2}{9}\cdot\frac{r^2(\rho-\sigma)g}{\eta}$. Where v_t = terminal velocity ρ & σ = density of the material & fluid.

9. $v_c=\frac{K\eta}{\rho r}$. Where ρ = density of liquid r = radius of the tube and K = Renold's number, v_c = critical velocity.

10. **In pitot tube:**

$v=\sqrt{\frac{2(P_1-P_2)}{d}}$, p_1, p_2 = Pressure, d = Density of liquid.

11. **In venturimeter :**

$Q=A_1A_2\sqrt{\frac{2gh}{A_1^2-A_2^2}}$. Where A_1, A_2 = Area, h = Height of liquid and

Q = volume of liquid flowing per second.

Elasticity

1. **Stress =** $\frac{F}{A}$. **S.I. unit** $N.m^{-2}$, F = Force, A = Area.

2. **Strain =** $\frac{\text{change in some measure}}{\text{total measure}}$

   (i) Longitudinal of tensile strain $= \frac{\text{Change in length}}{\text{Original length}}$

   (ii) Transverse strain $= \frac{\text{Change in diameter}}{\text{Original diameter}}$

   (iii) Volume strain $= \frac{\text{Change in volume}}{\text{Original volume}}$

   (iv) Shearing strain = Angle of shear

3. **Stress** = E × strain

   Where E = Elastic constant or modulus of elasticity.

   $E_s > E_l > E_g$ (s = Solid, l = Liquid, g = Gas).

4. **Hooke's law :** Within elastic limits *stress* $\propto$ *strain*

   $$Y = \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{\frac{F}{A}}{\frac{l}{L}}$$.(for solids only).

   Where l = change in length L = original length, Y = Young's modulus of elasticity.

5. k (Bulk modulus) $= \frac{\text{volume stress}}{\text{volume strain}}$, (for solids, liquids and gases).

$= \frac{\text{Hydrostatic pressure}}{\text{volume strain}} = \frac{\frac{F}{A}}{\frac{v}{V}}$. Where v = change in volume

$= \frac{\Delta P}{-\Delta V / V}, V =$ Original volume. S.I. unit $= N.m^{-2}$.

6. **Shearing or rigidity modulus**

$(\eta) = \frac{\text{shearing stress}}{\text{shearing strain}} = \frac{F}{A.\theta}$. Where θ = shearing angle. **S.I. unit** = $N.m.^{-2}$.

7. **Two types of Bulk modulus (k) :**

(i) **Isothermal** $k = p$ (p = pressure of the gas). (ii) **Adiabatic** $K = \gamma p, \gamma = \frac{C_p}{C_v}$.

8. **Relation between Y, k and η** : $\frac{9}{Y} = \frac{3}{\eta} + \frac{1}{k}$.

(i) $Y = 3k(1-2\sigma)$ (ii) $Y = 2\eta(1+\sigma)$

(iii) $Y = \frac{9k\eta}{\eta + 3k}$ (iv) $\sigma = \frac{3k - 2\eta}{6k + 2\eta}$

Here σ = Poisson's ratio, Y = Young's modulus, k = Bulk modulus η = Modulus of rigidity.

9. **Poisson's ratio** $(\sigma) = \frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{\frac{d}{D}}{\frac{l}{L}} = \frac{dL}{lD} = \frac{\Delta rl}{\Delta l.r}$.

Where d = change in diameter, D = original diameter.

10. Work done (W) in stretching a spring or P.E. of a stretched spring :

$W = \frac{1}{2}Kx^2$, where $K = \frac{F}{X}$ = spring constant.

11. **Compressibility** = $\frac{1}{k}$,

12. **Safety factor** = $\frac{\text{breaking stress}}{\text{working stress}}$.

13. Work done (W) in stretching a wire or the energy stored in a stretched wire:

$W = \frac{1}{2} \times$ stress $\times$ strain $\times$ volume.

14. When a rod is heated but not allowed to expand in length. The tension $F = YA\,\alpha\,\Delta\theta$.

Y = Young's modulus, A = Area of cross-section of the rod, α = Coefficient of linear expansion of the rod, $\Delta\theta$ = Rise in temperature.

15. Relation between torsion of a cylinder and shearing angle.

(i) $\phi = \frac{\theta . r}{l}$, Here ϕ = Shearing angle, θ = Torsion angle, r = Radius of cylinder, l = Length of cylinder.

(ii) **Torsional, Torque** $C = \frac{\pi\eta r^4}{2l} \frac{\text{Newton metre}}{\text{Radian}}$

(ii) Work done $W = \frac{\pi\eta r^4\theta^2}{4l} Joule. = 1/2\, C\theta^2$.

16. Interatomic force constant (K)

(i) $K = \frac{F_o}{r}$ (ii) $K = Y \times r_o$ Here F_o = Interatiomic force, r = Distance between atoms, r_o = Interatomic distance, Y = Young's modulus.

17. **Bending moment :**

$$G = \frac{YI_G}{R}, \text{ Here}$$

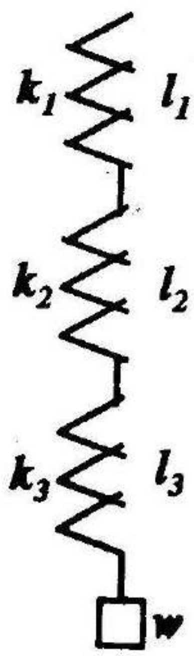
Y = Young's modulus of beam,

I_G = Moment of inertia of beam,

R = Radius of bending beam.

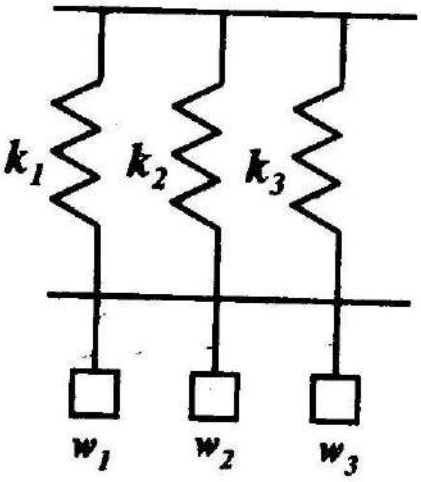
18. **Spring combination :**

(i) In series



$$l = l_1 + l_2 + l_3, k_s = \frac{k_1k_2k_3}{k_1k_2 + k_2k_3 + k_3k_1}$$

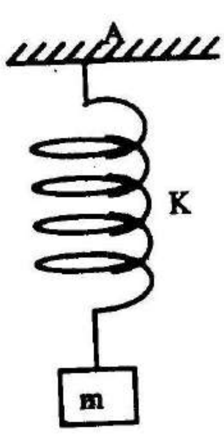
(ii) In parallel



$$W = W_1 + W_2 + W_3, K_P = K_1 + K_2 + K_3$$

Simple Harmonic Motion and Pendulum

1. (i) For S.H.M. $f \propto -y$. Where f = acceleration, y = displacement (ii) $\omega = \sqrt{\frac{K}{m}} = \frac{2\pi}{T}$ Here ω = Angular frequency, K = Force constant, m = Mass, T = Periodic time $1/n$, n = Frequency.
2. (i) a = amplitude, $\omega t + \phi$ = phase & ϕ = epoch or initial phase.
   (ii) At mean position, $y = 0$. In this case, $y = a \sin \omega t$.
3. (i) $v = a\,\omega \cos(\omega t + \phi) = \omega\sqrt{a^2 - y^2}$.
   (ii) $v_{max} = a\omega$, at $y = 0$, *i.e.* at the mean position.
   (iii) $v_{min} = 0$, at $y = \pm a$, *i.e.* at the turning points.
4. (i) $f = -a\omega^2 \sin(\omega t + \phi) = -\omega^2 y$.
   (ii) $f_{max} = \pm \omega^2 a$, at $y = \pm a$.
   (iii) $f_{min} = 0$, at $y = 0$.
5. (i) $K.E. = \frac{1}{2}m\omega^2(a^2 - y^2) = \frac{k}{2}(a^2 - y^2)$.
   (ii) $P.E. = \frac{1}{2}m\omega^2 y^2 = ky^2/2$.
   (iii) Total energy = $K.E. + P.E. = \frac{1}{2}m\omega^2 a^2$ (always constant).
6. **Motion of a body suspended by a spring**



$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{K}}$$

(i) If m_s be the mass of the spring, then the expression of time period given by

$$T = 2\pi\sqrt{\frac{m + \frac{m_s}{3}}{K}}$$

(ii) If a spring of force constant K is divided into n equal parts and one such part is attached to a mass m, then the time pariod is given by $T = 2\pi\sqrt{\frac{m}{nK}}$

(iii) If two springs of force constnat K_1 and K_2 are connected in parallel and a mass m is attached to them, then the time period is given by $T = 2\pi\sqrt{\frac{m}{K_1 + k_2}}$ where $K = K_1 + K_2$

(iv) If two springs of force constants K_1 and K_2 are connected in series and a mass m is attached to them, then the time period is given by $T = 2\pi\sqrt{\frac{m(K_1 + K_2)}{K_1K_2}}$

where $\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} = \frac{K_2 + K_1}{K_1K_2}$ or $K = \frac{K_1K_2}{K_1 + K_2}$

(v) If two masses m_1 and m_2 are connected by a spring, then the time period is given by $T = 2\pi\sqrt{\frac{\mu}{k}}, \mu = \frac{m_1m_2}{m_1 + m_2}$, Here μ is known as reduced mass.

7. Simple pendulum : $T = 2\pi\sqrt{\frac{l}{g}}$.

8. Compound pendulum :

$T = 2\pi\sqrt{\frac{L}{g}}$. Where $L = 1 + \frac{k^2}{l}$, $l =$ distance of C.G. fromthe support, K = radius of gyration about an axis passing through C.G. and parallel to the axis of oscillation.

9. **Torsional pendulum :** $T = 2\pi\sqrt{\frac{I}{c}}$, I = moment of inertia, C = torque.
10. **Second's pendulum** $T = 2$ second
11. (i) Body oscillating in a tunnel dug along any chord of earth $T = 2\pi\sqrt{\frac{R_e}{g}}$

    (ii) Body oscillating in the tunnel dug along the diameter of earth T = 84.6 *minutes*
12. **Equation of S.H.M.** $\frac{d^2y}{dt^2} + \omega^2 y = 0$

Rotational and Moment of Inertia

1. **Position of centre of mass**

$$r_{cm} = \frac{m_1r_1 + m_2r_2 + m_3r_3 + ... + m_nr_n}{m_1 + m_2 + m_3 + ... + m_n}$$

Here m_1, m_2, m_3 .... m_n mass of particles, r_1, r_2, r_3 .... r_n, rotating distance.

2. Angular momentum $L = I\omega$ (I = Moment of inertia, ω = Angular velocity) or $L = mvr = Pr$ (m = Mass, v = Velocity, P = Momentum)
3. **Laws of rotational motion :** $\tau = I\alpha$, τ = Torque, I = Moment of inertia, α = angular acceleration.
4. **Moment of a force (torque) :**

$\tau = F \times d$, τ = Torque, F = Force, d = Distance.

5. (i) **Angular momentum** $J = I\omega = mvr = pr = \frac{2E}{\omega}$

   (ii) **Angular acceleration,** $\alpha = a/r$

   r = Radius, a = Linear acceleration, α = Angular acceleration.

   (iii) $\Delta s = r\Delta\theta$, Δs = Linear displacement, $\Delta\theta$ = Angular displacement.

6. **K.E. of a rolling body** = $\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$.

7. M.I. **(I)** = $m_1r_1^2 + m_2r_2^2 + \ldots\ldots\ldots\ldots = \sum mr^2 = MK^2$ Radius of gyration $K = \sqrt{\frac{I}{m}}$.

8. **Theorem of parallel axex :** $I = I_{c.g} + Mx^2$.

9. **Theorem of $\perp$ axis :** $I_z = I_x + I_y$, [$\perp$ to each other]

10. **M.I. of a thin uniform rod of length L mass M:**

    (a) Axis through its centre and $\perp$ to its length : $I = \frac{ML^2}{12}$.

    (b) **Through one end and $\perp$ to length :** $I = \frac{1}{3}ML^2$.

11. **M.L. of a rectangular lamina :**

    (a) Axis through its centre and $\perp$ to the plane: $I = \frac{M}{12}(l^2 + b^2)$.

    (b) Through centre and parallel to length or breadth : $I = \frac{Ml^2}{12}$ or $\frac{Mb^2}{12}$.

12. M.I. of a circular ring or loop about an axis :

(a) Through centre and ⊥ to the plane : $I = Mr^2$.

(b) Through a diameter : $I = \frac{1}{2}Mr^2$.

13. M.I. of a circular disc about an axis:

(a) Through centre & ⊥ to the plane : $I = \frac{1}{2}Mr^2$.

(b) Through a diameter $I = \frac{1}{4}Mr^2$.

14. M.I. of a solid sphere about a diameter: $I = \frac{1}{5}Mr^2$.

15. M.I. of a hollow sphere about a diameter : $I = \frac{1}{3}Mr^2$.

16. Velocity & acceleration of a body rolling down an inclined plane without slipping :

$v^2 = \dfrac{2gh}{1+\left(\frac{k}{r}\right)^2}$ and $f = \dfrac{g\sin\theta}{1+\left(\frac{k}{r}\right)^2}$. $E_{total} = 1/2\, I\omega^2 + 1/2\, mv^2$

$\omega = \sqrt{\dfrac{2gh}{r^2+k^2}} = \sqrt{\dfrac{2mgh}{1+mk^2}}$. Kinetic energy

$E_T = \frac{1}{2}mv^2\left(1+\frac{k^2}{r^2}\right)\frac{k^2}{r^2}$ value → solid sphere – 2/5, hollow sphere – 2/3, ring and holow cylinder–1.

17. P.E. of a rolling disc or ring $= Mgr$.

18. P.E. of a sphere (solid or hollow) or cylinder = 0

Gravity and Gravitation

1. **Gravitational force of attraction** (F) in any medium. $F = G\frac{m_1 m_2}{r^2}$.

   where G = universal gravitational constant = 6.67×10^{-11} S.I. unit.

2. **Intensity (I) of gravitational field** at a distance r from a body of mass m: $I = \frac{G}{r^2} = -\frac{dV}{dr} = \frac{F}{m}$.

3. **Gravitational potential at** a point r distance apart from a body of mass m : $V = -\frac{GM_e}{r}$. [$romanat\ \infty$, $V_{\max} = 01$].

4. **Acceleration due to gravity g** on the surface of a planet of mass M. radius R and density ρ : $g = \frac{GM}{R^2} = \frac{4}{3}\pi GR\rho$.

5. **Variation of** g:

   (a) **Above the surface of the earth at a height**

   $h : g' = g\frac{R^2}{(R+h)^2} \cong g\left(1 - \frac{2h}{R}\right)$.

   (b) **At a depth h below the surface of the earth:** $g' = g\left\{1 - \frac{h}{R}\right\}$.

   At the centre of the earth, $g' = 0$

   (c) **Due to rotation of the earth :** $g' = g\left(1 - \frac{R\omega^2\cos^2\theta}{g}\right)$.

   Where ω = angular velocity of the earth & θ = latitude.

Special Cases –

(i) **At pole,** θ = 90°, $g' = g$ (maximum) *i.e.* maximum weight.

(ii) **At equtor,** $\theta = o^o, g' = g\left(1 - \frac{R\omega^2}{g}\right)$ minimum.

(iii) Difference, $g_p - g_e = g - g\left(1 - \frac{R\omega^2}{g}\right) = R\omega^2.$

(iv) Difference in weight of a body at pole & at equator $= mR\omega^2$.

6. **Escape velocity :**

$(v_e) = \sqrt{\frac{2GM}{R}} = \sqrt{2gR} = 7 miles/\sec = 11.2$ km/sec for Earth.

$(v_e) = 2.4$ km/sec for Moon.

Where M = Mass of the planet, R = radius of the planet.

7. **Orbital velocity** $(v_0) = \sqrt{\frac{GM}{R+x}} = 5$ miles/sec or 8 km/sec for the Earth.

Where x = distance of the body above earth's surface.

8. $v_e = \sqrt{2}v_0$, v_e and v_0 are independent of the mass of the body.

9. **Time period of revolution of the satellite (T)** $= 2\pi\sqrt{\frac{(R+x)^3}{G\ M}}$. If $x = 0$, then $T^2 \propto R^3$ (Kepler's law).

10. **Simple pendulum :** $T = 2\pi\sqrt{\frac{l}{g}}$

Pendulum in a lift :

(a) When lift is at rest $T = 2\pi\sqrt{\frac{l}{g}}$

(b) When lift is moving upward with an acceleration a, then

$$T = 2\pi\sqrt{\frac{l}{a+g}}$$

(c) When lift is moving downwards with an acceleration a

$$T = 2\pi\sqrt{\frac{l}{g-a}}$$

(d) When lift is falling freely $T = 2\pi\sqrt{\frac{l}{g-g}} = \infty$ (i.e. does not vibrate)

11. **Pendulum in an open cart :**

(a) Moving with an acceleration in horizontal direction

$$T = 2\pi\sqrt{\frac{1}{(a^2+g^2)^{1/2}}}$$

(b) Cart sliding down an inclined plane $T = 2\pi\sqrt{\frac{1}{g\cos\theta}}$

12. **Gravitational potential energy :**

(i) $U_g = m \times V_g = GM_e m / R_e, m =$ Mass, $V_g =$ Gravitational potential

At a distance r from the centre of the earth.

(ii) $U_g = -\frac{Gm_1m_2}{r}$ (ii) $U_g = 2 \times$ Kinetic energy

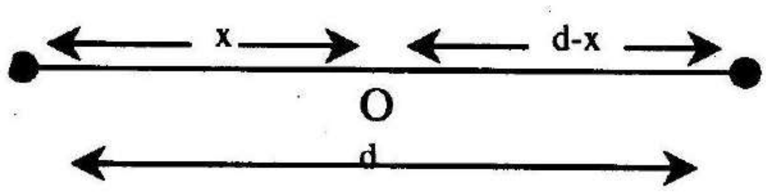
13. **Kinetic energy :** $K = 1/2mV^2 = \frac{GM_e m}{2r}$

14. **Total energy :** $E = -\frac{GM_e m}{2r}$

15. **Binding energy :** $E_b = \frac{GM_e m}{2r}$

16. **Energy of escape** : $E_e = \frac{GM_e m}{R_e}, R_e =$ Radius of earth

17. A point O (where the intensity of gravitational field is zero) of the line joining two masses m_1, m_2, then the distance from m_1 to O and m_2 to O is



Distance $x = \frac{\sqrt{m_1}d}{\sqrt{m_1} + \sqrt{m_2}}$, Distance $d - x =$

$$\frac{\sqrt{m_2}d}{\sqrt{m_1} + \sqrt{m_2}},$$

Specific Heat of Gases, Kinetic Theory of Gases, Gas Laws, Isothermal and Adiabatic changes

1. $C_p - C_v = \frac{R}{J}$ When R in *erg* or *Joule*. $C_P - C_v = R$, when R in calorie, C_p = Specific heat of gas at constant pressure, C_v = Specific heat of gas at constant volume, R = Universal gas con stant.

2. $\frac{C_p}{C_v} = \gamma$ (always > 1) S.I. unit of C_p and C_v = *joule mole*^{1} K^{-1}

$$C_p = \frac{(W+M)(t_2 - t_1)}{m\left(t - \frac{t_1 + t_2}{2}\right)}.$$

Where W = water equivalent of the calorimeter, M = mass of water, m = mass of the gas t_1 and t_2 = initial and final temperatures of water and t = temperature of the oil bath. $C_v = \frac{ML}{m(t_2 - t_1)}$

Where M = mass of the condensed steam, m = mass of the gas, L = latent heat of steam, t_1 = initial temperature of the steam chamber and t_2 = final temperature of the steam chamber.

3. For mono, di, tri-atomic gases

(i) γ = 1.66, 1.41, 1.33 respectively (ii) Degrees of freedom = 3,5,7 respectively.

4. **Presure** (P) : Pressure P, mn = mass of the gas, V = Volume of the gas, ρ = Density of the gas, $\overline{C}$ = Root mean square velocity (R.M.S.) of the molecules, E = Kinetic energy.

(i) $P = \frac{1}{3}\frac{mn}{V}\overline{C}^2$ (ii) $P = \frac{1}{3}\rho\,\overline{C}^2$ (iii) $P = \frac{2}{3}E$

5. **Average velocity** (C) :

(i) $C = \dfrac{C_1 + C_2 + C_3 + ... + C_n}{n}$ (ii) C=0.921 $\overline{C}$

Where C_1, C_2, C_3, ... C_n are the respective velocities of n different molecules.

6. **Maximum velocity :** $C_{max} = \sqrt{\dfrac{2}{3}} \times \overline{C} = 0.817\overline{C}$

7. **Mean square velocity** $(\overline{C})$:

(i) $(\overline{C})^2 = \dfrac{C_1^2 + C_2^2 + C_3^2 + ...C_n^2}{n}$ (ii) $\overline{C} = \sqrt{\dfrac{3P}{P}}$ (iii) $\overline{C} = \sqrt{\dfrac{3RT}{M}}$

Here $M = mn$ = mass of the gas, T = Temperature

(iv) $\overline{C} = \sqrt{\dfrac{3KT}{m}}$, m = mass of a gas molecule, K = Boltzmann's constant = 1.38×10^{-23} J/K

8. **Kinetic energy** (E) :

(i) $E = \dfrac{1}{2}m\overline{C}^2$ (ii) $E = \dfrac{3}{2}KT$ (iii) $E = \dfrac{3}{2}P$

9. **Boyle's law :** $P \propto \dfrac{1}{V}$ or PV = constant or $P_1V_1 = P_2V_2$ [When temperature is constant] Here P = Pressure, V = Volume.

10. **Charle's law :** [At constant pressure] $V \propto T$ or $\dfrac{V_1}{V_2} = \dfrac{T_1}{T_2}$

11. **Gas equation :** [For an ideal gas] $PV = RT$, Here R = Universal gas constant, T = Temperature.

12. **Graham's law of diffusion:**

Under similar conditions of temperature and pressure, the rate of diffusion of a gas is inversely proportional to the square root of their molecular weights or dencities, *i.e.* $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{d_2}{d_1}}$

13. **Dalton's law of partial pressure:**

The gases which do not react with each other, if enclosed in a vessal, the total pressure P will be the sum of the pressure exerted by each gas, provided they are at the same temperatures, *i.e.* $P = P_1 + P_2 + P_3 + ...$

14. **Vander Waal's gas law :**

(i) $\left(P + \frac{a}{V^2}\right)(V - b) = RT$ Here P = Pressure, V = Volume, T = Temperature, R = Universal gas constant, a, b are constant, $R = KN = 1.38 \times 10^{-23} \times 6.02 \times 10^{23} = 8.31\ J/K - mol$, K = Boltzmann's constant, $R = 8.31 \times 10^7\ erg/K - mol$, Dimensional formula of $a = ML^5T^{-2}$ Dimensional formula of $b = M^0L^3T^0$

(ii) Critical volume, $V_c = 3b$ (iii) Critical temperature, $T_c = \frac{8a}{27Rb}$

(iv) Critical pressure, $P_c = \frac{a}{27b^2}$ (v) $\frac{RT_c}{P_cV_c} = \frac{8}{3}$

15. **Isothermal process:** [At constant temperature]

(i) PV = Constant (Boyle's law). (ii) For a gas under isothermal condition, its specific heat is infinite

$$\because C = \frac{Q}{m.\Delta\theta} = \Delta\theta = 0 \Rightarrow C = \infty.$$

(iii) $E_\theta = P$, E_θ = volume elasticity, P = Pressure

16. **Adiabatic process** : $dQ = 0$

(i) $dU = -W$, W = work done, dU = change in internal energy. If work is positive (expansion of gas) internal energy decreases (dU is $-ve$) and if work is negative (compression) dU is $+ve$, internal energy increases.

(ii) PV^{γ} = constant, $\gamma = \frac{C_p}{C_v}$

(a) At constant pressure $TV^{\gamma-1}$ = constnat

(b) At constant volume $TP^{(1-\gamma)/\gamma}$ = constant

(c) $\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} \Rightarrow \frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma} \Rightarrow PV^{r} = \text{const.}$

(d) $\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} \Rightarrow \frac{V_2}{V_1} = \left(\frac{T_1}{T_2}\right)^{1/(\gamma-1)} \Rightarrow TV^{r-1} = \text{const.}$

(e) $\frac{T_1}{T_2} = \left(\frac{P_2}{P_1}\right)^{(1-\gamma)/\gamma} \Rightarrow \frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\gamma(1-\gamma)} \Rightarrow T^{r}P^{1-r} = \text{const}$

(iii) Specific heat (adiabatic) $= 0, C = \frac{Q}{m\Delta\theta} \because Q = 0, C = 0.$

(iv) Volume elasticity $E_{\phi} = \gamma p =$

18. $\frac{E_{\phi}}{E_{\theta}} = \gamma = \frac{C_p}{C_v}$, E_{ϕ} = Volume elasticity (adiabatic), E_{θ} = Volume elasticity (isothermal)

19. **For adiabatic changes :**

(i) $PV^{\gamma} = K$. (ii) $TV^{\gamma-1} = K$ (iii) $T^{\gamma} P^{1-\gamma} = K$, where K = constant.

20. Work done by a gas during

(i) isothermal (for 1 mole) : $W = RT \log_e \frac{V_2}{V_1} = RT \log_e \frac{P_1}{P_2}$

(ii) adiabatic (for 1 mole) : $W = \frac{R}{\gamma - 1}(T_1 - T_2) = \frac{1}{\gamma - 1}(P_1V_1 - P_2V_2$

Here W = Work, V_1 = Initial volume, V_2 = Fianl volume, P_1 = Initial pressure, P_2 = Final pressure, T_1, T_2 = Temperature.

Mechanical Equivalent of Heat, Transmission of Heat and Hygrometry

1. (i) $J = \frac{W}{H}$. Where W = mechanical work H = equivalent of heat and J mechanical equivalent of heat $\cong 4.2$ *Joule/cal*.

   (ii) $mgh = J\,ms\,\Delta T$ (iii) $\frac{mv^2}{2} = J\,ms\,\Delta T$

   (iv) $mgh = J\,mL$ (v) $\frac{mv^2}{2} = JmL$

   Here m = Mass, g = Acceleration due to gravity, h = Height, s = Specific heat, ΔT = Tem perature, L = Latent heat.

   In S.I. → W & H in Joule, hence J = 1 and W = H.

2. In steady state, amount of heat flown in time t:

   $Q = KA\frac{\theta_2 - \theta_1}{l}t$, Where $(\theta_2 - \theta_1)$ = difference of temperature over length l, A = cross-sectional area, K = co-efficient of thermal conductivity, t = time

   Here $\frac{KA}{l}$ = thermal conductance & $\frac{l}{KA}$ = thermal resistance.

   S.I. unit of $K = Js^{-1}m^{-1}k^{-1}$ or watt $m^{-1}K^{-1}$.

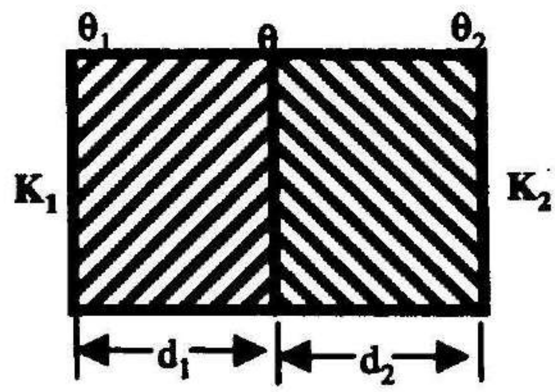
3. **Ingen Hauz's experiment :**

   $$\frac{K_1}{l_1^2} = \frac{K_2}{l_2^2} = \frac{K_3}{l_3^2} = \ldots\ldots = \text{constant.}$$

4. **Heat flow through a compound wall:**

   As shown in the figure, the temperature of the intermediate layer.

$$Q = \frac{\frac{K_1\theta_1}{d_1} + \frac{K_2\theta_2}{d_2}}{\frac{K_1}{d_1} + \frac{K_2}{d_2}}$$

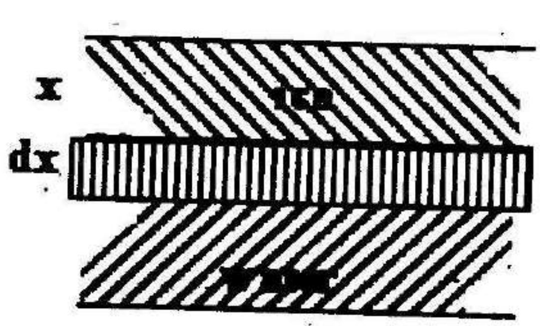


If $d_1 = d_2$, then = $\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

The heat flow from such a wall $Q = \frac{A(\theta_1 - \theta_2)}{\frac{d_1}{k_1} + \frac{d_2}{k_2}}$

where A = Area of the blocks, θ_1 = Temperature of first layer, θ_2= Temperature of second layer, θ = Temperature of intermediate layer, d_1, d_2 = Distances, K_1, K_2 = Coefficient of thermal conductivity.

5. (i) Time taking in forming the ice of thickness x is, $t = \frac{\rho L}{2K\theta}.x^2$



ρ = Density of ice. L = Latent heat of ice, K = Coefficient of thermal conductivity of ice, θ = Temperature of the air above the lake.

(ii) Time taken in increasing the height of ice from x_1 to x_2 is

$$t = \frac{\rho L}{2K\theta}\left[x_2^2 - x_1^2\right]$$

6. $h = \dfrac{K}{\rho s}$, where h = thermometric conductivity or diffusivity and ρs = thermal capacity/volume.

7. **Stefan's law**

(i) $E = \sigma T^4$ (ii) $E = \sigma(T^4 - T_0^4)$ (iii) $\dfrac{Q}{t} = \sigma e A T^4$

(iv) $\dfrac{Q_1}{Q_2} = \dfrac{A_1 e_1 t_1 T_1^4}{A_2 e_2 t_2 T_2^4}$ (v) $\dfrac{Q_1}{Q_2} = \left(\dfrac{r_1}{r_2}\right)^2 \cdot \left(\dfrac{T_1}{T_2}\right)^4$

(vi) $\dfrac{Q_1}{Q_2} = \left(\dfrac{d_1}{d_2}\right)^2 \cdot \left(\dfrac{T_1}{T_2}\right)^4$

Here σ = Stefan's constant, T = temperature of the body, T_0 = temperature of the surroundings, A = Area, t = time, r = radius, d = diameter, Q = Quantity, e = emissivity of the surface. Here temperature always taken in Kelvin.

(a) Newton's law of cooling: (i) $\dfrac{dQ}{dt} = -k(T - T_0), \dfrac{dQ}{dt}$ = Rate of flow of amount. T = Teperature of the body, T_0 = Temperature of the surroundings.

(ii) $\dfrac{dQ}{dt} = -k\left[\dfrac{\theta_1 + \theta_2}{2} - \theta_0\right]$ (iii) $\dfrac{Q_1 - Q_2}{t} = k\left[\dfrac{\theta_1 + \theta_2}{2} - \theta\right]$

θ_1 = Temperature in hot condition, θ_2 = Temperature in cool condition, θ_0 = Ambient temperature.

8. **Wein's displacement law :** $\lambda_m \times T$ = constant.

λ_m = Wavelength corresponding ot maximum, energy, T = Temperature in Kelvin

(i) $\frac{^{\lambda}m_1}{^{\lambda}m_2} = \frac{T_2}{T_1}$ (ii) $\frac{^{n}m_1}{^{n}m_2} = \frac{T_2}{T_1}$, n = frequency.

9. (i) $Q = mL$ (ii) $Q = ms\,\Delta\theta$

(iii) $\frac{C}{5} = \frac{F-32}{9} = \frac{R}{4} = \frac{K-273}{5}$

Here Q = Quantity, m = mass, L = latent heat, "s = specific heat, $\Delta\theta$ = temperature difference, C = degree celcius, K = Kelvin, R = Rumer, F = Fahrenheit

SOUND

Speed, Reflection, Refraction and Beats

1. $v = n\lambda$. Where v = Velocity of wave, n = Frequency, λ = Wave-length

2. $n = \frac{1}{T}$. Unit of n is 1 *cps* = 1 *hertz*. Where T = Time period

3. Distance travelled by the wave = number of vibrations × λ.

4. Normal hearing range → 20 *cps* to 20×10^3 *cps*.

5. Phase velocity $(v) = \frac{\text{Angular velocity } (\omega)}{\text{Propagation constant (K)}}$

6. MACH number $= \frac{\text{speed of the body}}{\text{speed of sound}}$.

7. Velocity of transverse wave $(v) = \sqrt{\frac{T}{m}}$

   Where T = Tension, m = Mass per unit length.

8. Speed of any longitudinal wave in any medium : $v = \sqrt{\frac{E}{\rho}}$.

   Where E = elasticity, ρ = density of the medium.

9. Speed in solid, $v_s = \sqrt{\frac{Y}{\rho}}$, Where Y = Young's modulus.

10. Speed in liquid $v_l = \sqrt{\frac{K}{\rho}}$, where K = Bulk modulus.

11. According to Laplace : $v = \sqrt{\frac{\lambda_p}{\sqrt{\rho}}} = C\sqrt{\frac{\gamma}{3}}$, where $\gamma = \frac{C_p}{C_v} = 1.41.$ C

= R.M.S. velocity and γP = adiabatic modulus of elasticity, V_{air} at N.T.P. = 332 *m/sec* = 1120*ft/sec*.

12. $\frac{V_t}{v_o} = \frac{\sqrt{T}}{T_o}$. here T is absolute temperature.

13. $v\frac{2d}{t}$. Where d = distance of reflector.

14. $\frac{v_A}{v_B} = \sqrt{\frac{\rho_B}{\rho_A}}$

15. $\frac{v_m}{v_d} = \sqrt{\frac{\gamma_m}{\gamma_d} \cdot \frac{\rho_d}{\rho_m}}$

Where v_m, v_d = velocities of sound in moist and dry air respectively, ρ_m, ρ_d = densities of moist and dry air respectively, γ_m, γ_d = values of γ for moist and dry air respectively.

16. Number of *beats/sec* = $n_1 - n_2$. i.e. difference in frequency.

Laws of Transverse Vibrations of String and Organ Pipe

1. $n = \frac{p}{2l}\sqrt{\frac{T}{m}}$, if the wire vibrates in p loop.

if $p = 1$, then $n_1 = \frac{1}{2l}\sqrt{\frac{T}{m}}$, fundamental tone or 1st harmonic.

if $P = 2$, then $n_2 = \frac{1}{2l}\sqrt{\frac{T}{m}}$, 1st overtone or 2nd harmonic

2. $n \propto \frac{1}{r}$.[l, T & p constant] $n \, \alpha \sqrt{T}$.

3. $n \propto \frac{1}{\sqrt{p}}$.[$l, T$ and r constant] $n \, \alpha \, l / \sqrt{m}$.

4. (i) $\lambda = 2l$, for single loop vibration

(ii) $\lambda = \frac{2l}{p}$, for p loop vibration.

5. **Velocity of any transverse wave in a medium:**

$v = \sqrt{\frac{T}{m}}$, whether wire vibrates in a single loop or p loops.

Symbols used above : T = tension, m = mass per unit length, l = length, r = radius, ρ = density and n = frequency.

6. **Fundamental frequency of the closed organ's pipe :** $n_1 = \frac{v}{4l}$.

7. **Fundamental frequency of open organ's pipe :**

$$n_2 = \frac{v}{2l} = 2\left(\frac{v}{4l}\right) = 2n_1.$$

8. **Other frequencies : (a) Closed pipe :** 1st overtone = $3n_1$ = 2*nd* harmonic, 2nd overtone = $5n_1$ = 3*rd* harmonic

(b) Open pipe : 1st overtone = $2n_2$ = 2*nd* harmonioc,. 2nd overtone = $3n_2$ = 3*rd* harmonic, 3rd overtone = $4n_2$ = 4th harmonic.

9. Diameter $\propto \lambda \propto \frac{1}{n}$, when length of the pipe is constant.

10. Effective length = $l + 0.6r$. Where r = radius, l = length 0.6r = end correction.

11. Equation of progressive wave

$y = a \sin(\omega t - \phi)$, where $\phi = 2\pi n.\ \frac{x}{v} = \frac{2\pi x}{\lambda}$,

$(\omega t - \phi)$ = Phase angle, y = Displacement, a = Amplitude, ω = Angular velocity, n = Frequency, v = Speed of wave.

12. $y = y_1 + y_2$ (Susperposition of wave), When displacement is parallel

to each other,

Where y = Resultant displacement, y_1 = Displacement of one particle, y_2 = Displacement of second particle.

13. $A = (a^2 + b^2 + 2ab \cos \phi)^{1/2}$

Where A = resultant amplitude, a and b are amplitude of waves, ϕ = phase difference.

Here we are taking that frequency of both waves are same, that is necessary condition for interference.

Case I. $A = a + b$ when $\phi = 0, 2\pi, 4\pi.....$

A = Maximum amplitude

Case II. $A = a - b$

If $\phi = \pi, 3\pi, 5\pi + ...$

A = Minimum amplitude $\frac{I_{max}}{I_{min}} = \left(\frac{a+b}{a-b}\right)^2$

Where I_{max} and I_{min} are the maximum and minimum intensity, a and b are the amplitude

14. $y = 2a\cos\frac{2\pi x}{\lambda}.\sin\frac{2\pi t}{T}$, antinodes at $v = \lambda$ $1\lambda/2, 2\lambda/2, ...$

[When a stationary wave reflected from free surface]

15. $y = -2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi t}{T}$ antinodes at $x = \lambda/y, \frac{3\lambda}{y}, \frac{5\lambda}{y}$ When a stationary wave reflected from a rigid surface.

Qualities of Musical Sound & Vibration of Bars

1. **Interval** = $\frac{n_1}{n_2}.[n_1 \geq n_2]$.

2. **Unision,** if $n_1 = n_2$; **Octave,** if $n_1 = 2n_2$.

3. **For plane sound wave :** $I = 2\pi^2 a^2 n^2 \rho\, v$, also $I \propto \frac{1}{r^2}$.

Where I = intensity, a = amplitude, n = frequency, ρ = density of the medium, v = velocity of sound r = distance of listner.

Unit of (I) $\rightarrow$ $watt/m^2$. 1 Bel (B) = 10 deci Bel (dB), Phon = dB at $n = 10^3$ HZ.

4. **Determination of pitch (frequency) :**

(a) **Siren plate method** : $N = m \times n$. Where : N = frequency, n = number of revolutions/sec, m = number of holes.

(b) **Stroboscopic method** : $N = \frac{1}{2} m \times n$.

(c) **Falling plate method** :

$$N = \frac{\text{Number of waves}}{\sqrt{\frac{2s}{g}}} = \frac{\text{Number of waves}}{\frac{\sqrt{I_2 - I_1}}{g}}$$

5. **Frequency of Tuning for :** $n = \frac{m^2 K}{2\pi l^2}\sqrt{\frac{\gamma}{\rho}}$.

Where m = a constant = 1.875, $K = a \times \sqrt{12}$, Where a = thickness of prong, l = length of prong, ρ = density of the fork.

6. $N' = \frac{v - v_0}{v - v_s} \times N$, Where N = Natural frequency, v = speed of sound,

v_s = Speed of source inthe direction of sound wave,

v_0 = Speed of observer in the direction of sound wave,

N' = Apparent frequency.

7. $N' = \frac{v - v_0}{v + v_s} N$, When both source and observer are in the opposite direction of wave motion $\frac{\lambda'}{\lambda} = \frac{N}{N'}$

8. If source is moving towards the stationary observer then $N' = \frac{v}{v - v_s} N$

9. If source is moving away from the stationary observer, then $N' = \frac{v}{v + v_s} N$

10. If observer is moving towards the stationary source, then $N' = \frac{v + v_0}{v} N$

11. If observer is moving away from stationary source, then $N' = \frac{v - v_0}{v} N$

12. If source and observer are approaching, then $N' = \frac{v + v_0}{v - v_s} N$

13. If source and observer are receding, then $N' = \frac{v - v_0}{v + v_s}$

ELECTROSTATICS

***Electric charge* (Page No. 33 to last)**

1. $Q =$ charge n = no. of electrons, e = chare of one electron = 1.6 × 10^{-19}C.

2. Surface charge density $(\sigma) = \frac{Q}{A}$ and Volume density of charge $(\rho) = \frac{Q}{V}$. For spherical conductor A = $4\pi^2$ and $V = \frac{4}{3}\pi r^3$.

3. **Coulomb's law in C.G.S. :** $F = \frac{Q_1Q_2}{Kr^2}$.

In S.I. : $F = \frac{1}{4\pi\varepsilon_o\varepsilon_r} \times \frac{Q_1Q_2}{r^2} = \frac{1}{4\pi\varepsilon} \times \frac{Q_1Q_2}{r^2}$**,** in homogeneous medium. Where K = dielectric constant of the medium or specific inductive capacity, ε_0 = absolute permitivity of the free space (air or vaccum),.ε_r = relative permitivity o the medium (no unit, for air or vacuum, ε_r=1) and $\varepsilon = \varepsilon_o\varepsilon_r$ = absolute permitivity of the dielectric or medium,

$$\varepsilon_0 = \frac{1}{36\pi \times 10^9} = 8.85 \times 10^{-12} \frac{coul^2}{N \times m^2} = \frac{\text{farad}}{\text{meter}}$$

and $4\pi\varepsilon_0 = \frac{1}{9 \times 10^9} \quad \frac{coul^2}{N \times m^2} = \frac{\text{Farad}}{\text{Meter}}$.

4. $E(vector) = \frac{Q}{4\pi\varepsilon_0\varepsilon_r r^2}$ in homogeneous medium.

Where E = intensity of electric field $E = \frac{1}{4\pi\varepsilon_0} . \frac{Q}{r^2}$ (in air).

5. $V = \frac{1}{4\pi\varepsilon_o\varepsilon_r} \times \frac{Q}{r}$ in homogeneous medium.

6. $E = -\frac{dV}{dx}, Where \frac{dV}{dx}$ is potential gradient.

7. **Force** (F) on a charge q at a point where electric field intensity is E : $F = q \cdot E$.

8. **Work done (**ΔW**)** in moving a charge Q between two points having a P.D. ΔV by any path: $\Delta W = Q\Delta V$.

9. **Electric displacement (*D*)** (vector) =

$$\varepsilon E = \frac{Q}{4\pi r^2}.$$

10. $d\phi = E, ds\cos\theta$. **In vector form :** $d\phi = \vec{E}.\vec{ds}$, where : $d\phi$ = electric flux (scalar), ds = small element of surface surrounding the point, θ = angle made by normal to ds to the direction of E. $\phi = \int_s \vec{E}.\vec{ds}$

11. **Mutual electric potential energy** (U) :

(i) $U = \frac{1}{4\pi\varepsilon} . \frac{Q_1Q_2}{r}$, when both Q_1 and Q_2 are + ve.

(ii) $U = -\frac{1}{4\pi\varepsilon} . \frac{Q_1Q_2}{r}$, if one of the charge is –ve.

Electric Dipole

1. **DIPOLE MOMENT** (vector) = electric charge × distance between them, *i.e.* $P = q \times 2l$. **S.I. unit** $\rightarrow$ coul × m.

Special unit $\rightarrow$ **debye. 1 Debye** = $1D = \frac{1}{3} \times 10^{-29}$ coul × meter.

2. Electric potential and intensity at a point r distance apart, making an angle θ with dipole moment vector :

$$V = \frac{1}{4\pi\varepsilon} \times \frac{P\cos\theta}{r^2}, E = \frac{P}{4\pi\varepsilon r^3} \times \sqrt{1+3\cos^2\theta}.$$

If α be the angle between $\vec{E}$ and $\vec{r}$, then

$$\tan\alpha = \frac{1}{2}\tan\theta$$

If β be the angle between $\vec{E}$ and $\vec{r}$, then

β = (α + θ).

3. **Special cases :**

(i) If the point be on the **axis** of dipole, *i.e.* θ = 0° or 180°; $V_1 = \frac{\pm P}{4\pi\varepsilon r^2}$

and $E_1 = \frac{2P}{4\pi\varepsilon r^3}, (\vec{E}_1 \parallel \vec{P})$.

(ii) If the point be on $\frac{1}{p}^{r}$ **bisector,** *i.e.* θ = 90° or 270°; $V_2 = 0$ and

$E_2 = \frac{P}{4\pi\varepsilon r^3}, (\vec{E}_2 \parallel -\vec{P})$.

4. **P.E. of an electric dipole in an electric field:**

$U = PE\cos\theta$ joule. **Where** : θ = angle between P and $\vec{E}$.

5. **Binding energy of the dipole** = $\frac{1}{4\pi\varepsilon} \cdot \frac{q^2}{r}$.

6. **Torque (τ)** acting on a dipole in uniform electric field: $\vec{\tau} = \vec{P} \times \vec{E}$ or τ = $PE\sin\theta$. Where θ = angle between $\vec{P}$ and $\vec{E}$.

7. **Electric flux (ϕ)** = $E\Delta s\cos\theta$. Where θ = angle between the direction of E and normal to the area Δ*s*.

In vector form : $\phi = \vec{E} \times \overrightarrow{\Delta s}$. S.I. unit = volt × *m or N* × $m^2/coul$.

Capacity and Condensers

1. $C = \frac{\text{charge Q}}{\text{potential V}}$,

2. **Capacity** of a sphere of radius r in a homogeneous mediumof permitivity ε:*In S.I.*.:C = 4πεr = $4\pi\varepsilon_0\varepsilon_r$r. In air $\varepsilon_r = 1$, $\therefore C_a$ = $4\pi\varepsilon_0$r (minimum).

   In medium $C_m = 4\pi\varepsilon_0\varepsilon_r r = C_a\varepsilon_r$,

   ∴ **In S.L. :** $C = \varepsilon_r = \frac{C_m}{C_a}$.

3. $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}$ Joule. Where U = electrostatic potential energy of charged conductor.

4. In sharing of charges between two conducors :

   (i) **Common Potential**

$$V = \frac{Q_1 + Q_2}{C_1 + C_2} = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$$

   (ii) **Loss of energy** =

$$\Delta U = \frac{1}{2}\left(\frac{C_1C_2}{C_1 + C_2}\right)(V_1 - V_2)^2.$$

   (iii) **For no energy loss :** $V_1 = V_2$. [ΔU is always + ve].

5. **Parallel plate condenser with simple dielectric** : In **S.I.**

   (i) $C = \frac{\varepsilon A}{d}$. Where A = Area of each plate, d = Distance between Plate, ε = Permittivity of the medium.

   (ii) $E = \frac{\sigma}{\varepsilon}$. Where E = Intensity of the field between plates, σ =

Surface charge density.

(iii) $V = Ed = \frac{\sigma d}{\varepsilon}$.

(iv) $Q = A\sigma = CV$.

(v) $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{Q^2}{2C}$. Where A = area of each of the plates.

d = distance between the plates.

6. **Parallel plate condenser with compound dielectric":**

$$C = \frac{A}{\frac{d-t}{\varepsilon_0} + \frac{t}{\varepsilon_0 \varepsilon_r}} = \frac{A}{\sum \frac{d}{\varepsilon}}.$$ Where t = thickness of insulating medium.

7. **Spherical condesner :** In S.I. : C = $4\pi\varepsilon \frac{r_2 r_1}{r_2 - r_1}$. Where r_1 = radius of inner sphere, r_2 = radius of outer sphere (earthed) and $r_2 - r_1$ = thickness of insulating material.

8. **Cylindrical condenser : In S.I. :**

$$C = \frac{2\pi\varepsilon l}{\log_e \frac{r_2}{r_1}}; (r_1 < r_2).$$ Where l = length of either cylinder, r_1 = radius of inner cylinder and r_2 radius of outer cylinder.

9. **Capacity of Leyden Jar : In S.I. :**

$$C = 4\pi\varepsilon \frac{r^2 + 2rh}{4d}.$$ Where r = radius of jar, h = height of plate, d = thickness of glass wall.

10. **in series :** $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots\ldots\ldots$

In series connection total potential differences is the sum of individual potential differences and all capacitors have same charge $V = V_1 + V_2 + V_3 + ...$

11. **In parallel :** $C = C_1 + C_2 + C_3 + ...$

In parallel connection all capacitors have same potential difference and all capacitor have different charge in the ratio of their capacitance.

Sl. N.	Units of Electrostatics Variables			
	Physical quantity with symbol and nature	**S.I. Unit**	**C.G.S. (e.s.u.)**	**Relation**
1.	Charge (Q) (Scalar)	*Coulomb (C)*	*Stat coul or e.s.u.*	*1 coul = 3 × 10^9 stat coul*
2.	Surface density charge (σ) (Scalar)	*Coul/m^2*	*Stat coul/cm^2*	*1 coul/m2=3 × 10^5 stat coul/cm^2*
3.	Intensity of electric field (*E*) (**vector**)	*Volt/m or Newton/coul*	*Stat volt/cm*	*1 stat volt/cm = 3 × 10^4 volt/m*
4.	Electric potential (*V*) (**Scalar**)	*Volt or joule/coul*	*Stat volt erg/stat coul*	*1 stat volt = 300 volt*
5.	Electric displacement (*D*) (**Vector**)	*Coul/m2*	*Stat coul/cm^2*	*1 coul/m^2= 3×10^5 stat coul/cm^2.*
6.	Electric flux (ϕ) (**Scalar**)	*Nm^2/coul or volt × meter*	*Stat volt cm*	*1 volt m =* $\frac{1}{3}$ stat volt × cm
7.	Electrostatic potential energy (*U*) (**Scalar**)	*Joule*	*erg*	*1 joule = 10^7 ergs*
8.	Electrostatic stress on a charged conductor (**vector**)	*Newton/m^2*	*Dyne/cm^2*	*1 newton/m^2 = 10 dynes/cm^2*
9.	Dipole moment (ρ) (**vector**)	*Coul×m*	*Stat coul × cm*	*1 coul × m = 3 × 10^{11} stat coul × cm*
10.	Torque (τ) (**vector**)	*Newton × m*	*Dyne × cm*	*1 N × m = 10^7 dyne × cm*
11.	Capacity (C) (**Scalar**)	*Farad or coul/ volt*	Stat-farad or e.s.u.of C.	*1 farad = 9 × 10^{11} stat farad* $1 \mu F = 10^{-6} F$ $1 pF = 10^{-12} F$

CURRENT ELECTRICITY

Electric Charge and Current

1. $I = \frac{\Delta Q}{\Delta t}$
2. Electric charge is a fundamental property
3. $Q = \pm ne$ = It (I = current)
4. Units S.I. - coloumb

   1 coulomb = 6.25×10^{18} electron
5. Strength of storage cell (A.H.) = charging current (*amp*) × time (*hr*). [*1 amp* × *hr* = 3600 coulomb].
6. Current density $\vec{j} = \frac{I}{A} Amp/m^2$
7. (A = Area of cross section perpendicular to the direction of (I)
8. v_d (drift velocity of electron) =

   $$\frac{I}{neA} = \frac{J}{ne} = \frac{\sigma E}{ne} = \frac{E}{\rho ne} = \frac{V}{\rho \ln e}$$

   E = Intensity of electric field

   V = P.d. across conductor
9. If length of a wire increased by x% then its resistance increases by $2x$%
10. If length of wire becomes n times. It's resistance becomes n^2 times

Ohm's *Law and Resistance*

1. $I \propto V$ or $V = IR$ or $I = GV$, provided physical conditions (temperature, magnetic field, radiation etc.) remain unchanged. Where G = conductance = $\frac{1}{R}$. [$\boldsymbol{R}$ = *resistance*].

$G = \frac{ne^2\tau}{2m}\left(\frac{A}{l}\right)$, $G = J/E$. Where m = Mass of electron τ = Relaxation time, E= Intensity of electric field, n = Number of free electrons A = Area, l = length.

S.I. unit of *G* = mho = ohm^{-1} =

$$\frac{1}{ohm} = \frac{amp}{volt} = siemen.$$

2. $R = \rho\frac{l}{A}$. Where l = length of wire (along the direction of flow of I), A = cross sectional area ($\perp$ to the directrion of flow of I) & ρ = specific resistance or electrical resistivity. σ (electrical conductivity or specific conductance) = $\frac{1}{\rho}$. Specific conductance $(\sigma) = \frac{J}{E}$

   Where J = Current density, E = Intensity of electric field.

   S.I. unit of ρ & σ = *Ohm* (Ω) × metre & *mho*/*metre* respectively.

3. $R = \rho\frac{l}{\pi r^2}$. (A = πr^2 for wire) = $\rho\frac{\frac{l}{\pi D^2}}{4}$. Where D = diameter.

4. $R = \frac{\rho^V}{\pi^2 r^4}$. Where V is the volume

5. $R_t = R_0(1 + \alpha t)$. Where α = temperature co-efficient of R. Unit of α is per °C.

6. **To be remembered :**

   (i) 1 *amp* = 10^{-1} *e.m.u.* of I = 3 × 10^9 *e.s.u.* of current.

   (ii) 1 *coul* = 10^{-1} *e.m.u.* of charge = 3 × 10^9 *e.s.u.* of charge

   (iii) 1 *Volt* = 10^8 *e.m.u.* of potential difference or 10^8 *ab* volt = $\frac{1}{300}$

e.s.u. of potential difference or $\frac{1}{300}$ *stat volt*.

(iv) 1 *ohm* = 10^9 *e.m.u.* of $R = \frac{1}{9\times10^{11}} e.s.u.$ of R

7. **Series grouping :** $R_s = r_1 + r_2 + r_3 + ... + r_n$. The equivalent conductance is given by

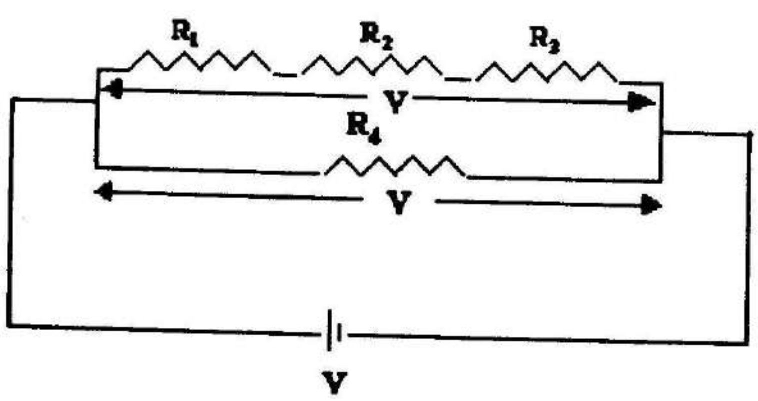
$$\frac{1}{G} = \frac{1}{g_1} + \frac{1}{g_2} + \frac{1}{g_3} + ...\frac{1}{g_n}$$

$$V = V_1 + V_2 + V_3 + ... V_n$$

* In a series potential difference a cross any resistance (r) is $v' = \frac{r'}{r_{eq}} V$

Where r_{eq} = equivalent resistance of series

V = voltage across series, for Ex, — from figure $V_1 = \frac{R_1}{R_1 + R_2 + R_3} . V$



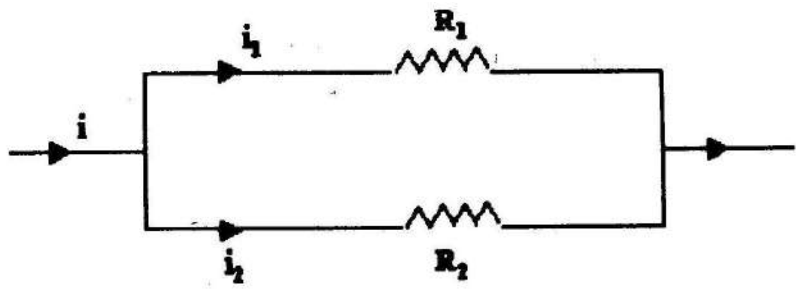
8. **Parallel grouping :**

$$\frac{1}{R_p} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + ... + \frac{1}{r_n}.$$

Or $G = G_1 + G_2 + G_3 + ... + G_n$

$I = I_1 + I_2 + I_3 + ...I_n$

* In parallel, current through any Branch $i_1 = i \times \dfrac{R_2}{R_1 + R_2}$



9. For two resistances in parallel : $R_p = \dfrac{r_1 r_2}{r_1 + r_2} = \dfrac{\text{product}}{\text{sum}}$

10. For n identical resistances : $R_s = nr$ (series). $R_p = \dfrac{r}{n}$ (parallel) and

$\dfrac{R_s}{R_p} = n^2$.

11. Approximate percentage change in $R = 2 \times$ small percentage change in length by stretching.

e.m.f., p.d. and Grouping of Cells

1. $\Delta V = \dfrac{\Delta W}{Q}$ or $\Delta W = Q\Delta V$. S.I. or practical unit of P.D. = *Joule / coul* = volt **e.s.u.** of P.D. = *erg/stat coul = stat volt.*

   e.m.u. of *P.D. = erg/ab coul = ab volt.*

2. $1\,eV = 1.6 \times 10^{-19}$ *Joule*. $1\,MeV = 1.6 \times 10^{-13}$ *Joule* (Million *eV*).

   $1\,BeV = 1.6 \times 10^{-10}$ *Joule* (Billion *eV*).

3. $I = \dfrac{E}{R + r}$ (closed circuit) or $E = V + Ir$ where $E = e.m.f.$, $V = P.D.$, r = internal resistance, R = external resistance and Ir = potential drop.

If, R = 0 (short circuit), I Will be maximum, $I_{max} = \frac{E}{r}$.

If, $R = \infty$ (open circuit), I will be minimum, $I_{min} = 0$

4. **Series grouping of cells :**

$$I = \frac{nE}{nr + R}; I_{max} = \frac{E}{r}, \text{ when } R << r.$$

5. **Parallel grouping of cell :**

$$I = \frac{nE}{r + nR}; I_{max} = \frac{nE}{r}, \text{ when } r >> R.$$

6. **Mixed grouping of cells :**

$$I = \frac{mnE}{nr + mR}; I_{max} = \frac{nE}{2R} = \frac{mE}{2r}, \text{ when } nr = mR.$$

Where n = number of cells in one row, m = number of rows and $m \times n$ = total number of cells.

7. **Wrong series connection :**

$$I = \frac{(n - 2m)E}{R + nr}; I_{max} = \frac{(n - 2m)E}{nr},$$

when $R << r$. Where n = total number of cells and m = number of cells wrongly connected.

Wheatstone Bridge & Kirchoff's Law

1. When galvanometer shows no deflection, $PR = QS$ (*i.e.* products of alternate arms resistance are equal) or $\frac{P}{Q} = \frac{S}{R}$.

2. **Kirchoff's Laws**

1st law : $\Sigma I = 0$ **2nd law =** $\Sigma I R = \Sigma E$

Where E = total *e.m.f.* of the mesh or circuit.

Heating Effect of Current and

Thermoelectricity

1. $Q = It$. Where Q = charge, I = current, t = time
2. **P.D.** across ends of conductor, $V = IR$. V = Voltage, I = Current R = Resistances
3. **Work done (W)** $= Q.V = VIt = I^2Rt = \frac{V^2}{R} \times t = P \times t.$
4. **Power consumption (P)** $= \frac{W}{t} = IV = I^2R = \frac{V^2}{R}$
5. **Heat produced (H) =** $\frac{W}{J} = \frac{VIt}{J} = \frac{I^2Rt}{J} = \frac{V^2}{R} \times \frac{t}{J} = \frac{P}{J} \times t.$
6. **Energy** $= P \times t.$
7. **Practical unit** of energy supply = killo-watt-hour (kWh). **1 I.B.O.T. unit** $= 1\ kWh = 36 \times 10^5\ Joules$. **1 H.P.** $= 746\ watt.$
8. **Number of units consumed** $= \frac{Watt \times hr}{1000} = kWh.$

   S.I. unit : $I \to amp,\ V \to volt,\ R \to ohm,\ t \to sec,\ W \to Joule,\ P \to watt,\ H \to Joule$

   M.K.S. Unit : $1 cal = 4.2\ Joule,\ H \to cal,\ J \to 4.2\ Joule/cal.$
9. Heat produced $H \propto R$ if I and t are constant, *i.e.* $\frac{H_1}{H_2} = \frac{R_1}{R_2}$.

10.. Heat produced $H \propto \frac{1}{R}$ if V and t constant, *i.e.* $\frac{H_1}{H_2} = \frac{R_2}{R_1}$

11. $H \propto I^2$ if R and t are constant
12. $H \propto t$ if R and I are constant
13. **Hot wire instrument** (for measuring both A.C. & D.C.) :

$\theta \propto H or \theta \propto i^2, i.e. \frac{\theta_1}{\theta_2} = \frac{i_1^2}{i_2^2}.$

14. $t_n = \frac{t_i + t_c}{2}$. Where t_n = neutral temperature t_i = inversion temperature & t_c = temperature of cold junction.

Chemical Effect of Current

1. **Faraday's first law:**

   By flowing a charge Q

   through a electrolyte if mass m of substance liberated or deposited at the electrode

   $m \propto Q \rightarrow m = zQ = z$ it z = Electrochemical equivalent of substance

   Second law - current flowing through different electrolytes Then

   $m_1 : m_2 : m_3 .... E_1 : E_2 : E_3$

   $\therefore m \propto E$

   E = chemical equivalent of substances

2. **Charge** on one ion = ne. Where n = valency of ion, e = electronic charge = -1.6×10^{-19} coul.

3. Number of ions liberated at electrode = $\frac{Q}{ne}$. Where Q = charge flowing in elctrolyte.

4. **Mass** of one atom = $\frac{A}{N}$. Where A = atomic weight N= Avogadro's number

5. Mass of element (w) liberated at electrode = number of ions liberated × mass of one atom,

   $i.e.\ w = \frac{Q}{ne} \times \frac{A}{N} = \frac{1}{Ne} \times \frac{A}{n} \times Q = \frac{E}{F} \times Q$. Where $E = eq.wt.$

6. $\frac{E}{F} = Z$ (electrochemical equivalent). S.I. unit of Z is *kg/coul*.

Shunt, Ammeter, Voltmeter and Branching of Current

1. To increase the range of an **ammeter** or to convert a **galvanometer** in to an **ammeter**, a low resistance (**Shunt**) is connected in parallel. $S = \frac{G}{n-1}$ (in parallel). $n = \frac{I}{I_g}$. Where S = shunt resistance,

   G = resistance of galvanometer $\frac{I}{I_g} = 1 + \frac{G}{S}$

   Where I_g = full scale deffection current or current which ammeter can measure

   I = Current to be an measured

2. To increase the range of a **voltmeter** or to convert an galvanometer into a **voltmeter**, a high resistance (R) is connected in series:

   $R = G(n-1) = \frac{V}{ig} - G$ Where = resistance of galvanometer.

   $n = \frac{V}{V_g}$ or $= \frac{New\,range}{old\;range}$. Where V_g or V_1 = voltage which the voltmeter can measure and V or V_2 = voltage to be measured.

* Where i_g = current flows through galvanometer, V = voltage to be measured

3. Branching of current in two parallel resistances:

   $I_1 = \frac{Ir_2}{r_1+r_2}$ and $I_2 = \frac{Ir_1}{r_1+r_2}$.

Magnetic Effect of Current

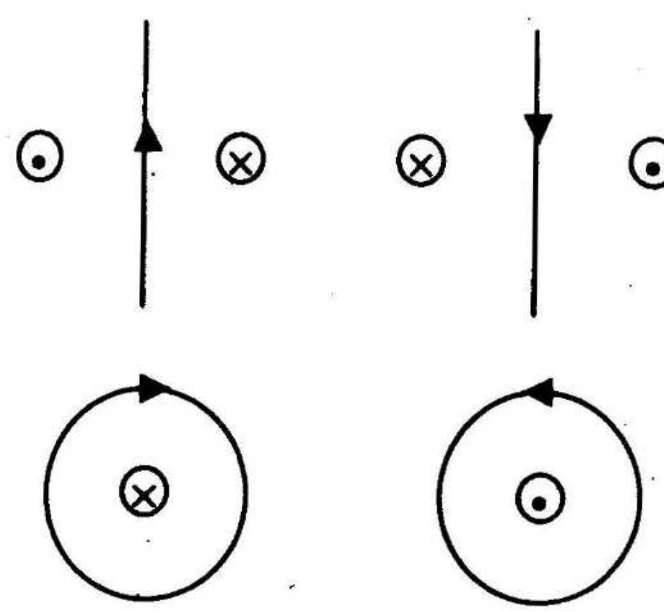
PART - A : ***Laplace's Law and Magnetic Field Induction***

1. Laplance's law or Biot savart law Magnetic field (dB) due to a long current (i) Conductor at a distance r. $dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2}$

   Where θ = Angle *Bet*^{n} line joining point at which intensity is to be find out to conductor and canductor $\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{i(\vec{r}\times\overrightarrow{dl})}{r^3}$

   Unit of B – **S.I. Unit** $\frac{wb}{m^2}$ Tesla, C.G.S. unit –Gauss, I $T = 10^4$ Gauss

2. Direction of magnetic field :

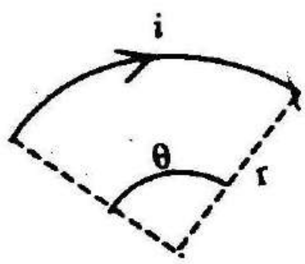


3. Intensity of magnetic field at the centre of circular coil carrying current $B = \frac{\mu_0}{4\pi}\times\frac{2ni}{r}$, r = radius of coil

* for n, no. of tuns $B = \frac{\mu_0}{4\pi}.\frac{2\pi ni}{r}$

* due to semi circular coil (At the centre) $B = \frac{\mu_0}{4\pi} \times \frac{\pi i}{r}$

* due to circular segment (At the centre)



$B = \frac{\mu_0}{4\pi} . \frac{\theta i}{r}, \theta$ = Angle made by segment at the centre. Intensity of magnetic field at the axis of a circular coil

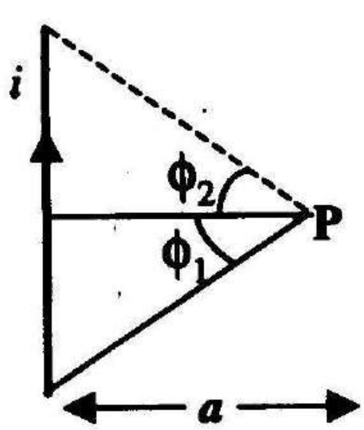
$B_{\text{axis}} = \frac{\mu_0}{4\pi} . \frac{2\pi n i r^2}{(r^2 + x^2)^{3/2}}, r =$ radius of coil, $x =$ distance from centre, at which intensity to be measured

* $\frac{B_{centre}}{B_{axis}} 2\left(1 + \frac{x^2}{r^2}\right)^{3/2}$

4. In tensity of magnetic field due to a straight current carrying conductor

for definite length of conductor

$B = \frac{\mu_0}{4\pi} \frac{i}{a} (\sin\phi_1 + \sin\phi_2)$



i = current flowing through the conductor

a = distance at which intensity is to be measured

* if $\phi_1 = \phi_2 = \phi$

$$B = \frac{\mu_o}{4\pi} \cdot \frac{2i}{a} sn\,\phi$$

* For infinite length of conductor $\phi_1 = \phi_2 = 90°$

$$B = \frac{\mu_o}{4\pi} \frac{2i}{a}$$

* If point lies at near one end of conductor

$\phi_1 = 0$ $\phi_2 = 90°$ or $\phi_1 = 90°$ $\phi_2 = 0°$

$$B = \frac{\mu_0}{4\pi} \frac{i}{a}$$

* Magnetic field at a point lies on the axis of conductor

$$B = 0$$

* Magnetic field at a poing lies on the conductor

$$B = \infty$$

5. Intensity of magnetic field due to a solenoid $B_{\text{inside}} = \mu_0 ni$

n = no. of turns per unit length of solenolid $B_{\text{end}} = \frac{\mu_0 ni}{2}$

6. If a current (i) carrying conductor (of length l) placed in a magnetic field (B). It experiences a force F = Bil sin θ, θ = Angle bet^n conductor field

Force bet^n two parallel current carrying conductor $F = \frac{\mu_0}{4\pi} . \frac{2i_1 i_2}{r} .l$

PART - B : *Interaction of Magnetic Field and Electric Current*

Motion of charged particle in magnetic field

Force $F = qvB\sin\theta$ in vector from $\vec{f} = q(\vec{v}\times\vec{B})$

q = charge on particle, v = velocity of particle, B = Intensity of magnetic field, θ = Angle bet^n direction of motion of particle and field

* Force will be max, when = 90°, $F_{max} = qvB$
* If $\theta = 90°$, particle moves along a circular path (of radius r) such that

$r = \frac{mv}{qB} = \frac{p}{qB} = \frac{\sqrt{2mk}}{qB}$, $m =$ mass of particle, k = K.E. of particle p = momentum of particle

Time period of particle $T = \frac{2\pi m}{qB} = \frac{2\pi r}{v}$

If direction of motion makes any angle θ with field (except 0°, 90°, 80°) $r = \frac{mv\sin\theta}{qB}$, For Any angle θ, $T = \frac{2\pi r}{v\sin\theta}$ Path will be Helical

PART-C : *Application in Galvanometer*

1. **Tangent galvanometer :** $B = B_H \tan\theta$ ($B \perp^{r} B_H$)

or $\frac{\mu_0 ni}{2r} = B_H \tan\theta$ or $i = \frac{2rB_H}{\mu_0 n}\tan\theta = K\tan\theta$, $k = \frac{2rB_H}{\mu_0 n}$.

Where B = magnetic field induction, B_H = horizontal component of earth's field induction θ = deflection of magnetic needle pivoted at the centre and K = reduction factor (same unit as current).

Unit of $B_H \longrightarrow weber/m^2$

2. **Sine galvanometer :** In S.I. system, $B = B_H \sin\theta$

or $\frac{\mu_0 ni}{2r} = B_H \sin\theta$ or $i = \frac{2rB_H}{\mu_0 n} \sin\theta = K \sin\theta$.

3. **Suspended coil galvanometer** or **moving coil galvanometer or D' Arsonval galvanometer:**

(i) $F = Bil \sin\theta$, if $\theta = 0°$ or $180°$, then $F = 0$ and if $\theta = 90°$ then $F = Bil$.

(ii) $i = \frac{C}{nAB}\theta = K\theta$ or $i \propto \theta, i.e. \frac{\theta_1}{\theta_2} = \frac{i_1}{i_2}$

Where C = couple per unit twist, A = area of coil and n = number of turns.

Electromagnetic Induction

1. **Faraday's laws : (i)** The induced e.m.f. is directly proportional to the rate of change of flux, associated with circuit,

$i.e.\ emf \propto \frac{\Delta\phi}{\Delta t}$ or $e = -K\frac{\Delta\phi}{\Delta t}$. **In C.G.S.,** $e = n\frac{\Delta\phi}{\Delta t} \to flux$

Units : n = number of turns, $\Delta\phi \to$ *maxwell*, $e \to$ *ab volt*, $\Delta t \to$ *sec*.
In S.I. $\Delta\phi \to$ *weber*, $e \to$ *volt*, $\Delta t \to$ *sec*.

Relation : 1 *weber* = 10^8 *maxwell*.

(ii) Induced current (I) = $\frac{e}{R} = \frac{1}{R}.\frac{\Delta\phi}{\Delta t}$.

(iii) Amount of charge that will flow (q) = $I \times \Delta t = \frac{\Delta\phi}{R}$.

2. Combined form of both **Faraday's & Lenz's law :**

$e = -\frac{\Delta\phi}{\Delta t}$(one turn), $e = -n\frac{\Delta\phi}{\Delta t}$($n$ turns).

3. **Self induction** : $e_1 = -L\frac{\Delta i}{\Delta t}$. Where = rate of change of current,

e_1 = induced e.m.f. & L = co-efficient of self inductance.

S.I. unit of L is $ohm \times sec = henry = 10^9$ *e.m.u.* (*ab henry*).

4. **Mutual inductance :** $e_2 = -M\frac{\Delta i}{\Delta t}$.

   Where M is mutual inductance. **S.I. unit** $\rightarrow$ *henry*.

5. If a conductor moves in a magnetic field e.m.f. induces across it's ends

   (a) For translatory motion $e = Bvl \sin\theta$

   (b) For Rotatory motion $e = 1/2\, Bl^2\omega$

   Where l = length of conductor, w = Angular velocity of conduct, v = linear velocity

   θ = linear velocity, θ = Angle made by conductor with the field

Transformer

1. **For an ideal transformer :**

$$V \propto N \text{ or } I \propto \frac{1}{N} \text{ or } \frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1}$$

   or I_1V_2 (input power) = I_2V_2 (output power), where N_2 and N_1 = number of turns in secondary and primary coils, V_2 (outpur) and V_1 (input) are voltage across secondary & primary and I_2 (output) and I_1 (input) are currents across secondary & Primary.

2. $\frac{N_2}{N_1}$ = Transformation ratio = k.

* $\frac{N_2}{N_1}$ = Transformation Ratio = k.

   for step up transformer $k > 1$, for step down transformer $k < 1$

3. **Efficiency** = $\frac{output\ wattage}{input\ wattage}$. **Percentage efficiency** =

$\frac{output wattage}{input\ wattage} \times 100.$

Alternating (Sinusoidal) Current

1. Induced e.m.f. $(e) = -\frac{d\phi}{dt}, = -\frac{d}{dt}$ $(nAB \cos \omega t)$, $nAB\omega \sin \omega t$, $= e_0$ $\sin \omega t$ Where $e_0 = nAB\omega$ Induced current, $i = \frac{e}{R} = \frac{-N}{R} . \frac{d\phi}{dt}$

where N = Number of turn. Induced charge $dq = i\, dt$

$$= -\frac{N}{R} d\phi, = \frac{N}{R}(\phi_1 - \phi_2)$$

Obviously charge induced is independent of time Induced power $P = ei$

$$= e \times \frac{e}{R}, = \frac{e^2}{R^2} = i^2 R = l^2 B^2 v^2 / R$$

2. Induced e.m.f (e) of a coil having self-inductance (L)

$$e = -\frac{d\phi}{dt}, = -L\frac{dI}{dt}$$

*. For small plane circular coil

$$L = \frac{\phi}{I} = \frac{BAN}{I} = \frac{\mu NINA}{2rI} = \frac{\mu N^2 \pi r}{2}, \frac{\mu_0 \mu_r N^2 \pi r}{2}$$

Where N = Number of turn, r = Radius of coil, μ_0 = Absolute permeability of the medium, μ_r = Relative permeability of the medium.

Also

$L = \mu_0 \mu_r = \pi r^2 n^2 l, = \mu_0 \mu_r n^2 V$

Where $n \frac{N}{l}$ = Number of turn in unit length of coil, V = Volume of coil.

Special case I. When two coils are connected in series having inductance L_1 and L_2 then $L = L_1 + L_2$

Here we are taking mutual inductance between them $(M) = 0$. If $M \neq 0$, then $L = L_1 + L_2 + 2M$

When current is flowing in oppoisite direction

Case II. When two coils are connected in parallel. Then

$$L = \frac{L_1 L_2}{L_1 + L_2} \text{ or } \frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}. \text{Here } M = 0$$

If $M \neq 0$, then $\frac{1}{L} = \frac{1}{(L_1 + M)} + \frac{1}{(L_2 + M)}$,

So $L = \frac{L_1 L_2 \pm M^2}{L_1 + L_2 \pm 2M}$

Case III. Self-inductance of two co-axial cylinder having radii r_1 and r_2.

$$L = \frac{\mu_0}{2\pi r} \log_e \frac{r_2}{r_1}, L = \frac{2.303}{2\pi r} \mu_0 \log_{10} \frac{r_2}{r_1}$$

3. Mutual inductance (M), $M = \mu_0 n_p N_s A, = \frac{\mu_0 N_p N_s A}{l_p}$

Where N_p = Total number of turn in primary coil,

N_s = Total number of turn in secondayr coil,

n_p = Number of turn in unit length of primary coil,

Special case

(I) Mutual inductance between two co-centric rings, haviang radii of r_s and r_p

$$M = \frac{\pi \mu_0 N_p N_s r_s^2}{2r_p}$$

Where r_p = radius of primary coil, r_s = radius of secondary coil.

(II) For two paired coil $M = K\sqrt{L_1 L_2}$

Where K is pair constant of two coils $0 \le K \le 1$ or $k = \frac{M}{\sqrt{L_1 L_2}}$

(III) M in the form of magnetic potential energy or work $M = \frac{2U_B}{I_0^2} = \frac{2W_m}{I_0^2}$

Where n = number of turns of the coil, A = area of the coil, B = magnetic field induction, ω = angular velocity of coil = $2\pi f$ and f (frequency) = number of revolutions/sec.

In S.I. : $A \to m^2, B \to weber/m^2, \omega \to rad/\sec \;\&\; e \to volt.$

4. $e = e_0 \sin \omega t \;\&\; I = I_0 \sin \omega t$. They are called sinusoidal or periodic or alternating voltage and current.

Where e and I = instantaneous voltage and current, e_0 and I_0 = maximum or peak voltage and current, ωt = phase angle, ω = angular velocity or angular frequency and $\frac{\omega}{2\pi}$ = frequency $(f) = \frac{1}{T}$.

5. **Average voltage and current :** Average value over half cycle = $\frac{2}{\pi}$ × maximum or peak value. Hence $I_{av} = \frac{2}{\pi} \times I_0 \;\&\; e_{av} = \frac{2}{\pi} \times e_0$.

6. **R.M.S. *or* Virtual or Effective value**

$$= \frac{peak\ value}{\sqrt{2}}, i.e. I_{r.m.s.} = \frac{I_0}{\sqrt{0}} \text{ and } e_{r.m.s.} = \frac{e_0}{\sqrt{2}}$$

7. **Form factor =** $\frac{R.M.S.value}{average value}$ = 1.1 and is constant

8. **Phase relations in A.C. circuits :**

(i) In case of circuit containing only resistance : $i = \frac{E}{R}$.

Where E =e.m.f. and R = resistance.

(ii) Circuit with resistance and inductance (L): $i = \frac{E}{\sqrt{R^2 + (L\omega)^2}} = \frac{E}{Z}$.

Where Z is called impedance and is the effective resistnace of an A.C. circuit and $L\omega$ is called inductive reactance.

(iii) Circuit with R and C : $i = \frac{E}{\sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}}$.

Where $\frac{1}{c\omega}$ = capacitive reactance and impedance (Z) = $\sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}$ (iv) Circuit with R.L. and C :

$i = \frac{E}{\sqrt{R^2 + (L\omega - \frac{1}{C\omega})^2}}$ Impedance $Z = \sqrt{R^2 + (L\omega - \frac{1}{C\omega})^2}$.

9. **Condition for resonance :** frequency $(f) = \frac{1}{2\pi} \cdot \sqrt{\frac{1}{LC}}$.

In this case, $i = \frac{E}{R}$, since $\left(L\omega - \frac{1}{C\omega}\right)^2 = 0$

Decay time :

$$t = \frac{L}{R}, I = I_0\left[I - e - \frac{R}{L}t\right], I = I_0\left[1 - e^{-1}\right] - I_0\left[1 - \frac{1}{e}\right],\ I = 0.63\ I_0$$

Where L = Self-inductance of a coil, R = Resistance of coil.

MAGNETISM

Pole Strength, Intensity, Induction and Potential

1. **Magnetic pole strength,** $m \equiv i\,\Delta l \sin\theta$, or $[m] = [IL]$.
2. **Magnetic field and its *unit* :**

   $\Delta F = I\,\Delta l\,B\sin\theta$, Where ΔF = Force in magnitude,

   B = Magnetic field strength, θ = Angle between $\Delta\vec{l}$ and $\vec{B}$. Also $\Delta F = q_0 vB\sin\theta$

   θ = Angle between $\vec{v}$ and $\vec{B}$, $B = \dfrac{\Delta F}{I\Delta l\sin\theta}\,tesla$
3. **Magnetic moment and torque** (τ) **for current carrying loop :** $\tau = ISB\sin\theta$, Where I = Current through loop, S = Area of loop,

   B = Magnetic field in *tesla*, θ = Angle between normal to loop and B. Magnetic moment $(m) = I \times S$
4. **Coulomb's law : In S.I. unit** →

   $$F = \frac{\mu_0\mu_r}{4\pi}\times\frac{m_1m_2}{r^2} = \frac{\mu}{4\pi}\times\frac{m_1m_2}{r^2}$$ in a homogeneous medium.

   For air or vacuum $\mu_r = 1$ hence $F = \dfrac{\mu_o}{4\pi}\times\dfrac{m_1m_2}{r^2}$.

   Where μ_o = permeability of vaccum, μ_r = relative permeability of the medium (no unit) and $\mu = \mu_o\mu_r$ = permeability indicates power of medium to conduct magnetic flux.

   In **S.I. system,** $\mu_o = 4\pi \times 10^{-7}$ weber/amp × m or henry/m or N/m^2.
5. The magnetic induction (B) due to single pole of strength m, at a distance r from it : $B = \dfrac{\mu_0 u_r}{4\pi}\cdot\dfrac{m}{r^2}$ in vacuum or air $B = \dfrac{\mu_0 m}{4\pi r^2}$, $(\because \mu_r = I)$.

6. A pole of strength m amp × m in field of magnetic induction B *weber/m*^{2} experiences a force of mB newton, *i.e.* $\vec{F} = m\vec{B}$.

For N-pole ($m = +ve$), $\vec{F} \parallel \vec{B}$. For s-pole ($m = -ve$), $\vec{F} \parallel -\vec{B}$. 7. $B = \mu H = \mu_o \mu_1 H$. Where H = auxiliary field or intensity of magnetic field. For a single pole of strength m; H at distance r : $H = \frac{1}{4\pi} \times \frac{m}{r^2}$ (independent of the surrounding). In magnetic field current flowing in unit length by closed path is known as H (Magnetic intensity), so $H = \frac{i}{L}$, where i = Current, L = Length, For circular current flowing ring at its centre $H = \frac{Ni}{2R}$, H due to small magnet at a distance r, $H = \frac{M}{r^3}\sqrt{1 + 3\cos^2\theta}$, H due to pole strength m_p at a distance r, $H = \frac{m_p}{\mu r^2}$, H due to solenoid, $H = \mu_0 ni$, Where n = number of turn in unit length, So $n = \frac{N}{L}$.

8. $\phi = \vec{B}.\vec{A}$ or $\phi = AB\cos\alpha$ where $\vec{A}$ = area vector, $\vec{B}$ = magnetic induction vector, ϕ = magnetic flux and α = angle between $\vec{B}$ and normal to area $\vec{A}$.

9. **Magnetic potential** (V) at a point at a distance r from a magnetic pole of strength $m : V = \frac{u}{4\pi}\left(\frac{m}{r}\right) = \frac{\mu_0 \mu_r}{4\pi}\left(\frac{m}{r}\right)$.

10. $B = -\frac{dV}{dr}$.

11. $M = m \times 2l$. Where M = magnetic dipole moment, $2l$ = separation

between poles and m = pole strength.

12. **Potential and magnetic induction due to a dipole :**

(i) The **magnetic potential** (V) at a point (r, θ) at a distance r from the dipole and making an angle θ with dipole moment (M) :

$V = \frac{\mu}{4\pi}.\frac{M\cos\theta}{r^2}$. If $\theta = 0°$, $V = \frac{\mu}{4\pi} \times \frac{M}{r^2}$ (on the axis of dipole), If $\theta = 90°$, $V = 0$, (at right angles to the axis).

(ii) **Magnetic induction** due to a dipole at a point (r, θ):

$B = \frac{\mu_0 \mu_r}{4\pi}.\frac{M}{r^3} \times \sqrt{1 + 3\cos^2\theta}$ and $\tan\alpha = \frac{\tan\theta}{2}$, If B makes an angle $\beta = (\alpha + \theta)$ with dipole moment.

(a) If $\theta = 0°$ or $180°$, $B = \frac{\mu}{4\pi}.\frac{2M}{r^3}$, $\alpha = 0°$, $\beta = 0°$ and $\vec{B}$ is in the direction of $\vec{M}\,(\vec{B} \parallel \vec{M})$

(b) If $\theta = 90°$, $B = \frac{\mu}{4\pi}.\frac{M}{r^3}$, $\alpha = 90°$, $\beta = 180°$ and $\vec{B}$ is opposite to $\vec{M}(\vec{B} \parallel -\vec{M})$.

13. The **moment of couple** (τ) of a magnetic dipole in uniform magnetic field = $MB\sin\theta$; $(\vec{\tau} = \vec{M} \times \vec{B})$.

14. **Potential energy** (W) of a magnetic dipole in uniform magnetic field : $W = MB\,(1 - \cos\theta)$.

Special conditions : (a) If $\theta = 0°$, $W = 0$ (minimum). (b) If $\theta = 90°$, $W = MB$. (c) If $\theta = 180°$, $W = 2MB$ (maximum).

15. **Magnetic field induction** (B) **due to a bar magnet :**

(a) End-on position (point-on axis of magnet):

$B = \frac{\mu}{4\pi}\left(\frac{2Md}{(d^2 - l^2)^2}\right), \vec{B} \parallel \vec{M}$. Where d = distance of point fromthe centre of a bar magnet.

In vacuum or air, $B = \frac{\mu_0}{4\pi} \times \frac{2Md}{(d^2 - l^2)^2}$ and $H = \frac{1}{4\pi} \times \frac{2Md}{(d^2 - l^2)^2}$. For a **short magnet** in vaccum or air:

$$B = \frac{\mu_0}{4\pi} \times \frac{2M}{d^3}, \vec{B} \parallel \vec{M} (\because l << d).$$

(b) Broad-side-on position (point on $\perp^r$ bisector) :

$$B' = \frac{\mu}{4\pi}\left(\frac{M}{(d^2 + l^1)^{\frac{3}{2}}}\right), \vec{B}' \parallel -\vec{M}. B' = \frac{\mu_0}{4\pi}\left(\frac{M}{(d^2 + l^2)^{\frac{3}{2}}}\right),$$ for vacuum or air.

$B' = \frac{\mu_0}{4\pi}\left(\frac{M}{d^3}\right), \vec{B}' \parallel -\vec{M}$. For a **Short magnet** in air ($l << d$).

16. **Intensity of magnetization** $(I) = \frac{M}{V} = \frac{m}{A}$.

Where M = Magnetic moment, V = Volume.

Magnetometry

1. **Gauss tangent law :** $B = B_H \tan\theta$, $(B \perp B_H)$,
2. **Tan A-position (of gauss) :**

$$B = \frac{\mu}{4\pi}\left(\frac{2Md}{(d^2 - l^2)^2}\right) = B_H \tan\theta.$$

For a **short magnet :**

$$B = \frac{\mu}{4\pi}\left(\frac{2M}{d^3}\right) = B_H \tan\theta.$$

3. **Tan B-position (of gauss) :**

$$B = \frac{\mu}{4\pi}\left(\frac{M}{(d^2+l^2)^{\frac{3}{2}}}\right) = B_H \tan\theta.$$

For a **short magnet :**

$$B = \frac{\mu}{4\pi}\left(\frac{M}{d^3}\right) = B_H \tan\theta.$$

4. **Oscillation magnetometer :** In uniform magnetic field of magnetic induction (B), **Time period,** $T = 2\pi\sqrt{\frac{I}{MB}}$ or $T = 2\pi\sqrt{\frac{I}{MB+C}}$.

 Where C = couple per unit radian twist.

 For a **bar magnet :** $I = w\frac{l^2+b^2}{12}$. Where w = mass

5. **For a given oscillating magnet :**

 $\frac{n_1}{n_2} = \sqrt{\frac{B_1}{B_2}}$, *i.e.* $n \propto \sqrt{B}$. Where n = frequency

LIGHT

Plane Mirrors

1. $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}, m=1$

   u = Object distance, v = Image distance, f = Focal length.

2. **Deviation of ray :** (i) **On single reflection :**

   $D = \pi - 2i = 180° - 2i.$

   (ii) **On successive reflections :** $D = 2(\pi - \theta) = 360° - 2\theta.$

3. **Number of images formed in two inclined mirror :**

   (i) If $\frac{360}{\theta}$ = odd, $n=\frac{360}{\theta}.n=\frac{360}{\theta}-1,$ for object exactly midway. n = Number of images formed, θ = Angle between two Plane mirrors.

   (ii) If $\frac{360}{\theta}$ = even, $n=\frac{360}{\theta}-1.$

   (iii) If $\frac{360}{\theta}$ = fraction, n = next whole number.

Laws of reflection :

(i) The angle of incidence is equal tothe angle of reflection $\angle i=\angle r.$

(ii) The incident ray, the normal and the reflected ray lie in the same plane.

Spherical Mirros

Formulae are based on cartesian co-ordinate axes sign convention .

1. According to this sign convention : (i) **For real image by concave** (converging) **mirror :** $u = -ve$, $v = -ve$, $f = -ve$ and $r = -ve$.

   (ii) **For virtual image** by **concave mirror :** $u = -ve$, $v = +ve$, $f = -ve$, and $r = -ve$.

(iii) **For virtual image** by **convex** (diverging) **mirror** : $u = -ve$, $v = +ve$, $f = +ve$, and $r = +ve$.

2. **For spherical mirrors of small aperture :** for axial rays : $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}=\frac{2}{r}$. For non-axial rays $\frac{1}{v}+\frac{1}{u}=\frac{2\cos i}{r}$

   r = Radius of curvature, i = Incident angle.

3. **Linear or transverse magnification (M) :**

   $$M=\frac{\text{size of image}}{\text{size of object}}=\frac{v}{u}=\frac{v-f}{f}=\frac{f}{u-f}=\frac{v-r}{u-r}$$

   M is positive for virtual image and negative for real image

4. **Surface magnification** = $\frac{v^2}{u^2}$.

5. **Longitudinal or axial magnification**

   $$(L)=\frac{v^2}{u^2}=M^2.$$

6. **Newton's formula** : $u.v = f^2$. Where u and v are distance of object and image respectively, formthe focus.

7. **Angular magnification** = $-\frac{1}{M}$. Where $M=\frac{v}{u}$.

Refraction at Plane Surface

1. $\mu=\frac{C_0}{C_m}=\frac{\lambda_o}{\lambda_m}$. Where u = refractive index of a medium.

   C_0 = velocity of light in air, C_m = velocity of light in medium, λ_0 = wavelength in air, λ_m = wavelength in medium.

2. $^a\mu_b=\frac{\text{R.I. of medium b}}{\text{R.I. of medium a}}=\frac{\text{velocity of light a}}{\text{velocity of light b}}$.

3. ${}^a\mu_b \times {}^b\mu_a = 1$ and ${}^a\mu_b = \frac{1}{{}^b\mu_a}$.

4. **Light passing through different media:**

(i) ${}^a\mu_b \times {}^b\mu_c \times {}^c\mu_a = {}^a\mu_a = 1$.(ii) ${}^a\mu_b \times {}^b\mu_c = {}^a\mu_c$.

5. **Snell's law :** For same colour of light : ${}^a\mu_b = \frac{\sin i}{\sin r}, [i \neq 0]$.

i = incident angle, r = reflection angle.

Generalised : $\mu_1 \sin \phi_1 = \mu_2 \sin \theta_2 = ...$
$= \mu_n \sin \phi_n$.

6. Cauchy's formula : $\mu = A + \frac{B}{\lambda^2}$. Where A and B are cauchy's constant.

7. Refraction through plane parallel plates : Lateral displacement $(D) = t \sec r \sin (i - r)$. Where t = slab's thickness.

8. **Object in denser and observer in rarer medium:**

(i) $\frac{\mu_2}{\mu_1} = \frac{\text{real depth}}{\text{apparent depth}}$. Where μ_2= R.I. of denser medium, μ_1= R.I. of rarer medium.

(ii) $\mu = \frac{t}{d} = \frac{t}{t-x}$ or $x = \frac{(\mu - 1)}{\mu}$. Where d = apparent position.

(iii) $d = \frac{t_1}{\mu_1} + \frac{t_2}{\mu_2} + ... + \frac{t_n}{\mu_n} = \sum \frac{t}{\mu}$.

9. **Object in rarer medium and observer in denser medium:**

$\frac{\mu_2}{\mu_1} = \frac{\text{apparent depth}}{\text{real depth}}$. $\mu_{\text{air}} = 1$, $\mu_{\text{water}} = 1.33$, $\mu_{\text{crown glass}} = 1.62$, $\mu_{\text{flint glass}} = 1.65$, $\mu_{\text{glycerine}} = 1.47$, $\mu_{\text{diamond}} = 2.418$, $\mu_{\text{glass}} = 1.5$.

10. **Total internal refraction :** $\frac{\mu_1}{\mu_2} = \sin C.$

Where μ_1 = R.I. of rarer medium and μ_2 = R.I. of denser medium.

If μ_1= 1 (for vaccum) ; $\mu_2 = \frac{1}{\sin C}$. Where C = critical angle.

11. **Vision of a fish or a diver :**

$r = \frac{h}{\sqrt{\mu^2 - 1}}$., r = Angle, h = depth, μ = R.I.

Prism, Combination of Prisms, Spectra

1. $D = i + i' - A$. Where i = angle of incidence, i' = angle of emergence and A = refracting angle of prism, D = angle of deviation.
2. $A = r + r'$. Where r = angle of refraction at the 1st surface and r' = angle of refraction at the second surface.
3. **For minimum deviation :** $i = i'$ and $r = r'$

   $\therefore D_m = 2i - A.$
4. $A_{max} = 2C$. **Where :** C = critical angle.
5. $\mu = \frac{\sin \frac{A + D_m}{2}}{\sin \frac{A}{2}}$ For a thin prism : $D_m = A(\mu - 1)$.
6. **Silvering one surface :**

   The rays are feflected back by the silvered portion. The focal length of the effective lens $\frac{1}{F} = \Sigma \frac{1}{f}$.

   where f = focal length of the mirror oir lens to be repeated as many times as the reflection and refraction takes place.

   (i) If a plano-convex lens is silvered at its plane surface, then the focal length of the lens F_1 is given by $\frac{1}{F_1}=\frac{\mu-1}{R}$ The focal length of the mirror F_m is given by $F_m=\frac{R}{2}$.

Thus the resultant focal length F is given by \

$$\frac{1}{F}=\frac{1}{F_1}+\frac{1}{f_m}+\frac{1}{F_1}=\frac{2}{F_1}(\text{since } f_m=\infty)$$

(ii) When it is silvered onthe convex surface, then

$$\frac{I}{F}=\frac{1}{F_1}+\frac{1}{f_m}+\frac{1}{F_1}=\frac{2}{F_1}+\frac{1}{R/2}=\frac{2\mu}{R}$$

(iii) A convex is silvered on a surface of which radius of curvature R_2, then

$$\frac{1}{F}=\frac{2}{F_1}+\frac{2}{R_2}$$

7. **Angular dispersion** $(\beta)=D_v-D_r=A(\mu_v-\mu_r)$. Where D_v and D_r = deviation for violet and red ray, μ_v and μ_r = R.I. for violet and red ray.

8. **Dispersive power** $(\omega)=\frac{\text{angular dispersion}}{\text{mean deviation}}=\frac{D_v-D_r}{D_y}=\frac{\beta}{D_y}$

$=\frac{\mu_v-\mu_r}{\mu_y-1}$. Where D_y = deviation for mean yellow colour μ_y = R.I. of mean yellow colour.

9. **Dispersion without deviation :**

(i) $\frac{\mu'-1}{\mu-1}=-\frac{A}{A'}$ (ii) **Total dispersion** $=A(\mu-1)(\omega-\omega')$

10. **Deviation without dispersion :**

(i) $\frac{\mu_v' - \mu_r'}{\mu_v - \mu_r} = -\frac{A}{A'}$.

(ii) **Total deviation of the mean ray =** $A(\mu - 1)\left(1 - \frac{\omega}{\omega'}\right)$

11. **VIBGYOR**

(i) Increasing frequency : From right to left.

(ii) Increasing wavelength : From left to right

12. **In Rayleigh scattering**

$I \propto 1\lambda^4$

I = scattered intensity, λ = wavelength.

Refraction of Light at Spherical Surfaces, Lenses and Defects of Vision

1. Refraction at a single spherical surface (small aperture):

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}.$$

2. **Sign convention :** (i) **For real image by convex** (converging) **lens** : **u** = –ve, v = + ve, f = +ve, p = + ve.

(ii) **For virtual image by convex lens :** u = –ve, v = –ve, *f=+ve, p=+ve.*

(iii) **For virtual image by concave** (diverging) **lens :** *u = –ve, v= –ve, f= –ve, p = –ve*

3. **Four thin lenses :**

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Where μ_2 & μ_2 = R.I. of lens material & surrounding medium.

The above relation is to be used with proper signs for R_1 and R_2 as follows-

(i) Double-convex : R_1 is + ve, R_2 is –ve

(ii) Plano – convex : R_1 is +ve, $R_2 = \infty$

(iii) Cancavo – convex : Both are –ve or both +ve

(iv) Double - concave : R_1 is –ve, R_2 is +ve

(v) Plano - concave : R_1 is – ve, $R_2 = \infty$

(vi) Convexo - concave : Both are –*ve* or both +ve.

4. **Linear or lateral or transverse magnification** (m) :

$$m = \frac{\text{size image (I)}}{\text{size of object (O)}} = \frac{v}{u}.$$

5. **Power of a lens** (P) = $\frac{1}{f}$. Where P in diopter, f in metres. $P = \frac{100}{f}$.

Where f in centimeter.

6. **Combination of lenses :**

(i) $P = P_1 + P_2 + P_3 + ...$

(ii) $P = P_1 + P_2$ (in case of two lenses).

(iii) If two thin lenses are separated by a distance d:

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} \text{ and } P = P_1 + P_2 - dP_1P_2$$

7. **Focal length of a lens in different media :**

$$\frac{f_{liq}}{f_{air}} = \frac{{}^a\mu_g - 1}{\frac{{}^a\mu_g}{{}^a\mu_l} - 1}$$ Where ${}^a\mu_l$ = R.I. of liquid w.r.t. air, ${}^a\mu_g$ = R.I. of glass w.r.t. air

8. **Newton's formula** : $\sqrt{u.v} = f$ (By using sign convention). Where u

and v = object and image distance from principal focus.

9. **Formation of** real image **by a convex lens :** $D_{\min} = 4f$.

10. **Focal length of a lens by displacement method :** $f = \frac{D^2 - d^2}{4D}$.

    Where D = distance between object & screen and d = displacement of lens.

11. **Lateral chromatic aberation =** $\frac{\omega}{f}$.

    Where ω = dispersive power and f = focal length.

12. **Achromatic lens** : (i) single : $\frac{\omega}{f} = 0$.

    (ii) Two lenses in contact : $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$ or $\frac{\omega_1}{\omega_2} = -\frac{f_1}{f_2}$.

    (iii) Two lenses separated by a distance $d : \frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} - \frac{\omega_1 + \omega_2}{f_1 f_2} = 0$.

    (iv) $d = \frac{1}{2}(f_1 + f_2)$ provided, $\omega_1 = \omega_2$.

13. Ratio of focal length of lens for violet and red rays : $\frac{f_v}{f_r} = \frac{\mu_r - 1}{\mu_v - 1}$.

14. **Hypermetropia or long sight :** $\frac{1}{f} = \frac{1}{D} - \frac{1}{d}$. Where f = focal length of correcting (convex) lens. d = near point of the fault eye and D = near point of corrected eye.

15. **Myopia** or **Short sight** : $\frac{1}{f} = \frac{1}{x} - \frac{1}{d}$. If $x = \infty, f = -d$. Where d = far point of the fault eye and x = far point of the corrected eye.

16. **Readymade formula :** $f = \frac{xy}{x-y}$.

Where f = focal length of correcting lens, x = distance which can be clearly seen and y = distance which is to be seen.

(i) If $x > y$, $f = +ve$, convex lens (**Hypermetropia**).

(ii) If $x < y$ $f = -ve$, concave lens (**Myopia**).

Optical Instruments

1. **Simple microscope or magnifying glass:**

(i) When image is formed at D distance, $M = 1 + \frac{D}{f}$ (for distinct setting). (ii) $M = 1 + \frac{D-a}{f}$ where a = distance of lens from eye. (iii) $M' = \frac{D}{f}$ (for normal setting). When image is formed at infinite.

2. **Compound microscope** : (i) **For distinct setting :** When image is formed at D distance

$$M = M_0 \times M_e = -\frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right).$$

Length, $L = v_0 + u_e$

Where M_o and M_e = magnification produced by objective lens and eye-piece respectively, u_o & v_a = object and image distance from the objective lens and f_e = focal length of eye-piece lens.

u_e and v_e = object and image distance from the eye-piece lens, L = distance between both lenses.

(ii) When the final image is at infinity. $M = \frac{-v_0}{u_0} \times \frac{D}{f_e}$

Length, $L = V_0 + f_e$

If the eye is at a distance a from the eye lens, then D is to be replaced by $(D-a)$.

3. **Astronomical telescope :** (i) For **normal setting** (image at ∞)

$$M = -\frac{f_0}{f_e}.$$

(ii) $M = -\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$, for **distinct setting**.

(iii) The length (L) of telescope in all cases = $V_0 + u_e$.

(iv) $L = f_o + f_e$ (for **normal setting).**

4. **Galilean telescope :** (i) $M = \frac{f_0}{f_e}$ (normal setting).

(ii) $M = \frac{f_0}{f_e}\left(1-\frac{f_e}{D}\right)$, for **distinct setting.**

(iii) Length $(L) = V_0 - u_e = f_0 - f_e$ (**normal setting**).

5. **Terrestrial telescope :**

It is a type of an astronomical telescope but having one more inverting lens (convex).

The formula for the magnifying power is that of an astronomical telescope.

Length of the tube $= f_0 + 4f + f_e$.

f = focal length of inverting lens.

6. **Photographic camera :** (i) $n = \frac{F}{d}$. (ii) $\frac{t_1}{t_2} = \left(\frac{n_1}{n_2}\right)^2$.

Where F = focal length, d = diameter of the stop and t_1 and t_2 are time of exposure f = number = F/d.

Interference of Light

1. **For constructive interference** : Phase difference $\phi = 2n\pi$ and path difference $(\Delta) = n\lambda$. Where $n = 0$ or any integer.

2. For **destructive interference :** $\delta = (2n + 1)\pi$ and $\Delta = (2n + 1)\frac{1}{2}\lambda$.

3. **Resultant amplitude :**

(i) $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$

(ii) $A = \sqrt{I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi}$

(iii) $A_{max} = a_1 + a_2, \phi = 2n\pi$

(iv) $A_{min} = a_1 - a_2, \phi = (2n + 1)\pi$

4. Phase difference $= \frac{2\pi}{\lambda} \times$ path difference, $\phi = \frac{2\pi}{\lambda} \times \Delta$.

5. (i) Path difference for bright fringe $= n\lambda$ (ii) path difference for dark fringe $= (2n + 1)\lambda/2$

n is number of fringes, λ = wavelength.

6. **Fring width** $(\beta) = \frac{\lambda D}{d}$; (**Young's double slit experiment**).

Where d = distance between two coherent sources and D = distance of the screen from the slit.

(i) $x_n = n\lambda\frac{D}{d}$ (Bright fringe)

x_n = distance of nth bright fringe form central bright fringe

x_{n+1} distance of n + 1th dark fringe form central bright fringe

(ii) $x_{n+1} = (2n+1)\frac{D\lambda}{2d}$ (Dark fringe)

7. **Fresnel's biprism :**(i) $\beta = \frac{\lambda D}{d}$. (ii) $d = \sqrt{d_1 d_2}$.

Where d_1 and d_2 = distance between the real images in two different position of the tens.

Doppler's Effect

1. $n' = n = \Delta n = \pm n\frac{v}{c}$. Where n = frequency when there is no relative motion, n' = apparent frequency, Δn = change in frequency, v = relative velocity between source and observer, c = velocity of light. + ve sign for approaching and –ve sign for receding.

2. $\Delta\lambda = \lambda' - \lambda = \pm\lambda\frac{v}{c}$.

Where –*ve* sign for approaching and +*ve* sign for receding.

MODERN PHYSICS

Photoelectric Effect

1. **Symbols used :** N = number of photoelectrons emitted, I = intensity of light, E_k = kinetic energy of photoelectrons, P = illuminating power, d = distance from photocell, ϕ = work function for the photometal, v = frequency of incident radiation, v_0 = threshold frequency, λ = wave-length of incident radiation, λ_0 = threshold wavelength, v = velocity, h = planck's constant, m = mass of the electron, e = electronic charge = -1.6×10^{-19} *coul*, V_s = stopping potential and v_{max} = maximum velocity of the electron.

2. **Laws of photoelectric effect :**

   (a) **1st law :** $N \propto I, N$ is independent of v of the incident radiation

   or $N \propto \frac{P}{d^2}$.

   (b) **2nd law :** V or $E_k \propto V$ but independent of I.

3. **For a given photometal :** $\phi = hv_o = \frac{hc}{\lambda_o}$

   Unit of ϕ = electron volt, $h = 6.62 \times 10^{-34}$ ***Joule sec.***

4. $v_{max} = \sqrt{\frac{2eV_s}{m}} or \frac{1}{2}mv_{max}^2 = eV_s$.

5. **Einstein's photoelectric equation:**

$$\frac{1}{2}mv_{max}^2 = h(v - v_o) = \frac{hc}{\lambda} - \frac{hc}{\lambda_o} . hv = hv_o + \phi$$

$$\frac{1}{2}mv^2 = \phi + \frac{1}{2}mv_{max}^2 .$$

Radioactivity

1. $T_{ag} = \frac{1}{\lambda}$. where T_{ag} = *mean life or average life* λ = disinegration constant.

2. **Half life,** $T_{\frac{1}{2}} = 0.693 \times T_{ag}$ = 69.3% of T_{ag} = 69.3% of T_{ag} = or

$$T_{\frac{1}{2}} = \frac{0.693}{\lambda} = \frac{\log_e 2}{\lambda}.$$

(a) $N = N_0\, e^{-\lambda t}$ (b) $A = A_0\, e^{-\lambda t}$

(c) $M = M_0\, e^{-\lambda t}$ (d) $\lambda = \frac{2.3027 \log_{10}\left(\frac{N_0}{N}\right)}{t}$

(e) $\lambda = \frac{2.3027 \log_{10}\left(\frac{A_0}{A}\right)}{t}$ (f) $\lambda = \frac{2.3027 \log_{10}\left(\frac{M_0}{M}\right)}{t}$

(g) $\lambda = \lambda_\alpha + \lambda_\beta$ (h) $\tau = \frac{\tau_\alpha \tau_\beta}{\tau_\alpha + \tau_\beta}$ (i) $N = \frac{N_0}{2^n} = \frac{N_0}{2^{(t/T)}}$

(j) $A = \frac{A_0}{2^{(t/T)}}$ (k) $M = \frac{M_0}{2^{(t/T)}}$ (l) (O) and (M)⊗

3. $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$. Where N_0 = original amount or number of nuclei, N = number of undisintegrated nuclei after time t, n = number of half lives passed and $n = \frac{t}{T}$.

A_0 = maximum initial activity, A = activity after time t, M_0 = initial mass, M = mass after time t, τ = decay time, T = half life time.

4. **Percentage radioactivity** $= \left(\frac{1}{2}\right)^n \times 100.$

Atomic Structure

1. $\frac{mv^2}{r} = \frac{KZe^2}{r^2}$ where K = Couloms force constant

2. $mvr = \frac{h}{2\pi}$ or $mvr = \frac{nh}{2\pi}.$

3. $r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m Z e^2}.$ For the 1st orbit, $n = 1$

   $\therefore r_1 = \frac{\varepsilon_0 h^2}{\pi m Z e^2}.$ or $r_n = n^2 r_1$, where r_n = *radius* of n^{th} orbit, $\varepsilon_0 = \frac{1}{4\pi k}.$

4. $v_n = \frac{Ze^2}{2\varepsilon_0 nh}$ or $v_n = \frac{v_1}{n}$ (for hydrogen atom Z = 1).

   Where v_n = velocity of electron in n^{th} orbit & v_1 = velocity in 1st.

5. $E_n = -\frac{mZ^2e^4}{8\varepsilon_o^2 n^2 h^2}.$ for $n = 1$, $E_1 = -\frac{mZ^2e^4}{8\varepsilon_o^2 h^2}$ or $E_n = -\frac{E_1}{n^2}.$ Where

   E_n & E_1 = are energy of electron in n^{th} & 1st orbit respectively.

6. $I\omega_n = mv_n r_n = \frac{nh}{2\pi}.$ Where ω_n = angular velocity in n^{th} orbit

7. **Frequency of electron in n^{th} orbit :**

$$f_n = \frac{4\pi^2 k^2 Z^2 e^4 m}{n^3 h^3} = \frac{6.62 \times 10^{15} Z^2}{n^3} Hz$$

8. **Time period of electron in n^{th} orbit :**

$$T_n = \frac{n^3 h^3}{4\pi^2 m e^4 K^2 Z^2}, T_n = \frac{1.5\times10^{-16} n^3}{Z^2} \text{second}$$

9. **Current due to velocity of electron in the *n*th oirbit:**

$$I_n = ef_n = \frac{4\pi^2 K^2 Z^2 e^5 m}{n^3 h^3}, \quad I_n = \frac{1.06 Z^2}{n^3} mA$$

10. **Magnetic induction due to motion of electron on the nucleus :**

$$B_n = \frac{\mu_0 I_n}{2r_n} = \frac{8\pi^4 K^3 Z^3 e^7 m^2}{n^5 h^5} = \frac{12.58}{n^5} Z^3 Tesla$$

11. **Magnetic moment of electron in the *n*th orbit due to motion of electron :**

$$M_n = \frac{ehn}{4\pi m}, M_n = 9.26\times10^{-24} n \ \ Ampere\ metre^2$$

12. **Potential energy of electron in the *n*th orbit:**

$$U_n = -\frac{KZe^2}{r_n} = \frac{-27.2}{n^2} Z^2 eV$$

13. **Kinetic energy of electron in the *n*th orbit :**

$$K_{kn} = \frac{KZe^2}{2r_n} = \frac{13.6 Z^2}{n^2} eV$$

15. **Ionization energy in the *n*th orbit :**

$$E_{\text{ion}} = E_\infty - E_n, E_{\text{ion}} - E_\infty = \frac{13.6 Z^2}{n^2} eV$$

16. **Ionization potential of electron :**

$$V_{\text{ion}} = \frac{13.6 Z^2}{n^2} volt$$

17. **Number of waves in distance** $d : N = \frac{d}{\lambda}$. **where λ is wavelength.**

18. **Wave number** $(\bar{v}) : \bar{v} = \frac{1}{\lambda}$

Electromagnetic Wave and X-Ray

1. $C_m = \frac{1}{\sqrt{\mu\varepsilon}}$. For air or vaccum $C_o = \frac{1}{\sqrt{\mu_o \varepsilon_o}}$.

   Where C_m & C_o are velocities of wave in medium & vacuum.

2. **Energy of single quanta or photon** *(E)* **=** ***hv*****.**

   Where h = Planck's constnat, v = Frequency of photons.

3. **Properties of photon : (i) rest mass = 0; (ii) charge = 0; (iii) energy =** $E = hv = \frac{hc}{\lambda}$; **(iv) momentum (*P*)** $= mc = \frac{hv}{c} = \frac{h}{\lambda}$; **(v) moving mass =** $\frac{hv}{c^2} = \frac{h}{\lambda c}$. Also $P = \sqrt{2mE}$, **(vi)** $C_o = 3\times10^8$ *m/s;* and **(vii)** spin = 1.

4. Intensity of X-ray α filament temperature (**Collidge tube**).

5. $E = eV = \frac{1}{2}mv^2 = hv_{max} = \frac{hc}{\lambda_{min}}$ or $v_{max} = \frac{eV}{h}$ & $\lambda_{min} = \frac{hc}{eV}$.

   Where V = applied accelerating potential to the tube, v = speed of incident electron & E = energy.

6. **Moseley's law** : v $\propto Z^2$. (Z = atomic number of the element).

7. Absorption of X-ray $\propto$ Z Absorption of X-ray $\propto \frac{1}{\lambda}$.

8. $K \propto Z^2$, *where* ***K*** = Absorption co-efficient.

9. **Rontgen is the unit of X-ray dose.**

We are given in radioactivity.

Nuclear Energy, Mass Defect and Binding Energy

1. $E = mc^2$, where m = Mass, E = Energy, c = Velocity of light.
2. 1eV = 1.6×10^{-19} *Joule* = 1.6×10^{-12} erg.
3. 1 *a.m.u.* = 1.66×10^{-27} *kg* = 1.66×10^{-24} *gm* = 931 *MeV*.
4. $\Delta m = [ZM_p + (A - Z) M_n] - M$ Where Δm = mass defect, Z = atomic number, A = mass number M = mass of nucleus, M_p = mass of proton and M_n = mass of neutron.
5. **Binding energy** = $\Delta m \times C^2$.
6. **Packing fraction** $= \frac{\Delta m}{A} \times 10^4$.