# $N_1V_1 = N_2V_2$ { Relation b/w Numerical value and units }

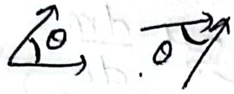
# In {add$^n$ & Sub$^n$ → number right of decimal is taken significant fig.
{Mul. & Div → all digits are taken into con. for sig-fig
→ Min is taken

# In non decimal number → No. of sig. figures: First non-zero to last non-zero

Decimal → Every after first non-zero

# $F_{electrostat} = 10^{39} F_{gravitational}$ } b/w electron,

# $\vec{v} = \vec{\omega} \times \vec{r}$, $\vec{L} = \vec{r} \times \vec{p}$, $\vec{\tau} = \vec{r} \times \vec{F}$

# Angle b/w two vectors 

# Speed = $\frac{\text{change in distance}}{\text{change in time}}$ | Average speed = $\frac{\text{Total distance travelled}}{\text{Total time taken}}$

# In uniform velocity, avg. velocity = Instantaneous velocity.

# Average velocity = $\frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$ } depends only on initial & final position of particle during that interval

$V_{av} = \frac{u+v}{2}$ } When vel. of body is not uniform but changes uniformly i.e. accelerated motion

# Avg. accl$^n$ = $\frac{\text{change in velocity}}{\text{change in time}} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}$ | $\vec{a}_{instant} = \frac{d\vec{v}}{dt} = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$

# $|\vec{v}_{21}| = |\vec{v}_{12}|$ } Magnitude same but $v_{21}$ & $v_{12}$ has opposite direction
⇓
$\sqrt{v_1^2 + v_2^2 - 2v_1v_2\cos\theta}$   θ → Angle b/w $v_1$ & $v_2$ }

# $S_{n^{th}} = u + \frac{a}{2}(2n-1)$

# $\vec{V}_{AB} = \vec{V}_A - \vec{V}_B$ {Rate of change of pos. of A w.r.t. object B}

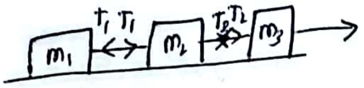
# In projectile motion; hor. motion & vert. motion are independent of each other.

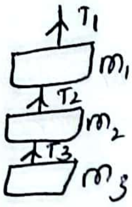
# At any point in trajectory,
$v_y = u_y + gt$ ; $v_x = u_x$ ; $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

# KEmax → At point of projection or point just before reaching ground
KEmin → At max. height

# $\boxed{\vec{F} = \frac{d\vec{p}}{dt}}$ | # For no net external force
$P_{initial} = P_{final}$
$\vec{F}_{AB} = -\vec{F}_{BA}$ } N III$^{rd}$ law | $\vec{P} = m\vec{v}$ | Impulse = $F_{av}\Delta t$
= change in momentum
= $\Delta(mv)$
$\int_{t_1}^{t_2} F\,dt = \int_{P_1}^{P_2} dP$

☆ $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ } → Principle of conservation of Linear momentum.

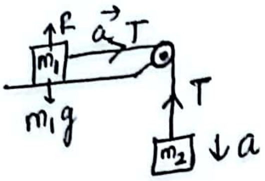
#  $\Rightarrow$ Common acc. $(a) = \dfrac{F}{m_1+m_2+m_3}$ | $T_1 = m_1 a$ | $T_2 = \left(\dfrac{m_1+m_2}{m_1+m_2+m_3}\right)$

# 

$\uparrow a$ $\Sigma F_{up} = T_1 - (m_1+m_2+m_3)g$

$(m_1+m_2+m_3)a + (m_1+m_2+m_3)g = T_1$

$\boxed{\Sigma F = ma}$

# 

$m_1 a = m_2 g - m_2 a$ } $a = \dfrac{m_2 g}{m_1+m_2}$

$T = m_1 a$  For inextensible string $\rightarrow$ T & a for both mass remains same.

# Thrust on rocket, $F = -u \dfrac{dm}{dt}$ → rate of ejection of fuel

(Accl^n of rocket keeps on increasing due to decrease in mass of fuel) { velocity of exaust gas.

{Thrust = wt. of rocket}

# Motion along rough inclined plane

- Body of mass m, moving down the inclined plane with acceleration 'a', net downward force needed is

$F_N = ma + mg\sin\theta - F_K = m(a + g\sin\theta - \mu_K g\cos\theta)$

$F_K$ → Frictional force

- Moving up,

$F_N = ma + mg\sin\theta + m\mu_K g\cos\theta$.

# $\mu_s = \tan\alpha = \tan\theta$

# Inertia: Inherent property of body } More mass → More inertia.

More difficult to change its state of motion

# WORK-ENERGY THEOREM

Blood ⇒ $\boxed{\text{Work done}(W) = \vec{F}\cdot\vec{s} = \text{Change in kinetic energy} = \frac{1}{2}mv^2 - \frac{1}{2}mu^2}$

# $\boxed{K.E = \dfrac{p^2}{2m}}$

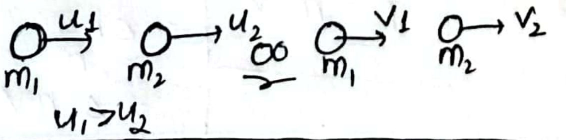
# For exploding objects, $\boxed{KE \propto \dfrac{1}{\text{mass}}}$

# For stretched spring $\boxed{P.E = \frac{1}{2}Kx^2}$ K → spring constant, x → stretched length

# Total mechanical is always conserved at all points as the body falls freely under the effect of gravity.

→ Total mechanical energy = K.E. + P.E.

# $\boxed{P_{av} = \dfrac{W}{t}}$ & $\boxed{P = \vec{F}\cdot\vec{v}}$

# 

If suffer elastic collision,

$\boxed{v_1 = \dfrac{(m_1-m_2)u_1 + 2m_2u_2}{m_1+m_2}}$

$\boxed{v_2 = \dfrac{(m_2-m_1)u_2 + 2m_1u_1}{m_1+m_2}}$

$\boxed{0 \le e \le 1}$

Coefficient of restitution $(e) = \dfrac{\text{Rel. vel. of separation}}{\text{Rel. vel of approach}}$

$e = \dfrac{v_2 - v_1}{u_1 - u_2}$

$e \rightarrow 1$ {perfectly elastic}

↳ 0 {Perfectly inelastic}

Average angular velocity $(\bar{\omega}) = \dfrac{\text{Angular displacement}}{\text{Time taken}} = \dfrac{\Delta\theta}{\Delta t} = \dfrac{\theta_2-\theta_1}{t_2-t_1}$

# $F_{centripetal} / F_{centrifugal} = \boxed{\dfrac{mv^2}{r} = mr\omega^2}$

# In vertical circular motion

(Tension in string) $- mg\cos\theta = \dfrac{mv^2}{r}$

$\Rightarrow \boxed{T = \dfrac{mv^2}{r} + mg\cos\theta}$

$\theta = 0°$ (Lowest point) $T_{max}$ $\rightarrow \boxed{V_{min} = \sqrt{5rg}}$

$\theta = 90°$ (horizontal point) $\rightarrow \boxed{V_{min} = \sqrt{3rg}}$

$\theta = 180°$ (Highest point) $T_{min}$ $\rightarrow \boxed{V_{min} = \sqrt{rg}}$

# Banking of track / Bending of cyclist $\Rightarrow \boxed{\tan\theta = \dfrac{v^2}{rg}}$

# In a level road, For safe turn $\boxed{V_{max} = \sqrt{\mu rg}}$

# In a banked road, For safe turn $\boxed{V_{max} = \sqrt{rg\tan\theta}} \rightarrow F_{friction}$ neglected

$\boxed{V_{max} = \sqrt{rg\left(\dfrac{\mu+\tan\theta}{1-\mu\tan\theta}\right)}} \rightarrow F_{friction}$ taken into account

# Conical pendulum, $\boxed{T = 2\pi\sqrt{\dfrac{l\cos\theta}{g}}}$ $\boxed{\begin{matrix} T\cos\theta = mg \\ T\sin\theta = mv^2/r \end{matrix}}$ $\boxed{TE = -KE = \dfrac{PE}{2}}$

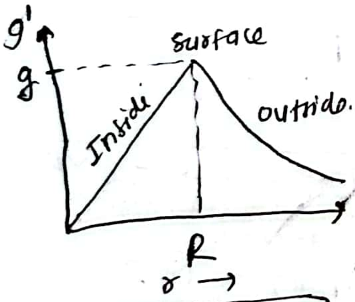
# $\boxed{GM = gR^2}$

# Variation of g $\rightarrow$ due to altitude $\rightarrow \boxed{g' = \dfrac{GM}{(R+h)^2}}$ $\boxed{\text{For } h << R \quad g' = g\left(1-\dfrac{2h}{R}\right)}$

$\rightarrow$ due to depth $\rightarrow \boxed{g' = g\left(1-\dfrac{x}{R}\right)} \left\{ \leq 1 \right.$ $\boxed{g_{surface} = \dfrac{4}{3}\pi RSG}$

$\rightarrow$ due to rotation $\rightarrow$ $g' = g - R\omega^2\cos^2\phi$

$\phi \rightarrow$ Latitude $\{\phi = 0°$ at eq. & $90°$ at pole$\}$




# $\boxed{E = \dfrac{GM}{r^2}} \rightarrow$ Field intensity (E)

# $\boxed{V = -\dfrac{GM}{r}}$ $\boxed{U = -\dfrac{GMm}{r}}$ $\boxed{E = -\dfrac{dV}{dr}}$

Potential  G.P.E.  bound

Escape velocity  $KE \geq PE$

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

$R_e \Rightarrow V_e = 11.2$ km/s {For earth

$G = 6.67 \times 10^{-11}\, Nm^2\, kg^{-2}$

$R_E = 6.4 \times 10^6 m$

$M_E = 6 \times 10^{24} kg$

# $\boxed{V_0 = \sqrt{\dfrac{GM}{R+h}} \quad \text{For } h<<R,\ V_0 = \sqrt{\dfrac{GM}{R}} = \sqrt{gR}}$

$\boxed{V_e = \sqrt{2}\, V_0}$

# Time period of satellite to revolve around orbit $(T) = \dfrac{\text{Circumference of orbit}}{\text{Orbital velocity}} = \dfrac{2\pi(R+h)}{V_0}$

$\boxed{T = \dfrac{2\pi}{R}\sqrt{\dfrac{(R+h)^3}{g}}}$

$R_e > R_p$

# Total energy of satellite $= K.E. + P.E$

$= \dfrac{1}{2}mv_0^2 + \left(-\dfrac{GMm}{r}\right) = -\dfrac{1}{2}\dfrac{GMm}{r}$

Total energy to raise satellite to desired height and set it in circular orbit (E)

P.E.  K.E

= Increase in P.E + K.E

$= \left[-\dfrac{GMm}{r} - \left(-\dfrac{GMm}{R}\right)\right] + \dfrac{1}{2}mV_0^2$

# For planet to have atmosphere, $c_{rms} < v_e$
# Rocket launched from west to east in eq. plane.
# P.E. gained in attaining max. ht. is same in two diff. planets for same person i.e. $\rightarrow mg_1h_1 = mg_2h_2$ }

# For maxima/minima $\rightarrow$ First derivative = 0 { w.r.t changing or varying components

# For body to be in eq$^m$,

① $\Sigma \vec{F}_{ex} = 0$ or $\vec{P}$ = constant
② $\Sigma \vec{\tau}_{ex} = 0$ or $\vec{L}$ = constant } but not zero.

# Coordinates of centre of mass of $n$ particles having mass $m_1, m_2 \ldots m_n$
↳ Take any reference point as origin. Then

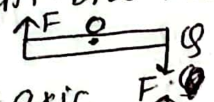
check dir. into account (+, −) { $R_{CM} = \left( \dfrac{m_1x_1 + m_2x_2 + m_3x_3 + \ldots}{m_1 + m_2 + \ldots}, \dfrac{m_1y_1 + m_2y_2 + m_3y_3 + \ldots}{m_1 + m_2 + \ldots} \right)$

# For stable eq$^m$ → ① C.G of body low ② Base of body large & ③ C.G. must lie within base of body on displaced position.

# Moment of force = Force × ⊥r distance from axis of rotation.

# In rotational eq$^m$, Clockwise moment = Anticlockwise moment i.e. $F_1 \times r_1 = F_2 r_2$

# Moment of couple = Any one of equal Force × ⊥r dist. b/w them
= F × PQ

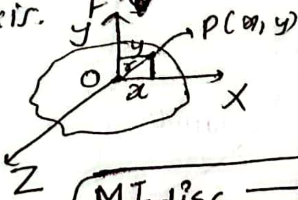


$\boxed{n = \dfrac{\theta}{2\pi}}$

# Moment of inertia: Depends upon choice of axis.

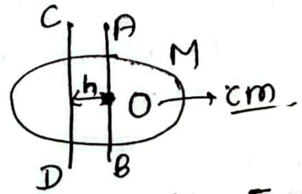
# Theorem of ⊥r axes:

$I_z = I_x + I_y$ } $I_x = my^2$, $I_y = mx^2$



# Theorem of ‖el axes:

I about axis CD ‖ to AB $\rightarrow \boxed{I = I_{cm} + Mh^2}$



MI disc $\longrightarrow \frac{1}{2}MR^2$
↳ axis through centre & ⊥r to plane
MI ring = $MR^2$

# Moment of inertia of diff. bodies:

| S.N. | Object | Axis | MI |
|---|---|---|---|
| 1. | Thin rod | Mid-point | $I = \frac{1}{12}ml^2$ |
| | | end | $I = \frac{1}{3}Ml^2$ |
| 2. | A thin ring | diameter | $I = \frac{1}{2}MR^2$ |
| 4. | Circular disc | diameter | $I = \frac{1}{4}MR^2$ |
| 5. | Solid sphere | center | $I = \frac{2}{5}MR^2$ |
| 6. | Hollow sphere | center | $I = \frac{2}{3}MR^2$ |
| 7. | Rect. Lamina | center | $I = \left(\frac{l^2+b^2}{12}\right)$ |
| 8. | Solid cylinder | symmetry axis | $I = \frac{1}{2}MR^2$ |
| 9. | Hollow cylinder | symmetry axis | $I = MR^2$ |

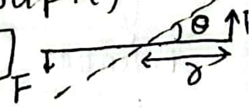
# For no resultant torque on the system for rotating bodies, i.e. $I\omega$ = constant

$\boxed{L = \text{constant}}$

# Work done by couple,

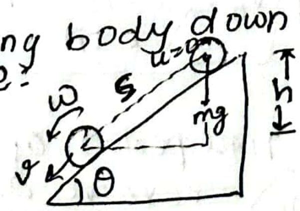
$\boxed{W = \tau\theta}$

$\boxed{\tau = F(2r)}$



# Acc$^n$ of rolling body down the inclined plane:

$\boxed{a = \dfrac{g\sin\theta}{\left(1 + \frac{I}{mr^2}\right)}}$



# Total K.E. of rolling body

Total K.E. $= \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$

# mass ≡ Moment of Inertia {In R.D}

# $\vec{\tau}$ & $\vec{\alpha}$ ⇒ Directed along axis of rotation

; Stress $= \frac{F}{A}$ # Moduli of elasticity $= \frac{\text{stress}}{\text{strain}}$

# Shrear strain = angular deviation from original position $= \theta$

# Within elastic limit, (i) stress $\propto$ strain (ii) $F \propto e$

# Bulk modulus $(K) = \frac{dP}{(-\Delta V/V)}$ | Compressibility $(k) = \frac{1}{K} = \frac{\Delta V}{-dPV}$

In gas, $\Delta V = \gamma V \Delta T$

# P.E. stored in stretched wire $(W) = \frac{1}{2} \times$ stretching force $(F) \times$ extension $(e)$

Energy density $(U) = \frac{1}{2} \times$ stress $\times$ strain

# If P.E. of stretched wire provides KE for missile, $\frac{1}{2} Fe = \frac{1}{2} mv^2$

# Poisson's ratio $= \frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{-\Delta D/D}{\Delta L/L}$ $\boxed{\text{Temp} \uparrow \text{ Elasticity} \downarrow}$

# Y & $\eta \rightarrow$ only for solid | $K \rightarrow$ for all solid, liquid & gas.

# More elastic $\rightarrow$ material which stretches lesser extent for given load.
$\hookrightarrow$ more moduli of elasticity.

# $V = \frac{m}{\rho} \Rightarrow dV = -\frac{m}{\rho^2} d\rho \Rightarrow \boxed{\frac{dV}{V} = -\frac{d\rho}{\rho}}$ ⇒ since mass remains constant.

# In SHM, $F_{restoring} \propto x$ ↳ disp. from mean position

$\boxed{a \propto x}$ $\boxed{F = -kx}$ $k \rightarrow$ force constant

# $\boxed{y = A \sin(\omega t + \phi_0)}$ $\Rightarrow \phi_0 \rightarrow$ phase at $t=0$ i.e. initial phase.

{mean position $\rightarrow x = 0$
Extreme position $\rightarrow x = A$} Max displacement

# $\boxed{V = A\omega \cos(\omega t + \phi_0) = \omega\sqrt{A^2 - x^2}}$

# $\boxed{a = -\omega^2 x}$

# Time period $\boxed{T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{\text{Displacement}}{\text{Acceleration}}}}$

$\boxed{T_{spring} = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{\text{Inertia factor}}{\text{spring factor}}}}$ $\boxed{T = 2\pi\sqrt{\frac{m}{K}}}$

# $\boxed{K = m\omega^2}$ $\boxed{F = m\omega^2 x}$

# $\boxed{KE = \frac{1}{2} m\omega^2 (A^2 - x^2)}$ $\boxed{PE = \frac{1}{2} m\omega^2 x^2 = \frac{1}{2} K x^2}$

# $\boxed{TE = KE_{max} = PE_{max} = \frac{1}{2} m\omega^2 A^2}$

$\boxed{T_{simple\ pendulum} = 2\pi\sqrt{\frac{l}{g}}}$
{At space, $g = 0 \rightarrow T \Rightarrow \infty$ so can't measure}

# When two springs are connected in series ↳ $\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2} \Rightarrow K = \frac{K_1 K_2}{K_1 + K_2}$

In parallel $K_{ef} = K_1 + K_2$

$\boxed{T = 2\pi\sqrt{\frac{m}{K_1 + K_2}}}$ {CAPACITOR} $\left\{T = 2\pi\sqrt{\frac{m(K_1 + K_2)}{K_1 K_2}}\right\}$

# In simple pendulum, Time period increase $\rightarrow$ Loss of time } oscillates slowly
Time period decrease $\rightarrow$ Gain of time } oscillate quickly.

# Weight of the body = Weight of liquid displaced } Law of Floatation.

i.e. $\boxed{V_b \times \rho_b \times g = V_{in}\, \sigma_l \times g}$ $\boxed{\text{Fraction inside} = \frac{V_{in}}{V} = \frac{\rho_b}{\sigma_l}}$

$m_b \times g$. (Archimide completely or partially dipped, Loss in wt of body = wt. of liquid displaced)

# Specific gravity $= \dfrac{\text{Density of substance at } t^\circ C}{\text{Density of water at } 4^\circ C \rightarrow 1\,g/cc \text{ or } 1000\,kg/m^3}$

# For stable eq$^m$: Metacentre must lie above C.G.

# $P_{at\ depth\ h} = P_{atm} + h\rho g$ } $P_{mean}$ on wall of vessel containing liquid upto ht. 'h' $= \dfrac{h\rho g}{2}$

# $P_{Absolute} = P_{Gauge} + P_{atm}$

# $P_{atm} \downarrow \Rightarrow$ water vapours $\uparrow \Rightarrow$ Possibility of rain } $P_{atm} \downarrow$ suddenly $\Rightarrow$ Possibility of storm.

# Apparant wt. of body in water = Wt in air − Upthrust $= V\rho_b \times g - V_{in}\,\sigma_l \times g$

# $\underset{\text{minimize S.A.}}{\text{Surface tension}}\ (T) = \dfrac{F}{L}$ → For rectangular object, $L = 2(l+b)$ → circular disc, $L = 2\pi r$

# Increase in surface energy, $W = \begin{pmatrix}\text{Surface}\\ \text{Tension}\end{pmatrix} \times$ (Increase in Area of liquid surface) (or work done)

$W = TXA$ } one free surface → drop, air bubble

$W = 2(TXA)$ } Two free surface → bubble, soap bubble.

$\boxed{\text{split}} \rightarrow \boxed{R = n^{1/3} r}$

# $R \rightarrow n$ drops of $r$ } surface energy increases

$W = 4\pi T R^2\{n^{1/3} - 1\} = 4\pi T(Nr^2 - R^2)$

liq. drop

# Excess pressure, $P = \dfrac{2T}{R}$ (one free surface) | $P = \dfrac{4T}{R}$ (Two free surface) $\{P = P_i - P_o\}$

# Capillary tube $h\rho g = \dfrac{2T}{R}$ } $R \rightarrow$ Radius of meniscus; $R = r/\cos\theta$ } $r \rightarrow$ radius of tube, $\theta \rightarrow$ Angle of contact

$\boxed{h = \dfrac{2T\cos\theta}{r\rho g}}$ } $\theta \rightarrow$ acute (rise) → liquid which wet glass: $F_A > F_C$ → concave → eg: water

↳ obtuse (fall) → liquid which do not wet glass: $F_C > F_A$ eg: Hg → convex meniscus

* For pure water and clean glass, $\theta = 0 \Rightarrow \cos\theta = 1$

* $h \propto \dfrac{1}{r}$ } For T, $\rho$, g & $\theta$ constant; smaller radius of tube $\Rightarrow$ Greater rise or fall of liquid.

* For tube of insufficient length, $\boxed{hR = \text{constant}}$ } Liquid doesn't overflow.

# Surface energy (SE) = Surface Area × Surface Tension

For liquid drop, $\boxed{SE = 4\pi R^2 T}$ } For bubble, $\boxed{SE = 8\pi R^2 \times T}$

# Bubble → Coalease ($PV \rightarrow$ constant) | contact → solve using Pressure diff.

# Viscocity, For liquid $\boxed{T \uparrow \eta \downarrow}$; $\boxed{\text{For gas } \eta \propto \sqrt{T}}$; $\boxed{\text{Except water, } P\uparrow\ \eta\uparrow}$ → For other liquid

# $\boxed{F_V = -\eta A \dfrac{dv}{dx}} \Rightarrow \eta \rightarrow$ SI unit = decapoise ($Nsm^{-2}$ or Pascal sec.)

$\boxed{1 \text{ decapoise} = 10 \text{ poise}}$ Poise → CGS.

# $\boxed{Q = \dfrac{V}{t} = \dfrac{\pi P r^4}{8\eta l}}$ → Flow of viscous liquid through horizontal pipe. {$P$ = Press-diff. of two points at length $l$} {For streamline flow}

↳ Volume of liquid flown per sec i.e. Q remains same.

# $\boxed{F_V = 6\pi\eta r v_t}$ → For body falling in viscous medium {viscous force on body of rad. r}

# $\boxed{v_t = \dfrac{2}{9}\dfrac{r^2(\rho - \sigma)g}{\eta}}$ → sphere falling in fluid. $\Rightarrow W = U + F_V$ {$F_V$ → always opposite to the direction of motion of body}

If n droplets of radius 'r' moving with with '$v_t$' coalease to form single drop with radius R with ter-vel. '$v_t'$' } $\boxed{\dfrac{v_t'}{v_t} = \dfrac{R^2}{r^2} = \dfrac{n^{2/3} r^2}{r^2}}$

air bubble rises up in water {∵ $\rho_{air} < \sigma_{water}$} $\boxed{v_t' = n^{2/3} v_t}$

The vol. of a liquid flowing per second through a pipe of cross-section $A$ with velocity $v$, $\Rightarrow \frac{V}{t} = Av \Rightarrow \boxed{v \propto \frac{1}{A}}$

Equation of continuity, $\frac{V}{t}$ = constant i.e. $Av = C \Rightarrow A_1 v_1 = A_2 v_2$

Bernoulli's formula,

(For streamline flow of ideal fluid → non-viscous and incompressible)

$\Rightarrow P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant} \;|\; \frac{P}{\rho} + \frac{1}{2}v^2 + gh = \text{constant}.$

For horizontal flow of liquid, $h$ = constant

$$P + \frac{1}{2}\rho v^2 = \text{constant} \Rightarrow P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

[ $P\uparrow \Rightarrow v\downarrow$ and vice versa]

# Flying airoplane,

$F_{lift} = (P_2 - P_1) \times A \Rightarrow$ { Upward force due to pressure diff = $\Delta P A$ } level flight

$\Downarrow$

wt. of ~~…~~ aircraft

$$F_{net} = \underbrace{(P_2 - P_1) A}_{\frac{1}{2}\rho(v_1^2 - v_2^2)} - mg$$

# vel. of air inside the roof = 0.

# viscous force → electromagnetic interaction.

# Heat and thermoDynamics

Rapidly chang. Temp → Thermocouple

- At absolute zero: molecular motion stops, zero pressure & zero volume on gas. $(-273.15^\circ C)(0K)$ {cylindrical bulb respond quickly the sphericals}
- → It is not possible to define temperature for a single molecule, It is macroscopic concept.
- → Gas Thermometer more sensitive than Hg - Thermometer.
- → $\frac{C-0}{100-0} = \frac{\text{Temp. on faulty scale} - LFP\,\text{(ofID)}}{UFP - LFP\,\text{(of faulty)}}$ $\left\{ \begin{array}{l} F \to 212^\circ F \,\&\, 32^\circ F \\ K \to 373K \,\&\, 273K \end{array} \right\}$
- $\left( \frac{(T)_\theta - \theta_1}{\theta_2 - \theta_1} = \frac{R_t - R_{\theta_1}}{R_{\theta_2} - R_{\theta_1}} \right)$
- → $\frac{\alpha}{\alpha'} = \frac{l'}{l}$ } For no differential expansion.
- → $\gamma_r = \gamma_a + \gamma_v \Rightarrow \gamma_r = \gamma_a + 3\alpha_v$ $\{4^\circ C \equiv 39.2^\circ F \equiv 277K\}$
- → At $4^\circ C$, water has maximum density & min volume
- → $\frac{\Delta l}{l} = \alpha \Delta\theta$ } due to exp. of rod
- Specific heat: solid < liquid < gas
- → $F = YA\alpha\Delta\theta$ } Force on a wall due to exp. of rod
- → $\rho_\theta = \frac{\rho_0}{1+\gamma\Delta\theta} = \rho_0(1-\gamma\Delta\theta)$ {T ↑, ρ ↓ : except anamolous exp.}
- coeff. of cubical exp. of ideal gas at constant pressure, $\gamma = \frac{\Delta V}{V\Delta T} = \frac{1}{T}$
- Bimetallic thermostat: ↳ bend towards lower α ↳ high α on convex
- Al → 78, −117°C; Hg → −39 − 357°C
- → Water eqv (w) = $m\,s_w$ (gram)
- Heat capacity = $ms$ (cal °C$^{-1}$)
- → Melting point of ice decreases with increase in pressure.
- $W = JH$ → heat (cal); W → Mech energy (Joule)
- → Heat flows from high temp to low temp.
- → $L_f = 80\,\text{cal/g} = 3.36 \times 10^5\,\text{J/kg}$ } $L_v = 540\,\text{cal/g} = 2.26 \times 10^6\,\text{J/kg}$
- → $1\,\text{cal} = 4.2\,J$ } $1\,\text{cal/g} = 4200\,\text{J/kg}$.
- For, $\alpha_{scale} < \alpha_{rod}$: Temp. dec., $l' = l - \Delta l$; Temp inc., $l' = l + \Delta l$; $\Delta l = l(\alpha_{rod} - \alpha_{scale})\Delta\theta$
- → $V_\theta = V_0(1+\gamma_p\theta)$, $V_\theta = V_0(1+\gamma_v\theta)$, $\gamma_p = \gamma_v$ → If given mass of gas obeys Boyle's law & Charle's law.
  - $\gamma_p$ → Volume coefficient
  - $\gamma_v$ → Pressure coefficient
- $PV = mrT = nRT$, $r = \frac{R}{M}$ } diff for diff gas
- $\sqrt{\bar{c^2}} = c_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3K_BT}{m}}$ → depends only on temp.
- → $P = \frac{1}{3}\frac{Nm\bar{c}^2}{V}$; M → Molar mass; m → mass of each molecule.
- $K_B = \frac{R}{N_A} = 1.38 \times 10^{-23}\,JK^{-1}$; $\boxed{\rho = \frac{m}{V}}$
- → $E_K = \frac{1}{2}m\bar{c}^2 = \frac{3}{2}K_BT$ } mean Kinetic energy per molecule of a gas
- → $E_K = \frac{3}{2}nRT$ } KE of n moles of gas.
- → $RH = \frac{\text{Amt. of water vapour actually present in a certain Vol. (m)}}{\text{Amt. of water vapour req. to saturate the same vol. at same temp. (M)}} \times 100\%$
- MP: P↑ V↑ MP↑; P↑ V↓ MP↓ (ice); BP P↑ BP↑
- $RH = \frac{\text{SVP at dew point (p)}}{\text{SVP at room temp (P)}} \times 100\%$
- Vapour above $T_c$ → gas; Gas below $T_c$ → vapour
- → $\frac{Q}{t} = \frac{KA(\theta_1-\theta_2)}{l} \Rightarrow \left\{ \frac{Q}{t} = \frac{\theta_1-\theta_2}{\left(\frac{l}{KA}\right)} \right\}$ comparable to $I = \frac{V}{R}$
- $\frac{l}{KA}$ = Thermal resistance.
- → In convection, Heat current (H) = $hA(d\theta)^{5/4}$
- → Amt. of heat energy radiated per second per unit surface area of a black body $(E) = e\sigma T^4$

→ Heat current or radiated power of a black body $(P) = e\sigma AT^4$

Stefan's constant → $\sigma = 5.67\times10^{-8} Wm^{-2}K^{-4}$

A → surface area {For sphere → $4\pi r^2$}

→ Stefan-Boltzmann law,

$P = \sigma eA(T^4 - T_0^4)$ T → Absolute temp.

$$T = \left[\left(\frac{r}{R}\right)^2 \frac{S}{\sigma}\right]^{1/4}$$
r → mean dis. of earth from sun
R → radius of sun
T → temp. of sun (surface temp)
S → solar constant.

# For % change

$x \propto y^m$

$\%\ \Delta y = a\%$

$$\%\ \Delta x = \left[\left(1 \pm \frac{a}{100}\right)^m - 1\right]\times 100$$

y↑ → +ve sign
y↓ → −ve sign.

→ Zeroth law defines temp. &
First law defines internal energy.

# $\lambda_{max} = \frac{b}{T}$ } $b = 0.002898 mK$.
$\lambda_{max}$ = wavelength as with max. energy emission

→ $dQ = dU + dW$
- Heat added to a system, Q → +ve
- Heat transferred out of system, Q → −ve
- Work done by system → +ve
- Work done on system → −ve.

$dQ = nC_pdT = mc_pdT$
$dU = nC_vdT = mc_vdT$
$dW = PdV = nRdT$
$W = \int_{V_1}^{V_2} PdV$

→ $\frac{C_p}{C_v} = \frac{Mc_p}{Mc_v} = \frac{c_p}{c_v} = \gamma$ } $C_p - C_v = R$
$c_p - c_v = \frac{R}{M} = r$

In indicator diagram,
Work done → +ve if loop is traced clockwise
Work done → −ve if loop is traced anti clockwise.

→ $W = nRT \log_e \frac{V_2}{V_1}$ } In isothermal process.

→ $W = \frac{nR}{\gamma - 1}[T_1 - T_2] = \frac{1}{\gamma-1}[P_1V_1 - P_2V_2]$ } In adiabatic process.

↳ $T_1 > T_2$ → W is positive ; gas expands adiabatically. {i.e. gas cools}
↳ $T_1 < T_2$ → adiabatic compression → gas heats up} − Work done −ve.

→ 1 Cal = 4.2 J } $dU_{Ideal} \to f(T)$, $dU_{Real} \to f(V,T)$.

→ $\eta = \left(1 - \frac{Q_2}{Q_1}\right)\times 100\% = \left(1 - \frac{T_2}{T_1}\right)\times 100\%$ } $W = Q_1 - Q_2$ { $Q_1$ → heat input.
η → Independent of working substance.

→ $\eta = 1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 1 - \left(\frac{1}{\left(\frac{V_2}{V_1}\right)}\right)^{\gamma-1} = 1 - \left(\frac{1}{\rho}\right)^{\gamma-1}$ $\rho = \frac{V_2}{V_1}$ = compression ratio.

→ coeff. of performance of refrigerator $(\beta) = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$ = $\frac{\text{Quantity of heat extracted/cycle}}{\text{Mechanical work done by ext. agency to do so.}}$

→ $dS = \frac{dQ}{T}$ } dQ → amt. of heat added in rev. isothermal process
entropy

$\boxed{dS \geq 0}$ $dS = 0$, holds for reversible process.
$dS > 0$, holds for irreversible process.

Illuminance $(I) = \dfrac{\text{luminous flux } (\phi)}{\text{Surface area } (A)} = \dfrac{\phi}{4\pi r^2}$ $\Big\{ = \dfrac{4\pi L}{4\pi r^2} = \dfrac{L}{r^2}$

lumen (cd/sr)

Luminous intensity $(L) = \dfrac{\text{Luminous flux}(\phi)}{\text{Solid angle}(\omega)}$

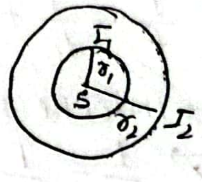
↓ For sphere, $\omega \to 4\pi\, sr$

Source dependent (Illuminating power of source)

$L = \dfrac{\phi}{4\pi} \Rightarrow \boxed{\phi = 4\pi L}$

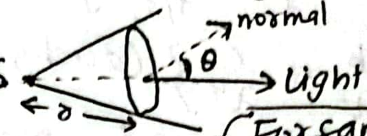
$\dfrac{I_1}{I_2} = \left(\dfrac{r_2}{r_1}\right)^2$

i.e. $I = \dfrac{L}{r^2}$.




# Lambert's cosine Law: $I = \dfrac{L\cos\theta}{r^2}$

→ when light falls obliquely on surface {$\theta \to$ angle made by normal to the surface with dir. of light}



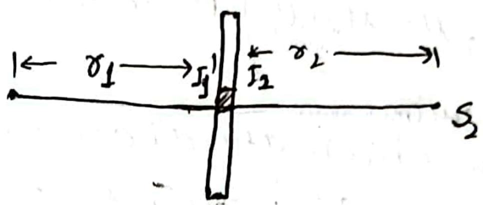

For same quality prints, (Same energy) $I_1 t_1 = I_2 t_2 \Rightarrow \dfrac{L_1}{r_1^2} \times t_1 = \dfrac{L_2}{r_2^2} \times t_2$

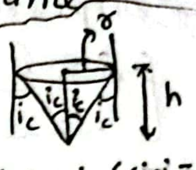
# When two sources of diff. luminous intensity produce same illuminance on surface.

i.e. $I_1 = I_2$ $\boxed{\theta = 0^\circ}$

Amt. of light energy on surface (Q) $= I \times A \times t$

$\boxed{\dfrac{L_1}{r_1^2} = \dfrac{L_2}{r_2^2}}$




$r = h\tan i_c$ $\Big\{ \sin i_c = \dfrac{1}{\mu}$
$= h \times \dfrac{1}{\sqrt{\mu^2 - 1}}$ $P = 1$, $n = \mu$

# $\phi \to$ lumen = cd-sr | $L$ = candela (lm/sr) | $I$ = lux (lm/m²)

~~# For point source/cylindrica~~

# For point/spherical source, $I \propto \dfrac{1}{r^2}$ | For linear or cylindrical, $I \propto \dfrac{1}{r}$.

# Luminous efficacy $(\eta) = \dfrac{\text{luminous flux}}{\text{Power fed}} = \dfrac{\phi}{P}$ unit: lumen/watt.

→ similar for lens {Every part of the mirror forms complete image, but intensity will be reduced if mirror is obstructed {half obstructed by black paper → Intensity reduced to half}

→ If object in denser medium is observed from rarer medium, the real depth is found greater than app. depth. But, if object in rarer medium is observed from denser medium, the real depth is smaller than the app. depth.

→ $\boxed{{}_w\mu_g = \dfrac{{}_a\mu_g}{{}_a\mu_w}}$ $\boxed{{}_g\mu_a = \dfrac{1}{{}_a\mu_g}}$ $\boxed{\text{Apparent shift } (d) = R.D (t)\left(1 - \dfrac{1}{{}_a\mu_w}\right)}$

$t \to$ real depth of water

#

→ $\boxed{\text{Lateral shift } (d) = \dfrac{t\sin(i - r)}{\cos r}}$ $t \to$ thickness of slab. $\mu_1 r \propto \frac{1}{i}, t, \mu_i$

→ $\boxed{\sin C = \dfrac{1}{\mu}}$ $\lambda \uparrow C$

$\boxed{\text{Temp} \uparrow \mu \downarrow \quad {}_a\mu_b \times {}_b\mu_c \times {}_c\mu_a = 1}$

(I)

(II) → $\boxed{\mu \propto \dfrac{1}{V}} \boxed{\propto \dfrac{1}{\lambda} \propto \delta}$ → Refraction: is due to change in vel. in two diff. media.

(III) → In reflection, speed, freq. & wavelength of light do not change but amplitude & intensity decreases on reflection.

(IV) → Freq. is property of source not medium.

→ $\boxed{A + \delta = i + e}$ $\boxed{A = r_1 + r_2}$ ← Prism

refracting angle ⇓ Angle of prism.

(V) In min deviation, $i = e$; $r_1 = r_2 = r$; $\delta = \delta m \Rightarrow i = \dfrac{A + \delta m}{2}$; $r = A/2$

(VI) $\dfrac{\mu_p}{\mu_m} = {}_m\mu_p = \dfrac{\sin\left(\frac{A + \delta m}{2}\right)}{\sin A/2}$ → Deviation from small angled prism

(VII) $\boxed{\delta = A(\mu - 1)} \Rightarrow$ independent of angle of incidence.

→ Lens is combination of small angled prism.

→ $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ } Len's maker's formula.

Concave → R: −ve  Plane → R: ∞.
Convex → R: +ve

→ $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \dots$

→ Thickness of lens ↑ ⇒ f ↓ ⇒ P ↑

→ $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$ } If two lenses are kept at distance d apart.

→ $\mu = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4}$ } Cauchy's formula.

→ Angular dispersion by prism $(\theta) = \delta_v - \delta_r = A(\mu_v - \mu_r)$

↳ Angular sepⁿ b/w two extreme colours in visible spectrum.

→ Dispersive power $(\omega) = \frac{\text{Angular dispersion } (\theta)}{\text{Mean deviation } (\delta)} = \frac{\mu_v - \mu_r}{\mu - 1}$

$$\left[\delta = \underbrace{\frac{\delta_v + \delta_r}{2}}_{\text{Yellow (meanidian)}},\ \mu = \frac{\mu_v + \mu_r}{2}\right]$$

→ Longitudinal chromatic aberration / Length of chromatic aberrative.

↳ $\boxed{f_r - f_v = \omega f}$ → mean focal length.

→ Achromatic combination of lens: Two lens combined suitably to remove chromatic aberration.

$\frac{\omega}{\omega'} = -\frac{f}{f'}$

$\boxed{\frac{\omega}{f} = -\frac{\omega'}{f'}}$


$\boxed{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}}$

$f_1 = \left(\frac{\omega_2 - \omega_1}{\omega_2}\right)F$

$f_2 = \left(\frac{\omega_1 - \omega_2}{\omega_1}\right)F$

→ Scattering intensity $(I) \propto \frac{1}{\lambda^4}$ } wavelength is not changed during scattering.

→ Magnifying power $(M) = \frac{\beta}{\alpha}$.

→ Simple microscope: $M = -\left(\frac{D}{f} + 1\right)$ } Image at D } $M = -\frac{D}{f}$ } Image at infinity. (Normal adjustment)

→ Compound microscope → $f_o < f_e$

$M = M_e \times M_o = -\frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$ } L − optical length of microscope
→ image at D
↳ $L = v_o + u_e$.

$M = -\frac{v_o}{u_o}\left(\frac{D}{f_e}\right) = -\frac{L}{f_o}\left(\frac{D}{f_e}\right)$ } → Image at ∞
→ $L = v_o + f_e$

→ Telescope → $f_o > f_e$.

$M = \frac{f_o}{f_e} = \frac{\text{Diameter of objective } (D_o)}{\text{Diameter of eye ring } (d_e)}$ } → Normal adjustment (image at ∞) (Relaxed eye)
→ Length of tube $(L) = f_o + f_e$.

$M = \frac{f_o}{u_e} = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$ } → Final image at D
→ $L = f_o + u_e$

→ Camera.

f-number → gives size of aperture

diameter of aperture $(d) = \frac{f \text{ → focal length of camera.}}{\text{f-number}}$

Brightness $\propto \frac{d^2}{f^2} \propto \frac{1}{(\text{f-number})^2}$

Time of exposure $\propto (\text{f-number})^2 \propto \frac{f^2}{d^2}$

→ Defect of vision

↳ अहिले कति सम्म देख्छ

↳ −v

↳ कति सम्म देख्नु पर्ने हो (Using lens) → u

↳ Focal Length → Diverging → −ve
→ Converging → +ve

magnitude of induced charge is equal to that of inducing charge only when inducing and induced charge are very close to each other, otherwise magnitude of inducing charge is always greater than induced charge.

# Repulsion is sure test of charge.

- Attraction → Oppositely charged (Fes) or neutral (Induction)
- Repulsion → Similar nature of charges.

# $\boxed{F = \frac{1}{4\pi\epsilon} \frac{q_1 q_2}{r^2}}$ → $\epsilon_0 = 8.85\times10^{-12}\, C^2N^{-1}m^{-2}$ or $8.85\times10^{-12}$ Farad $m^{-1}$

→ $\frac{1}{4\pi\epsilon_0} = 9\times10^9\, Nm^2C^{-2}$ (In SI) & 1 C in CGS)

→ $\boxed{\epsilon = \epsilon_0 \epsilon_r}$ → For free space $\epsilon_r = 1$.

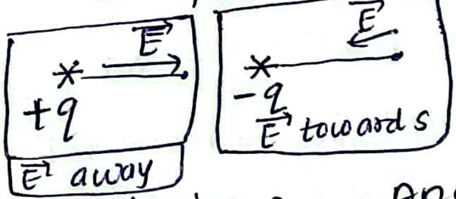
# $\vec{F_1} = \vec{F_{12}} + \vec{F_{13}} + \dots + \vec{F_{1n}}$

# $\boxed{E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}}$ → $\vec{E} = \vec{E_1} + \vec{E_2} + \dots + \vec{E_n}$ } $\vec{E}$ at a point due to several point charges.

$\boxed{\vec{E}: +ve \text{ to } -ve}$

do not pass through the conductor: $\vec{E}$ lines of force

# $\boxed{F = qE}$




# $\boxed{\phi = EA\cos\theta} = \vec{E}\cdot\vec{A}$ ⇒ $\phi$ { +ve : outgoing, -ve : Incoming } $\theta$ → Angle b/w $\vec{A}$ ($\perp$ to plane) & $\vec{E}$

# $\boxed{\phi_t = \frac{1}{\epsilon_0} q_{net}}$ Gauss's Law } Total flux passing through any close surface is $1/\epsilon$ times total charge within the surface.

# When hollow metallic conductor is charged, all the charges will be distributed on its outer surface. Inside, there will be no electric field.

# $\boxed{V = \frac{q}{4\pi\epsilon_0}\frac{1}{r}}$ → Potential at a point due to point charge } $V_{Total\ at\ A} = V_{AB} + V_{AC} + V_{AD} + \dots$ } $V \propto \frac{1}{r}$

# $\boxed{V_{AB} = V_A - V_B = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{a} - \frac{1}{b}\right)}$

# $\boxed{U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}}$ → P.E at a point due to another point charge.

# $\boxed{\text{Workdone}(W) = qV}$

# $\boxed{1eV = 1.6\times10^{-19}J}$

# Every point on equipotential surface has equal electric potential and potential diff. b/w any two points in equipotential surface is zero.

↳ Electric field: always normal to equipotential surface.

# $\boxed{E = -\frac{dV}{dr}}$ } -ve sign → electric field is directed towards decreasing potential } $\boxed{E = \frac{V}{d}}$

# In conducting sphere, charge resides on the surface (not inside)

But, In non-conducting charged solid sphere, the charge can reside everywhere inside because charge cannot flow in non-conductor.

# When soap bubble is charged, its radius increases.

# $\lambda = \frac{q}{l}$, $\sigma = \frac{q}{A}$, $\rho = \frac{q}{V}$ } # Charge flows from Higher potential to lower potential

# Dielectric → insulators or non-conductors

# When conducting material is introduced b/w the plates of the capacitor then its capacitance becomes infinite. {Metal → infinite dielectric constant}

# Energy stored in capacitor

$$dW = V\,dq \quad \{\text{battery supplies } dq \text{ to capacitor at constant potential } V\}$$

$$W = \int_0^q V\,dq \quad \{q = CV\}$$

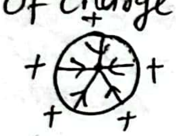
$$\boxed{W = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}qV = \frac{1}{2}CV^2}$$

# Force of attraction b/w plates of PPC,

$\vec{E}$ b/w two plates $= \frac{\sigma}{\epsilon_0}$ | $\vec{E}$ due to one plate $= \frac{\sigma}{2\epsilon_0}$ $\left\}\ \sigma = \frac{q}{A}\right.$

$$F = E \times q = \frac{\sigma}{2\epsilon_0} \times q = \frac{q^2}{2A\epsilon_0}.$$

# Coulomb's law: valid for stationary point charges or spherical distribution of charge.



$$F = \frac{K q_1 q_2}{r^2} \qquad q_1 \xrightarrow{F} \xleftarrow{} q_2 \ (r)$$

$K = \frac{1}{4\pi\epsilon_0}$ — $9\times10^9$ (MKS) / 1 (CGS)

$\epsilon_0 = 8.82\times10^{-12}\ C^2N^{-1}m^{-2}$

# Equilibrium point: ① Like charges – within
Unlike charges – outside
② Near small magnitude charge.

{–ve → Just nature of nature}
⇓
In coulomb's law force
{only magnitude of charge.

# Electric field intensity: Force experienced by unit +ve test charge.

$\vec{E}$ → +ve to –ve

$+q \longrightarrow qE$, $\vec{E}$ → [+q charge ⇓ $\vec{F} \parallel \vec{E}$] (away from charge)

$F = qE \leftarrow -q$, → [–q charge ⇒ $\vec{F}$ anti∥ $\vec{E}$]
↳ $\vec{E}$ towards the charge.

✓ $\vec{E}$ {High potential ⟶ Low potential}

✓ $\vec{E}$ due to point charge at its own location is not considered.

# Electric potential (V): Work done in shifting unit +ve test charge from ∞ to given point without accⁿ (KE = constant)

$V = \frac{W}{q}$ {J/C = volt}

∞ ---→ +Q ---- P, $r$ : $V = \frac{KQ}{r}$ | –Q ——— P, $r$ : $V = \frac{-KQ}{r}$

{✓ In potential formula charge must be written with sign. (V → scalar)

# potential energy (U): of a charge.

$\boxed{U = qV}$ $\quad q_1 \leftarrow r \rightarrow q_2$

$$U_{q_1} = \underbrace{q_1}_{\text{Test charge}} \times \underbrace{\overbrace{\frac{Kq_2}{r}}^{V}}_{V \text{ at } q_1 \text{ due to } q_2} = \frac{Kq_1q_2}{r} \quad \left\{ U_{q_2} = q_2 \times \frac{Kq_1}{r} = \frac{Kq_1q_2}{r} \right.$$

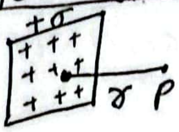
✓ Self happening process → PE↓
✓ Need to apply force from outside → PE↑

eg: ⊕ → --- ← ⊕ ⇒ Need to apply force
PE↑

⊕ → --- ← ⊖ ⇒ Happens by itself
⇓
PE↓

## Electric field of diff. shapes

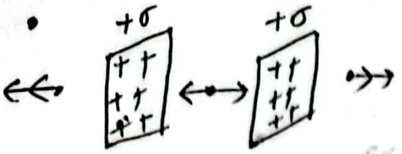
**Uniformly charged non-conducting plane sheet:**




$$\boxed{E = \frac{\sigma}{2\epsilon_0}}$$ → distance independent formula.

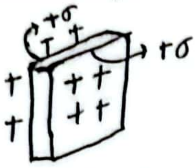
} If non-mentioned, the type of sheet it is non-conducting.

$\sigma$ → surface charge density.




$$\left\}\begin{aligned} E_{inside} &= \frac{\sigma}{2\epsilon_0} - \frac{\sigma}{2\epsilon_0} = 0 \\ E_{outside} &= \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0}. \end{aligned}\right.$$

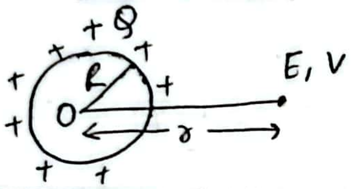
- **Uniformly charged conducting plane sheet:**




→ $E_{inside} = 0$ $\quad \sigma = \frac{q}{A}$

→ $E_{outside} = \frac{\sigma}{\epsilon_0}$

- **All conducting spheres**




| | Position | E | V |
|---|---|---|---|
| (i) | $r > R$ | $KQ/r^2$ | $KQ/r$ |
| (ii) | $r = R$ | $KQ/R^2$ | $KQ/R$ |
| (iii) | $r < R$ | 0 (no charge inside conducting sphere) | $KQ/R$ (conductors are equipotential surface) |
| (iv) | $r = 0$ | 0 | $KQ/R$ |

P.D b/w any two points inside or on the surface of conductor is zero.

# Conductor
↳ charge resides outside the surface
↳ conductors are equipotential surface i.e. potential inside the sphere is same as potential at outer surface of sphere.

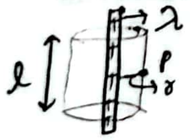
- $E_{surface} = \frac{KQ}{R^2}$

$$E_{surface} = \frac{1}{4\pi\epsilon_0} \times \frac{\sigma \times 4\pi R^2}{R^2} = \frac{\sigma}{\epsilon_0}.$$

- $V_{surface} = \frac{KQ}{R} = \frac{1}{4\pi\epsilon_0} \cdot \frac{\sigma\, 4\pi R^2}{R} = \left(\frac{\sigma}{\epsilon_0}\right)R = E_{surface} \times R \Rightarrow E_{surface} = \frac{V_{surface}}{R}$

- **Due to linear charge**

$$\phi = EA = \frac{1}{\epsilon_0} \times q_{net}$$




$$\boxed{E = \frac{1}{2\pi\epsilon_0}\frac{\lambda}{r}}$$

# $+q\,\overset{r}{O}$ $+q\,\overset{r}{O}$ . . . n > (R) Q } n drops of radius 'r' ⇒ single drop of radius 'R' (Volume conserved)

(i) $Q_{big} = n\, q_{small}$ } Charge conservation

(ii) $R_{big} = n^{1/3} r_{small}$ } volume conservation $\left\{ \frac{4}{3}\pi R^3 = n\,\frac{4}{3}\pi r^3 \Rightarrow R = n^{1/3} r \right\}$

(iii) $E_{big} = n^{1/3} E_{small}$ } $E = \frac{KQ}{R^2} \propto \frac{n}{(n^{1/3})^2} \propto n^{1/3}$

(iv) $\sigma_{big} = n^{1/3}\sigma_{small}$ } $\sigma = \frac{Q}{4\pi R^2} \propto \frac{n}{(n^{1/3})^2} \propto n^{1/3}$

(v) $C_{big} = n^{1/3} C_{small}$ } $C = 4\pi\epsilon_0 R \propto n^{1/3}$

(vi) $V_{big} = n^{2/3} V_{small}$ } $V = \frac{KQ}{R} \propto \frac{n}{n^{1/3}} \propto n^{2/3}$

(vii) $U_{big} = n^{5/3} U_{small}$ } $U = \frac{KQ_1Q_2}{R} \propto \frac{n^2}{n^{1/3}} \propto n^{5/3}$

# Capacitance(C): charge holding capacity of conductor. $C \rightarrow$ Farad {C/V}

$Q \propto V \Rightarrow Q = CV$ {C doesn't depend upon Q & V}

# Spherical conductor of radius 'R'

$\boxed{C = 4\pi\epsilon_0 R}$ → capacitance depends upon dimension (size) of conductor & surrounding medium.

$\boxed{C_{med} = 4\pi\epsilon_m R = 4\pi\epsilon_0\epsilon_r R}$ ⇒ ☆ $\boxed{Temp\uparrow \ \epsilon_r\downarrow \ C\downarrow}$

# Capacitance of earth

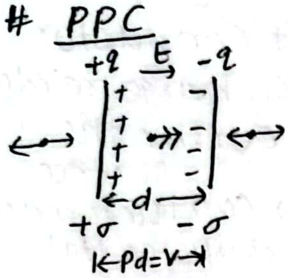
Theoretically, $C_{earth} = 4\pi\epsilon_0 R_e = 4\pi\epsilon_0(6.4\times10^6) = 711\mu F$

Practically, Earth can store unlimited charge ⇒ $\boxed{C_{earth} = \infty}$

→ Capacitance of earthed conductor → $\infty$

$V_{earth}$ = slightly negative $\approx 0$

# PPC



(i) Electric field($\vec{E}$)

$E_{inside} = E_+ + E_- = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0}$ or $\frac{\sigma}{\epsilon_0\epsilon_r} = \frac{V}{d}$

$E_{outside} = \frac{\sigma}{2\epsilon_0} - \frac{\sigma}{2\epsilon_0} = 0$

(ii) PE(U) → stored in the form of electric field b/w plates.

$U = \frac{1}{2}CV^2 = \frac{1}{2}qV = \frac{1}{2}\frac{q^2}{C}$ } q → equal & opposite charge as $\boxed{q_{net} \text{ in capacitor} = +q - q = 0}$

(iii) Capacitance (C) ⇒ $C_{air} = \frac{\epsilon_0 A}{d}$ } A = Common facing area.

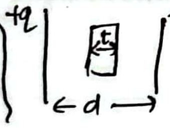
For metal $\epsilon_r \rightarrow \infty$. So, if metal foil is introduced C ↑

$C' = \frac{\epsilon_0 A}{(d-t)+(t/\infty)}$

$(d-t)\downarrow \Rightarrow C'\uparrow$

$|1/\epsilon_r|$ $C_{med} = \frac{\epsilon_0\epsilon_r A}{d} = \epsilon_r \times C_{air}$ } when dielectric media is introduced b/w PPC capacitance increases

Partial medium



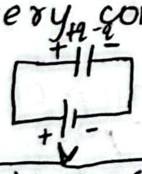
$C_{partial} = \frac{\epsilon_0 A}{(d-t)+\left(\frac{t}{\epsilon_r}\right)}$

Many partial mediums

$C = \frac{\epsilon_0 A}{d - [t_1+t_2+..] + \left(\frac{t_1}{\epsilon_{r_1}}\right) + \left(\frac{t_2}{\epsilon_{r_2}}\right) + ..}$

(iv) Energy density(u) $= \frac{1}{2}\epsilon_0 \times E^2$

# Battery connected



$\boxed{Pd = V = \text{constant}}$

→ $C = \frac{\epsilon_0\epsilon_r A}{d}$

→ $V \equiv$ constant

→ $Q = CV \Rightarrow Q \propto C$

→ $E = \frac{V}{d} \Rightarrow E \propto \frac{1}{d}$

→ $U = \frac{1}{2}CV^2 \Rightarrow U \propto C$

# Battery disconnected:

$\boxed{q = \text{constant}}$

☆ If not mentioned, then battery disconnected is considered.

→ $C = \frac{\epsilon_0\epsilon_r A}{d}$

→ $Q \equiv$ constant

→ $Q = CV \Rightarrow V \propto \frac{1}{C}$

→ $E = \frac{V}{d} = \frac{Q}{Cd} = \frac{Q}{\epsilon_0\epsilon_r A}$

→ $U = \frac{Q^2}{2C} \Rightarrow U \propto 1/C$

# Series combination: Q same, V divides.

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$ ; $Q = CV \Rightarrow V \propto 1/C \Rightarrow V_1 : V_2 : V_3 = \frac{1}{C_1} : \frac{1}{C_2} : \frac{1}{C_3}$

# Parallel combination: V same, Q divides

$C_{eq} = C_1 + C_2 + C_3$ ; $Q = CV \Rightarrow Q \propto C \Rightarrow Q_1 : Q_2 : Q_3 = C_1 : C_2 : C_3$

[Initial: $C_1, Q_1, V_1$ & $C_2, Q_2, V_2$]

# Joining (i) Like terminals/poles together of capacitor

↳ $Q_1 + Q_2 = Q_1' + Q_2' \Rightarrow V = \frac{C_1V_1 + C_2V_2}{C_1 + C_2}$ | $\Delta E = \frac{C_1C_2}{2(C_1+C_2)}(V_1 - V_2)^2$

(ii) Unlike poles together:

$Q_1 - Q_2 = Q_1' + Q_2' \Rightarrow V = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}$ | $\Delta U/\Delta E = \frac{C_1C_2}{2(C_1+C_2)}(V_1 + V_2)^2$

M.R. No. ....................

Note:-

Surface Tension → free surface of water behaves like stretched membrane

(1) Surface Tension always tends to minimize the surface area of a liquid.

Minimum surface area → sphere [for constant volume]

(2) Surface Tension of the liquid decreases with addition of impurities.

$\boxed{ST \propto \frac{1}{Temp}}$

Surface Tension $\propto \frac{1}{\text{wettability}}$ [For the given perimeter circle has maximum surface area]

Cleansing action

(3) Surface Tension $\propto \frac{1}{\text{spreading}}$

(4) Gravitational pull tends to change the drop into flat structure.

(5) cohesive force > adhesive force → no sticking → ($\theta > 90°$) → convex meniscus → depression

adhesive force > cohesive force → sticking → ($\theta < 90°$) → concave meniscus → rising.

(6) When capillary tube of insufficient height is dipped in water, concave meniscus tends to have larger radius till atm. pressure on concave side = pr. by liquid column ↓ But do not overflow.

Happy Birthday B B Happy Birthday B B B



B&C/MR-09

# $T = Y A \alpha \Delta\theta$

$$\boxed{\rho \rightarrow f(T)}$$

# $\alpha_{scale} < \alpha_{rod}$

$$\Delta l = l(\alpha_{rod} - \alpha_{scale})\Delta\theta$$

Temp $\uparrow \rightarrow l' = l + \Delta l$  temp. $\downarrow \rightarrow l' = l - \Delta l$.

# Mercury overflow,

$$(V_{Hg})_{overflow} = V(Y_{Hg} - Y_{glass})\Delta\theta$$

$V \rightarrow$ volume of vessel.

# Pendulum clock,

Temp increase $\longrightarrow$ length of pendulum increase $\downarrow$ loss of time.

Temp decrease $\rightarrow$ length of pendulum decrease $\downarrow$ gain of time.

Loss/gain of time per day $= \frac{1}{2}\alpha\Delta\theta \times 86400$

OR,

$$T_\theta = 2\pi\sqrt{\frac{l_\theta}{g}} \quad \text{—(I)}$$

$$T_{\theta+\Delta\theta} = 2\pi\sqrt{\frac{l_{\theta+\Delta\theta}}{g}} \quad \text{—(II)}$$

$$\frac{T_{\theta+\Delta\theta}}{T_\theta} = \sqrt{\frac{l_0(1+\alpha\Delta\theta)}{l_0}} = 1 + \alpha\Delta\theta$$

$$\frac{T_{\theta+\Delta\theta} - T_\theta}{T_\theta} = \underline{\quad * \quad} \text{ per sec.}$$

# $P_\theta = \frac{P_0}{1 + Y\Delta\theta}$

same linear difference at all temp.

# For no different expansion,

$$\boxed{\frac{l}{l'} = \frac{\alpha'}{\alpha}}$$

Date/Time :

CONTINUATION SHEET

M.R. No. ........................

$$\left(\frac{d\theta}{dt}\right) = \frac{-K}{ms}(\theta - \theta_0)$$

$$\left(\frac{\theta_2-\theta_1}{dt}\right) = \frac{-K}{ms}(\theta-\theta_0) \rightarrow \boxed{\theta = \frac{\theta_1+\theta_2}{2}}$$

$_a\mu_b$ → a → medium surrounding prism
→ b → medium of prism
→ only in case of minimum deviation

$_a\mu_b$ → a → From which medium
→ b → To which medium
→ In case of the formula $\boxed{_a\mu_b = \frac{\sin i_a}{\sin r_b}}$

$_a\mu_b$ → b → denser → $_a\mu_b = \frac{1}{\sin C}$
→ a denser → $_a\mu_b = \sin C$

$\boxed{r_1 + r_2 = A}$

Grazing? → $\boxed{i_{\text{denser medium}} = \text{Critical angle}}$

For NO TIR, the emergent ray should graze from second face.

$\boxed{\text{Graze} \rightarrow 90}$

Date/Time : M.R. No. ........................

# Expresss Temp. in Kelvin scale

# $1 atm = 760 mm\ Hg = 1.01 \times 10^5 Nm^{2}$ (SI unit)

# $1L = 10^{-3} m^3 = 1000cc$. (SI unit) $1 mole = 22.4L = 22400cc = 22.4 \times 10^{-3} m^3$.

# $PV = nRT$

$\boxed{n = \frac{m}{M}}$ m → Given mass, M → Molar mass

$R = 8.31 J mol^{-1} K^{-1}$

↑ Universal gas contant

# In terms of molar mass,

$PV = mrT$, $m = nM$, $r = \frac{R}{M}$

↑ Gas constant per unit molar mass, nor universally constant

# $P = \frac{1}{3} \rho \bar{c}^2$ [Pressure exerted by gas on wall of container]

$p = \frac{1}{3} \times \frac{m}{V} \bar{c}^2$

$\bar{c}^2 = \bar{u}^2 + \bar{v}^2 + \bar{w}^2 = \frac{v_1^2 + v_2^2 + v_3^2 + \dots v_n^2}{n}$

~~Root mean square speed of gas molecules.~~

↳ f(T)

$C_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}}$

$\frac{C_1}{C_2} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{\rho_2}{\rho_1}}$

For constant M; For constant T

# Express molar mass in kg.

*For KE of gas molecules :

$\frac{1}{2} m \bar{c}^2 = \frac{3}{2} k_B T$ → Boltzman's constant $k_B = \frac{R}{N_a} = 1.38 \times 10^{-23} JK^{-1}$.

m → Mass of gas molecule

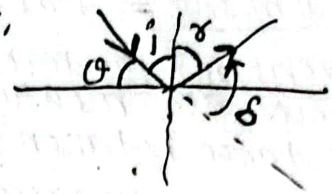
For 1 mole,

$\frac{1}{2} M \bar{c}^2 = \frac{3}{2} RT$

# Optics

(I) In reflection, $\angle i = \angle r$.

(II) Deviation of light due to plane mirror,



$\delta = 180 - (i+r)$.

$\boxed{\delta = 180 - 2i}$ $\boxed{\delta = 2\theta}$

$\theta \to$ glancing angle

★ Eyes see, where the ray meet.

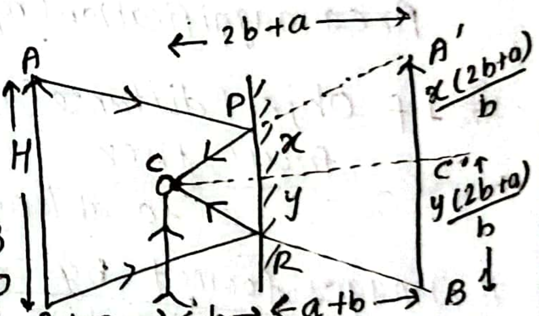
(III) Reflection from plane mirror,

Image – erect, virtual & laterally inverted.

- $u = v \Rightarrow$ magnification $(m) = 1$
- Mirror rotated by $\theta \Rightarrow$ Reflected ray rotated by $2\theta$.
- If object moves towards mirror with 'v' → then image also move with same speed v

So, Object & image approach with $2v$

- If mirror is moved towards (or away), the object with 'v', then image will move towards (or away) with $2v$
- Minimum length of mirror for a person
  (i) Of height 'H' to see his full image in plane mirror → $H/2$
  (ii) midway b/w hill of ht. 'H' and mirror to see full image of hill → $H/3$
  (iii) Standing 'b' distance from mirror to see full image of object of height 'H' at 'a' distance from him $= \frac{Hb}{2b+a}$ $(x+y)$



$H = A'C' + C'B' = \left(\frac{2b+a}{b}\right)(x+y)$

$\boxed{x+y = \frac{Hb}{2b+a}}$

★ Clock problems
Time shown in plane mirror
- Subtract actual time from
12:00:00
OR
11:59:60

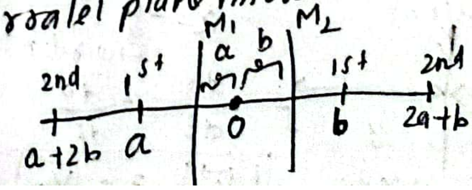
- There is no change in velocity, wavelength & frequency of light due to reflection.
- Reflection from plane mirror ⇒ phase change of 'π'
- Rad. of curvature & focal length of plane mirror → ∞
  ⇒ Power = 0

(IV) No. of images formed by two plane mirrors at angle 'θ'.

$\boxed{n = \frac{360^\circ}{\theta}}$ i.e.
- $n \to$ odd ⇒ unsymmetrical → n images
- Other cases → $(n-1)$ images.
- $n \to$ fraction → take integral part

→ plane & parallel mirrors → infinite images, $(\theta = 0^\circ)$

(V) Distance b/w $n^{th}$ images on two parallel plane mirrors
$= 2n(a+b)$
↳ distance ... of obj...



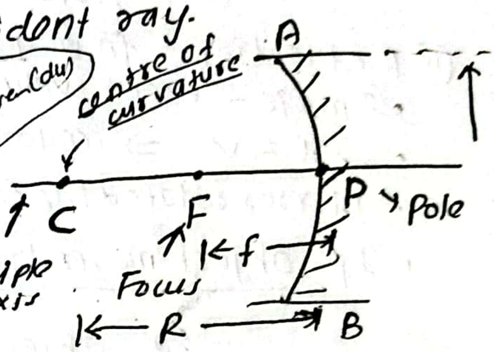
# Concave mirror – Reflection takes from concave side.
& Convex mirror → " " " convex side.

# For Spherical mirror ⇒ Focal length = $\frac{1}{2}$ Radius of curvature ⇒ $\boxed{R = 2f}$

# Sign convention for mirror,
(I) All distances are measured from pole.
(II) Real distance is taken '+ve' and virtual (erect) distance is taken '–ve'
(III) For concave mirror ⇒ f & R are 'positive'
For convex mirror ⇒ f & R are 'Negative'
(IV) Positive direction ⇒ direction of incident ray.

# $\boxed{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$ $\boxed{v = \frac{uf}{u-f}}$ $\boxed{u = \frac{vf}{v-f}}$

on differentiating ⇒ $\boxed{\frac{dv}{dt} = -\frac{v^2}{u^2}\frac{du}{dt}}$ $\left\{ \frac{dv}{du} = \left(\frac{v}{u}\right)^2 \right\}$ If length of object is given (du)




AB → aperture.

# Linear magnification (m) = $\frac{\text{size of image (I)}}{\text{size of object (O)}} = \frac{v}{u}$

Area magnification ($m_A$) = $\frac{\text{Area of image}}{\text{Area of object}} = m^2$

# If object distance ($x$) and real image distance ($y$) are measured from focus, then
focal length ($f$) = $\sqrt{xy}$ } Newton's formula

For convex mirror, since it produces virtual image so magnification is taken '–ve' OR N → –ve

# Images formed by concave mirror

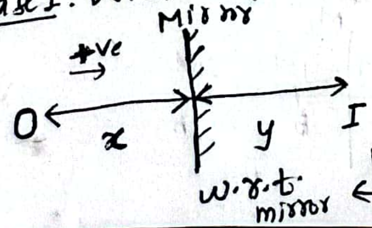
| | Position of Object | Position of image | Magnification | Nature of images |
|---|---|---|---|---|
| (I) | At infinity → | At focus → | $m \to 0$ | Real, inverted |
| (II) | B/w C & ∞ → | B/w F & C → | $m < 1$ | Real, inverted |
| (III) | At C → | At C → | $m = 1$ | Real, inverted |
| (IV) | B/w C & F → | Beyond C → | $m > 1$ | Real inverted |
| (V) | At F → | At ∞ → | $m \to \infty$ | Real, inverted. |
| (VI) | B/w P & F → | Behind the mirror → | $m > 1$ | virtual, erect |

Note:
★ Erect + magnified image → concave mirror
& Erect + diminished image → convex mirror.

# Images formed by convex mirror.

| | | | | |
|---|---|---|---|---|
| (I) | At infinite → | At focus → | $m \to 0$ | virtual, erect |
| (II) | At any point in front of mirror → | B/w P & F → | $m < 1$ | virtual, erect |

# Velocity in plane mirror
Case I: When object moves ⊥r to mirror




$x = -y$ ← w.r.t. mirror

$\frac{dx}{dt} = -\frac{dy}{dt}$

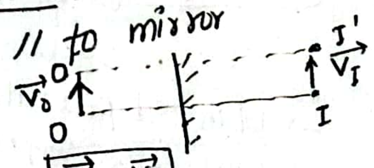
$\boxed{(\vec{V_0})_{\perp r} = -(\vec{V_I})_{\perp r}}$ ⇒

$\vec{V_0} - \vec{V_M} = -(\vec{V_I} - \vec{V_M})$

⇒ $\boxed{\vec{V_M} = \frac{\vec{V_I} + \vec{V_0}}{2}}$

Remember vector laws (+ve, –ve, $\hat{i}, \hat{j}, \theta, \ldots$)

Case II: When object moves ∥ to mirror




$\boxed{\vec{V_0} = \vec{V_I}}$

★ No effect on $\vec{V_0}$ or $\vec{V_I}$ on parallel motion of mirror.

# K(I)L : $\Sigma I = 0$ in junction {I flowing towards +ve, flowing away → -ve}
K(II)L : $\Sigma E = \Sigma IR$, Conservation of energy
↳ In cell, -ve to +ve path Ee जाना → $\Delta V = +ve$ — $\Delta V = +\varepsilon$
In resistor, path I की opp. Ee जाना → $\Delta V = +ve$ — $\Delta V = -IR$

# Meter bridge $R \propto l$

$$\frac{R}{l} = \frac{S}{(100-l)}$$

R → known, S → unknown
l → balancing length (wheatstone bridge)

Resistance of
(I) Ideal voltmeter → $\infty$
(II) Ideal Ammeter → 0.

# Potentiometer (null-point method) → 10m uniform wire.
$\boxed{V \propto l}$ → balancing length.

(I) Pot-gradient $\left(\frac{dV}{dl}\right) = \frac{V_A - V_B}{l} = \frac{P.D}{\text{length of wire}}$

(II) Com. of emf, $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

(III) Internal resistance, $r = \left(\frac{l_1}{l_2} - 1\right)R$
R → known resistance.
$l_1$ → balance Length for emf
$l_2$ → balance length for terminal p.d.

# Joules law of heating → current passed ⇒ conductor gets heated.
Heat produced $(H) = W = VIt = I^2Rt = \frac{V^2}{R}t$

Power $(P) = \frac{dw}{dt} = VI = I^2R = \frac{V^2}{R} = \frac{qV}{t}$

Electrical energy: 1 kWh = P(in kW) × (t in hour) $= 3.6 \times 10^6$ J = 1 unit

# Rated power of bulb is always inv. proportional to Resistance
↳ $P \propto \frac{1}{R}$ so, $R \propto 1/P$

Brightness is directly prop. to rate of heat production of bulb.

- In Series, I same, $H \propto R \propto \frac{1}{P}$ | • In parallel, V same, $L \propto H \propto \frac{1}{R} \propto P$
L → intensity of glowing bulb.
- Electrical appliances are manufactured for parallel combination.

# Faradays law of electrolysis conservation of energy.
# Thermoelectric effect (Seebeck effect) ⇒ when junction of two dissimilar metals are maintained at diff. temp., emf is produced depending upon nature of metals.

Thermoelectric series → Antimony, Iron, Zinc, Silver, Gold, Tin, Lead, Copper, Platinum, Nickel, Bismuth.
$\boxed{\text{AnIZnSiGOTiLCoPlaNiBi}}$

- Flow of current → ABC i.e. Antimony to Bismuth in Cold Junction
- Thermo-emf: sep. of members in TES i.e. An-Bi max. Thermo emf.

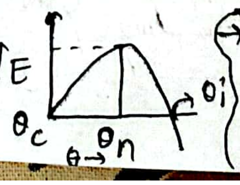
Peltier → Inverse of Seebeck & Thomson → temp. diff. maintained b/w diff. parts of same metal & I is passed, then heat is either produced or evolved along metal.

# Induced emf in Thermocouple:
$\boxed{E = \alpha\theta + \frac{1}{2}\beta\theta^2}$

At, $\theta_n$ → E is max
↳ thermoelectric power is 0

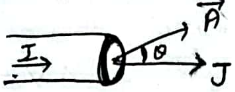
At $\theta_i$, E = 0, $\theta_i = 2\theta_n$

Cold junc. → 0°C
Hot junc. → θ °C.




→ Thermocouple not pref. used above $\theta_n$
→ $\theta_n$ depends only on nature of metals.

# Direction of current: direction of +ve charge

# $\vec{J} = \dfrac{I}{A\cos\theta}$  A/m² $\quad \leftarrow \ominus \equiv \oplus \rightarrow$ e−

# $V_d = \dfrac{I}{nAe}$ } n = no. of e⁻/Volume, A = Area of cross section of conductor } $V_d$ in order of $10^{-4}$ m/s.

# Ohmic conductor, R : depends on Temp, nature & dimension

# $R = \dfrac{\rho l}{A}$ } $\rho$ → sp. resistance : depends upon Temp & nature of material of conductor.
↳ independent of dimension

$\rho_C < \rho_{SC} < \rho_{In}$..

→ $\rho = \dfrac{1}{\sigma}$ → conductivity | $\boxed{J = \sigma E}$ → E = electric field strength.

# $R_t = R_0(1+\alpha t)$ } $R_0$ → Resistance at 0°C, $\alpha$ → temp. coeff. of resistance → 1°C

$\alpha$ → +ve for conductors (Temp↑ R↑ flow of current↓)
$\alpha$ → −ve → semiconductors
$\alpha = 0$ → super conductor (offer least resist for flow of curr)

# Series combination: end to end, Voltage divider $V_1 : V_2 : V_3 = R_1 : R_2 : R_3$
Parallel combination: one end at one point & other end of each to other point.
↳ $I_1 : I_2 : I_3 = \dfrac{1}{R_1} : \dfrac{1}{R_2} : \dfrac{1}{R_3}$

# EMF: PD b/w terminals of cell in open circuit (no current drawn from source)

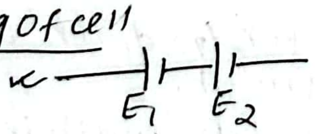
$\boxed{E = \dfrac{W}{q_0}}$ → work done in moving ~~unit~~ test charge in entire closed circuit including sol. of cell.

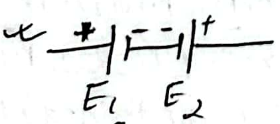
Terminal p.d → $\boxed{V = \dfrac{W_{ext}}{q_0}}$   E > V : Cell being discharge
E < V : cell being charged (opp. charge flows in cell)

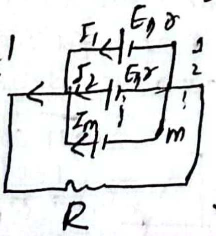
$\boxed{r = \dfrac{E-V}{I}}$ → resistance offered by sol. of cell b/w its electrode.   $\boxed{V = E - Ir}$ → cell discharge.

$\boxed{P = I^2R = \dfrac{E^2R}{(R+r)^2}}$ → Electrical power consumed due to heating effect.
$P_{max} \Rightarrow R = r$

Short circuit → very low Impedance
Open circuit → Infinite resistance b/w terminals & no current flows

# Grouping of cell
(I) Series:  ⇒ $E_t = E_1 + E_2$ } For n cells, $E_t = nE_{individual}$

 ⇒ $E_t = E_1 - E_2$ if $E_1 > E_2$ & $E_t = E_2 - E_1$ if $E_2 > E_1$
$E_1 = E_2 \Rightarrow E_t = 0$

(II) Parallel 


Total emf = E
Net Res = $R + \dfrac{r}{m}$
I in R = $\dfrac{E}{R + r/m}$

(I) $R << \dfrac{r}{m}$ $\quad I = m\dfrac{E}{r}$ } For max current
= m × curr. due to one cell

(II) $R >> r/m$ $\quad I = \dfrac{E}{R}$
= current due to

# Wave:

→ During wave motion disturbance/energy travels forward ; particle does not travel.

→ Frequency is intensive property of wave. $\left(f = \frac{1}{T} = \frac{\omega}{2\pi}\right)$.

→ Sound → Mechanical wave (needs material medium for propagation).

→ Two particle in wave are said to be in phase if $\phi = 0$
out phase if $\phi \neq 0$.

→ velocity of wave $(v) = f\lambda$
↳ depends upon physical properties of medium.

→ Plane progressive wave → wave with constant Amplitude, frequency, time period, velocity throughout.

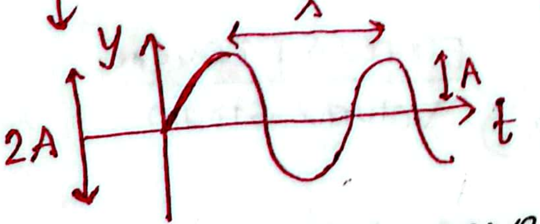
→ $\phi = \left(\frac{2\pi}{\lambda}\right) \times \Delta x$
↑ path difference
phase difference
↑ wakenumber (K)

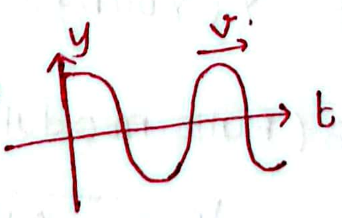
→ Equation of wave motion (displacement of particle at position x at time 't')

$\boxed{v = \frac{\omega}{K} = \frac{x}{t}}$ $y = A \sin(\omega t - Kx)$ (wave travelling in +ve x direction)
If + then it denotes wave travelling in -ve x direction.

$\boxed{\omega = 2\pi f \text{ or } \frac{2\pi}{T}}$ $\boxed{k = \frac{2\pi}{\lambda}}$

sine equation → At $t=0$ & $x=0$ string is at mean position
cosine equation → At $t=0$ & $x=0$ string is at max. upward displacement (amplitude)




→ Differential wave equation:-

$$\boxed{\frac{d^2y}{dt^2} = v^2 \frac{d^2y}{dx^2}}$$

New

→ Power of wave (P) = $\frac{1}{2}(\mu v)(\omega A)^2$

↓ Emitted in 1 sec

$A$ → Amplitude.

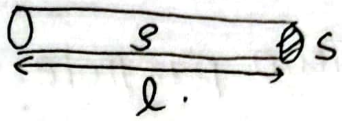
$\mu$ → linear mass density (kg/m)

→ Intensity of wave (I) = $\frac{P}{S}$

↓ Power per unit cross section area.

$I = \frac{\text{Energy}}{\text{Area} \times \text{time}}$

$\boxed{\mu = \rho S \times l}$




$\boxed{I = 2\pi f^2 \rho A^2 v}$

$\boxed{I = \frac{1}{2}(\rho v)(\omega A)^2}$

$\boxed{\begin{matrix} I \propto f^2 \propto \omega^2 \\ I \propto A^2 \end{matrix}}$

$\frac{1}{2}(\rho v)$ → Property of medium (constant for given medium)

$\boxed{I \propto A^2 f^2}$

$\boxed{I = \text{Watt/m}^2}$

$\boxed{I = \frac{P_0^2}{2\rho v}}$

$P_0$ = Press. amplitude

$\boxed{\frac{I_1}{I_2} = \frac{f_1^2 A_1^2}{f_2^2 A_2^2}}$

For sph. wave,
$I \propto \frac{1}{r^2} \propto A^2$
i.e. $A \propto \frac{1}{r}$

→ Wave speed of transverse wave on a string

$\boxed{v = \sqrt{\frac{T}{\mu}}}$

$T$ → Tension on string (Need to apply NLM sometime)

$\mu$ → Linear mass density

→ velocity of sound → solid > liquid > Gas/Air.

→ In a medium sound speed,

$\boxed{v = \sqrt{\frac{E}{\rho}}}$

$E$ → modulus of elasticity of medium

$\rho$ → density of medium

For solid: $E = Y$ (Young's modulus = $\frac{\text{Stress}}{\text{Strain}}$)

For fluid : B (Bulk modulus) = $\frac{\text{Excess pressure}}{\text{Volume Strain}}$

$\boxed{B = \frac{-\Delta P}{\Delta V/V}}$ ← $P_{ex}$

## Newton's Formula for sound in air

Sound propagation in air is an Isothermal phenomenon

$PV = \text{constant}$

solving,

Bulk modulus $\rightarrow \boxed{B = P}$

$$\boxed{v = \sqrt{\frac{P}{\rho}} = \sqrt{\frac{RT}{M}}}$$

↑

But, putting corresponding value at NTP obtained value deviates a lot from experimental value of $v_{sound}$ in air (i.e. 332 m/s)

# Laplace correction in Newton's formula:

Sound propagation in Air is Adiabatic phenomenon.

(During compression → T↑)

$PV^{\gamma} = \text{constant}$

diff. & solving

$B = P\gamma$

$$\boxed{v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}}$$

* Effect of Temperature on velocity of sound

$$\boxed{v = \sqrt{\frac{\gamma RT}{M}}}$$

($\gamma, R, M \longrightarrow$ Medium dependent)

$\boxed{v \propto \sqrt{T}} \leftarrow$ For same media.

$$\boxed{\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}}$$

For different media,

$$\boxed{\frac{v_1}{v_2} = \sqrt{\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}}}$$

} Unit in SI kg, K

# Audible range → 20 Hz to 20 KHz.

# $y = A\sin(\omega t - kx) \Rightarrow$ Along <u>+ve</u> $x$-direction
$y = A\sin(\omega t + kx) \Rightarrow$ Along −ve $x$ direction.
$\omega = 2\pi f = \frac{2\pi}{T}$ | $k = \frac{2\pi}{\lambda} = \frac{2\pi f}{v} = \frac{\omega}{v}$

# wave velocity : $\boxed{v = \frac{\omega}{k}}$ <u>or</u> $\boxed{\text{Phase} = 0}$

# Particle velocity: $\boxed{v_p = \frac{dy}{dt}}$ $\boxed{(v_{max})_p = A\omega = A v_\omega \times k}$

# $\underbrace{\Delta\phi}_{\text{phase diff.}} = \frac{2\pi}{\lambda} \times \Delta x = \frac{2\pi}{T} \times \Delta t$

# If $\Delta\phi$ b/w two particles is <u>+ve</u>, the 2nd particle is leading ahead the first.

# For two waves emitting wave of freq. $f_1$ & $f_2$ } Phase diff $= \Delta\phi = \phi_1 - \phi_2$
$= 2\pi f_1 t - 2\pi f_2 t$
$= 2\pi(f_1 - f_2)t$

# $\Delta\phi = 2n\pi$ } In phase (or) same phase
$\Delta x = n\lambda$

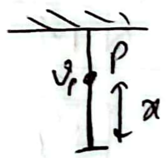
# $\Delta\phi = (2n+1)\pi$ } out of phase
$\Delta x = (2n+1)\frac{\lambda}{2}$, $n = 0, \pm 1, \pm 2, \ldots$

# <u>Eq^n of progressive wave in pressure variation form</u> :
$\boxed{P = P_0 \cos(\omega t - kx)}$ } $P_0$ = pressure amplitude (max press)
$P = P_0 \sin(\omega t - kx + \pi/2)$ } $= BAk = \rho v^2 Ak$ $\left(v = \sqrt{\frac{B}{\rho}}\right)$

$\Delta\phi$ b/w displacement amp. & press. am. is $\pi/2$ i.e. where <u>displacement is maximum</u>, <u>pressure is minimum</u> & vice-versa

# Wave on a string
$v = \sqrt{\frac{T}{\mu}}$ } $\mu$ = mass per unit length (or linear mass density)
$\mu = \frac{m}{l} = \frac{\rho A \times l}{l} = \rho A = \rho \times \pi r^2$, cylindrical wire of rad 'r'

# <u>Vel. of transverse wave in wire hung from rigid support at a distance 'x' from lower end</u>




$v = \sqrt{\frac{\frac{M}{L} xg}{M/L}} = \sqrt{xg}$

# $v = \sqrt{\frac{\gamma RT}{M}}$ → kelvin.
For, $\Delta$ of 1°C/1K → $\Delta v = 0.61$ m/s.

☆ If the temp. of gas remains constant, vel. of sound doesn't change with change in press. $P \propto \rho$ $\boxed{\frac{P}{\rho} = \text{constant}}$.

☆ $v_{\text{moist air}} > v_{\text{dry air}}$.

☆ But, velocity of sound in hydrogen decreases with increase in humidity.

$\boxed{\rho_{mix} = \frac{m_1 + m_2}{V_1 + V_2}}$

# Gases; $A : B = x : y$ (or $n_1 : n_2$) → prop. of vol.,
$\boxed{M_{mix} = \frac{xM_A + yM_B}{x + y}}$ $\boxed{\gamma_{mix} = \frac{n_1\gamma_1 + n_2\gamma_2}{n_1 + n_2}}$ $\boxed{\rho_{mix} = \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}}$

Date/Time : CONTINUATION SHEET M.R. No. ........................

# Wave motion

→ $v = \nu \lambda$

$v$ → velocity of sound (wave)

$\nu$ → frequency

$\lambda$ → wavelength

→ $v = \frac{\lambda}{T}$

→ $\nu \propto \frac{1}{\lambda}$

$\boxed{v = \frac{\omega}{K}} = \frac{x}{t}$

$\omega = \frac{2\pi}{T} = 2\pi\nu$

$K = \frac{2\pi}{\lambda}$ = wave no.

$\nu \propto \frac{1}{\lambda}$ (check)

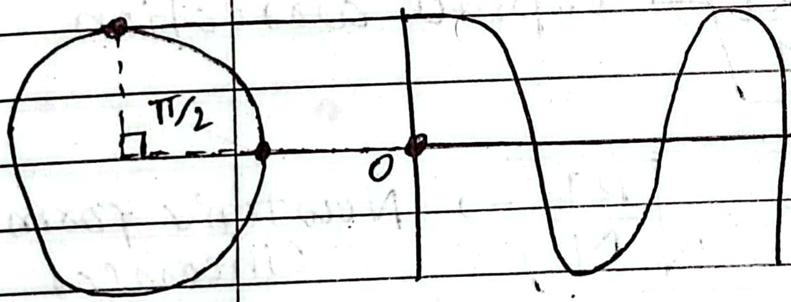
→ $y = A\sin(\omega t - Kx)$ [For +x dir.]

$y = A\sin(\omega t + Kx)$ [For −x dir]

$y = A\sin[\omega t - Kx + \phi]$ [For phase diff.

For finding wave velocity set/let $\phi = 0$

i.e $\boxed{\omega t - Kx = 0}$




→ Velocity of sound in wind (Relative velocity concept)

wind →, $\vec{v}_{wind}$ ($v_\omega$)

$\vec{v}_{sound/wind}$ ($v_{s/\omega}$)

$v_{sound/ground}$ ($v_{s/g}$) $= v_{s/\omega} - v_\omega$

→ Eg. A man heard echo after 3sec he fired gun,

Distance between man & reflecting obj $\boxed{d = \frac{v \times T}{2}}$ $\boxed{2d = vt}$

(Check)

→ $\frac{v_1}{v_2} = \sqrt{\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}}$ (For diff. media)

$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$ (For same media)

$\boxed{\sqrt{\frac{\gamma P}{\rho}}}$ ← $\boxed{v = \sqrt{\frac{\gamma RT}{M}}}$ → Laplace correction.

$\boxed{v = \frac{P}{\rho} = \sqrt{\frac{RT}{M}}}$ → Newton's formula (incorrect)

$M \rightarrow$ kg/mol $\gamma = \frac{C_p}{C_v}$

→ Frequency, depends only upon the source.

→ $M =$ vapour density ($\rho$) $\times 2$.

→ Domino effect

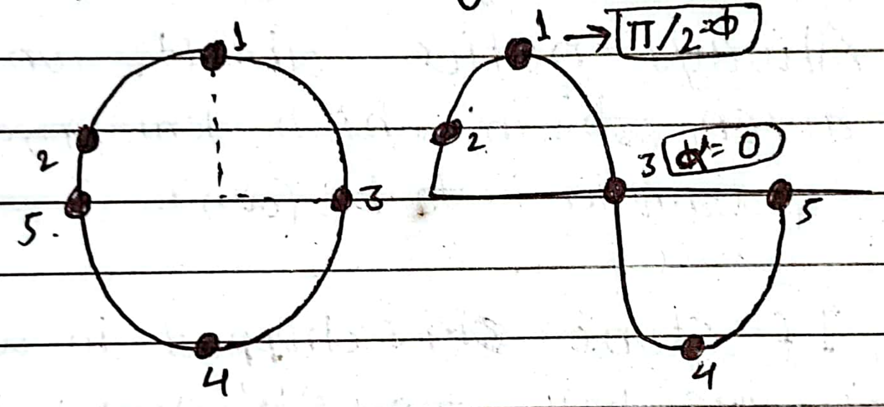
Speed of sound: solid > liquid > gas

→ Speed of sound is greater in moist air (Kiran) due to reduced av. molar mass.

→ $\phi = K\Delta$

$$\frac{\phi}{\Delta} = \frac{2\pi}{\lambda} \qquad \boxed{K = \frac{2\pi}{\lambda}}$$

→ phase → imagine circular motion



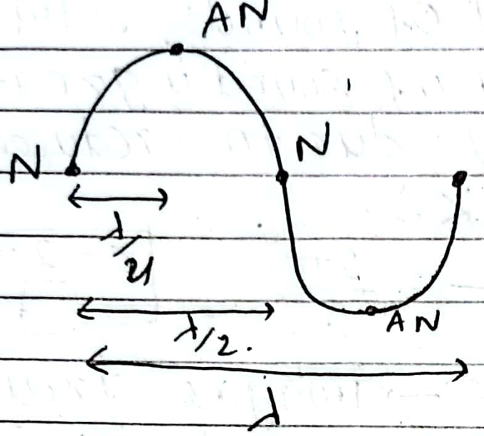

→ ~~Ea~~ ~~g~~ $\omega$ will be with t
k will be with x.

→ $(v)_{max} = \omega A$.
↑
of particle.

⇒ $v \propto \frac{1}{\sqrt{P}}$

→ Pressure amplitude or max. pressure variation = BAK
$(P_0)$

→ Distance between node and antinode = $\lambda/4$




→ Always notice about which temp, pres, etc is given, in which tem, pr., etc. the required parameter is to be found.

→ If stone is dropped in well where depth of water below top is 'h' and velocity of sound is 'v'. Then, splash of water is heard after

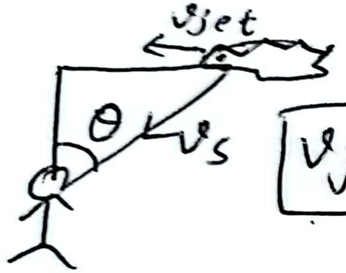
$$T = \left(\sqrt{\frac{2h}{g}} + \frac{h}{v}\right) \text{sec.}$$

→

# Time period b/w thunder & lightning    d → distance of cloud.

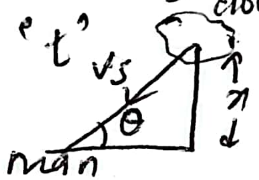
$$\Delta t = t_{sound} - t_{light} = \frac{d}{v_s} - \frac{d}{c} = \frac{d}{v_s} \quad \{ c >> v_s)$$

#




$$\boxed{v_{jet} = v_{sound} \times \sin\theta}$$

# 't'




⇒ when thunder is heard after time 't' observing of lightning.

Speed of sound = $v_s$

Vertical ht. of cloud ⇒ $\sin\theta = \frac{x}{v_s t}$

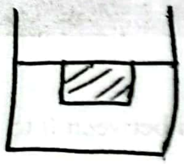
$$\boxed{x = v_s t \sin\theta}$$

# $\boxed{\text{Mach number} = \frac{v_{supersonic\ body}}{v_{sound}}}$

# Sound not heard at A.N & heard at note.

# $\boxed{\text{frequency } (f) = \frac{\text{No. of waves}}{\text{time}}}$

→ If bird is in air tight box then reading remain same.
If bird is in cage, then reading decreases if bird fly.

→ 

wt = upthrust ⇒ $\underline{\rho_b = \rho_l}$

when slightly pushed then it goes at bottom.

→ when surface area

(I) increases → energy required

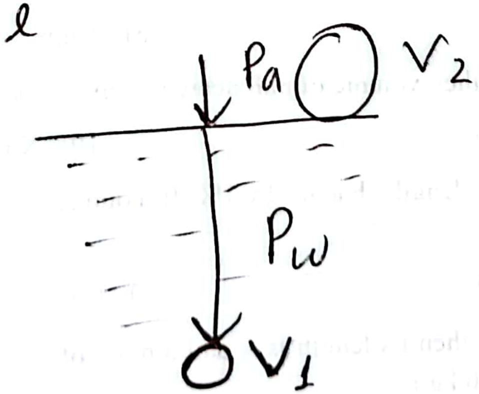
(II) decreases, energy released.

→ wt = Upthrust

$mg = V_{in}\,\rho_l \times g$

→ % inside $= \frac{V_i}{V} \times 100\% = \frac{\rho_b}{\rho_l} \times 100\%$

→ $\underline{(P_a + P_w)V_1 = P_a(V_2)}$.



→ When a block of ice floting in water

(i) contains (metal, stone, glass) i.e. heavier than water
then level falls if ice melt

(ii) contains (cork, wood, lighter then water) level constant

→ $v_t = \dfrac{2r^2(\rho-\sigma)g}{9\eta}$

→ on adding soap, surface tension decreases.

→ The least energy state is most stable state i.e. spherical shape

→ When length of tube is not sufficient, then
- liquid rises top
- radius of menisus at top increases
- angle of contact increases.
- liquid never overflow.

→ Work done = change in surface energy $= T \times \Delta A$

$= 4\pi R^2 T(n^{1/3}-1)$

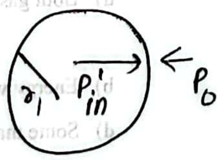
- while splitting, energy required
- while merged, energy released

→ When arrangent of capillary is in free fall then $wt = 0$ so,

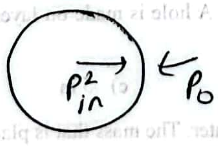
- liquid rises to top of capillary tube due to surface tension.

→ Two liquid Bubbles,

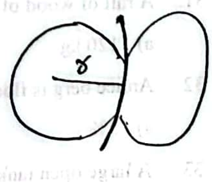
$P_{in}^{1} - P_{out} = \dfrac{4T}{r_1}$ —(1)



$P_{in}^{2} - P_{out} = \dfrac{4T}{r_2}$ —(2)



- Comes in contact : forms common interface of radius r



$P^1 - P_2 = \dfrac{4T}{r_1} - \dfrac{4T}{r_2} = \dfrac{4T}{r} \Rightarrow \boxed{\dfrac{1}{r} = \dfrac{1}{r_1} - \dfrac{1}{r_2}}$

- coalease (at isothermal) ⇒

$P_1V_1 + P_2V_2 = PV \Rightarrow \dfrac{4T}{r_1} \times \dfrac{4}{3}\pi r_1^3 + \dfrac{4T}{r_2} \times \dfrac{4}{3}\pi r_2^3 = \dfrac{4T}{r} \times \dfrac{4}{3}\pi r^3$

$r_1^2 + r_2^2 = r^2 \Rightarrow \boxed{r = \sqrt{r_1^2 + r_2^2}}$

→ $\eta = \frac{F}{A\theta}$ ( ~~stress~~ Modulus of Rigidity = $\eta$) $\boxed{\cancel{\theta = \frac{dv}{dx}}}$

For liquid, $\theta = \infty$, $\eta = 0$

(θ) Shear strain = 0 means no displacement

→ Spring balance is made by metal of high elasticity.

→ $F = \frac{YAe}{l}$ → depends on material $\boxed{e = l_{final} - l_{initial}}$

→ Breaking force = $\underline{\text{Breaking Stress}}$ × Area

- Depends on nature of material & independent of length.

→ Bulk modulus $= \frac{PV}{-\Delta V} = \frac{P}{(-\Delta V/V)}$ $\boxed{P = \rho g h}$

→ $F \propto e$ [Hooke's law]

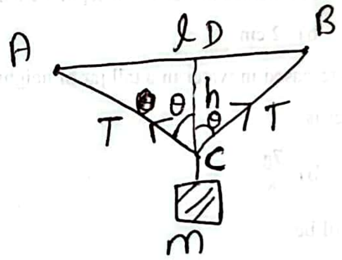
→ $W = \frac{1}{2} Fe = \frac{1}{2}\frac{YAe^2}{l}$

→ In catapult

Energy stored = KE of missile

$\frac{1}{2} Fe = \frac{1}{2} mv^2$

→ Mass in middle of rope




$e = 2AC - AB$

$AC = \sqrt{(l/2)^2 + h^2}$

Stress $= \frac{Ye}{l}$

$\frac{T}{A} = \frac{Ye}{l}$ $A = \frac{\pi d^2}{4}$ $\{2T\cos\theta = mg\}$

→ When lift is moving up or down, the fraction of body in liquid remain same.

→ $F_v = \eta A \frac{dv}{dx}$

→ In indicator diagram, PV curve
Work done = Area under curve

→ In adiabatic process, $dQ = 0$ ; so, $dW = -dU$.

→ Work done ; on gas → −ve
by gas → +ve

Heat; Released by gas → −ve
Absorbed by gas → +ve

Heat supplied → +ve
Heat absorbed → −ve
internal energy inc. → +ve
" " dec. → −ve
work done by gas → +ve
" " on gas → −ve.

→ $dQ = ms\,d\theta$

→ $du = nC_v dT$

→ $dQ = nC_p dT$ {At const. pressure}

→ $\gamma = \frac{C_p}{C_v}$ ; $\gamma_{diatomic} = \frac{7}{5}$ & $\gamma_{monoatomic} = \frac{5}{3}$

→ $PV^{\gamma} = \text{constant} \Rightarrow P \propto V^{-\gamma}$
differentiating $\Rightarrow \frac{\Delta P}{P} = -\gamma \frac{\Delta V}{V}$

Fuel balda niskine energy
⇓
Input

→ $W_{Adiabatic} > W_{Isothermal}$.

→ $\eta = \left(1 - \frac{T_{sink}}{T_{source}}\right) \times 100\%$

• $\eta = \left(1 - \frac{Q_2}{Q_1}\right) \times 100\%$. $\{Q_1 - Q_2 = W\}$

→ coeffecient of performance $(\beta) = \frac{Q_2}{W}$ → Heat extracted. $= \frac{Q_2}{\cancel{Q_1 - Q_2}} \Rightarrow \frac{T_2}{T_1 - T_2}$

→ side by side : parallel ; end to end : series.

→ $P = \sigma A (T^4 - T_0^4) = ms\frac{d\theta}{dt}$

surface area ;
cube < sphere < plate

$A$ ↓ Curved surface Area

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

→ Heat radiation $(E) = \sigma A T^4$

→ Ratio of conductivity is same as Ratio of length.

Eg: $K_A = 2K_B$
$\Rightarrow$ 1 m of A = 2 m of B.

→ Time for Ice formation
$t = \frac{\rho L_f}{2K\theta}(x_2^2 - x_1^2)$

→ K.E. of n moles of gas $(KE) = \frac{3}{2} nRT$

→ Conduction

$$\frac{Q}{t} = \frac{KA\,d\theta}{l} \qquad K_{eq} = \frac{l_{eq}}{R_{eq}\,A_{eq}}$$

$R \rightarrow$ Thermal Resistance.

→ $\lambda_1 T_1 = \lambda_2 T_2$ [Wien's displacement law]

→ $RH = \frac{m_{present}}{m_{required}} \times 100\%$

→ RH Less ⇒ Rate of evaporation increases so person feels cold.

→ $m \propto$ ~~RH~~ S.V.P.

→ $RH = \frac{p}{P} \times 100\%$

→ SVP : do not follow gas law

→ $\sigma = 5.67 \times 10^{-8}$

(i) $F_m = Bqv\sin\theta$ } For any moving charge in magnetic field
$F_m = q(\vec{v} \times \vec{B})$ ⇓ current

(ii) Specific charge $= \frac{q}{m}$

(iii) For coil, $B_{center} = \frac{\mu_0 N I}{2R}$ $\mu_0 = 4\pi \times 10^{-7}\ TmA^{-1}$
$\left\{ \boxed{I = \frac{q}{t} = q \times f} \right.$

$$B_{axis} = \frac{\mu_0 N I R^2}{2(x^2+R^2)^{3/2}}$$

(iv) If a charge moves perpendicular to external magnetic field then,

$$B_{ex} \times q \times v = \frac{mv^2}{r}$$ } i.e. charge moves in circular path with same velocity.

$$Bqr = \underbrace{mv}_{\text{momentum}}$$

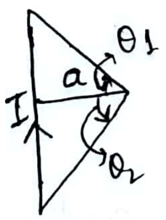
(v) Field at centre will be zero if, $B_{centre} = B_{earth\ magnetic\ field}$ $(5\times10^{-5} T)$

(vi) $B_{circle} = \frac{\mu_0 I}{2R}$ ; $B_{semicircle} = \frac{\mu_0 I}{4R}$

$$B_{arc} = \frac{1}{n}\left(\frac{\mu_0 I}{2R}\right) \Big\}\ n = \frac{360^\circ}{\theta}$$

(vii) For straight conductor

$$B = \frac{\mu_0 I}{4\pi a}(\sin\theta_1 + \sin\theta_2)$$



→ Infinitely long, $\theta_1 = \theta_2 = 90^\circ \Rightarrow B = \frac{\mu_0 I}{2\pi a}$

→ At one end, $\theta_1 = 0^\circ, \theta_2 = 90^\circ \Rightarrow B = \frac{\mu_0 I}{4\pi a}$.

For conductor, B along its path 'zero'.

(viii) 


$B_{centre} = 0$

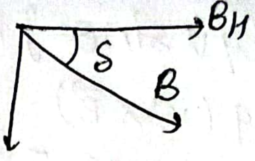

$B = 0$.

(ix) Magnetic moment $= NIA$

(x) Force per unit length in two parallel current carrying wires seperated by distance 'd'

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$ { Attraction if $I_1$ & $I_2$ same direction; Repulsion if $I_1$ & $I_2$ opp. direction

# Angle of dip ($\delta$) $\tan\delta = \frac{B_V}{B_H}$




# For Bar magnet

$B \rightarrow$ Total field intensity.

$$M = m \times 2l$$

Pole strength ($m$) = depends on cross section area.

# Work done in rotating magnet by angle $\theta \Rightarrow W = MB(1-\cos\theta)$

# Time period of oscillation for bar magnet,

For bar magnet, $\boxed{I = \frac{1}{12} ml^2}$ $T = 2\pi\sqrt{\frac{I}{MH}}$ } Oscillation magnetometer

# For permanent magnet,

↳ High coercivity & high retentivity.

# $\boxed{E = -\frac{d\phi}{dt}}$ → EMI $\boxed{E = -L\frac{dI}{dt}}$ → self inductance $\boxed{E_2 = -M\frac{dI_1}{dt}}$ → Mutual inductance

$\boxed{\phi = BAN}$ $\boxed{\phi = LI}$ $\boxed{Q = \frac{d\phi}{R}}$ $\boxed{\phi_2 = MI_1}$

# In transformer, $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$ $\boxed{\eta = \frac{P_{out}}{P_{in}} \times 100\%}$

$\boxed{P = E \times I}$

# ↳ Emf developed across axle of ~~rotating~~ rotating wheel

centre & rim { $\boxed{E = BAf}$ } Doesn't depend upon number of spokes

# For a rotating loop

$\boxed{E_0 = BA\omega N}$ $\boxed{E = \frac{1}{2}LI_0^2}$ → Energy stored.

# $\boxed{I = \frac{E - E_b}{R}}$ $\boxed{\text{For inductor, } V - L\frac{dI}{dt} = IR}$

# Choke → preferred to control current without loss of power

↳ low resistance, high inductance

# $\boxed{V_{rms} = \frac{V_0}{\sqrt{2}}}$ → Given value is RMS value. $\boxed{\cos\phi = \frac{R}{Z}}$ ⇒ Power factor $\boxed{P = V_{rms} I_{rms} \cos\phi}$

# Growth of current, $\boxed{I = I_0(1 - e^{-Rt/L})}$ $\boxed{I = I_0(1 - e^{-t/RC})}$

# $\boxed{X_L = \omega L = 2\pi f L}$ $\boxed{X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}}$

# For Radio tuning → Resonance ($X_L = X_C$)

# For flying aeroplane (or moving train) $E = B_V l v = B_H \tan\delta\, l v$

# Electrons

## (1) Millikan's oil drop experiment:-

(i) Motion of oil drop under the effect of gravity alone:
(No electric field applied)

Net upward force = Net downward force
→ when drop attains the condition of terminal velocity.
(no acceleration) ⇒ $\boxed{F_{net}=0}$
→ when motion is downward

~~Upth~~

$$\underbrace{\text{Upthrust}}_{(U)} + \underbrace{\text{viscous force}}_{(F_v)} = \text{weight}\ (W)$$

Upthrust → provided by medium

viscous force → exists only when body is in motion (opposite to motion of body)


mass of drop (m) = $V \times \rho$

$$\left(\frac{4}{3}\pi r^3\right)\sigma g + 6\pi\eta r v_1 = \left(\frac{4}{3}\pi r^3\right)\rho g$$

$(V\ \sigma\ g)$

$\sigma$ → density of medium

$V$ → volume of air displaced ‖ volume of oil drop

$\rho$ → density of body

$v_1$ → terminal velocity of oil drop during motion of gravity alone

$\eta$ → coefficient of viscocity of medium

$r$ → radius of oildrop

$$6\pi\eta r v_1 = \frac{4}{3}\pi r^3(\rho-\sigma)g$$

$$r = \sqrt{\frac{9}{2}\frac{\eta v_1}{(\rho-\sigma)g}}$$

* density of air being very small sometimes upthrust (U) might be neglected. i.e. U=0

For, U=0

(i) Viscous force = weight.

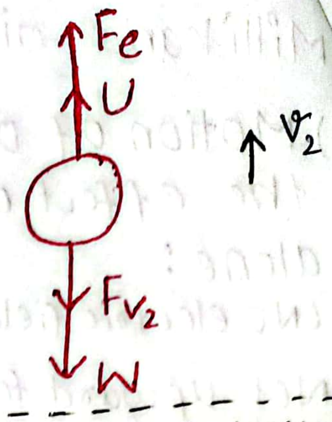
* The plates might be vertical or horizontal.
(see P.B. p.g. no 291 eg-13)

(ii) Motion under the combined effect of gravity and electric field:-

For positive charge situation might reverse.

Condition 1:-

As oil drop is negatively charged so move towards positive plate




When the drop aquires condition of terminal velocity,

$$F_{net} = 0$$

$E = \frac{V}{d}$ → $V$: Potential difference b/w two plates; $d$: distance b/w two plates.

Net upward force = Net downward force

Electrostatic force + Upthrust = Viscous force + weight

$$\underbrace{q}_{\text{Charge on oildrop}}\underbrace{E}_{\text{Strength of electric field}} + \left(\frac{4}{3}\pi r^3\right)\sigma g = 6\pi\eta r \underbrace{v_2}_{\text{Terminal velocity when electric field is applied}} + \left(\frac{4}{3}\pi r^3\right)\rho g$$

$$qE = 6\pi\eta r v_2 + \underbrace{\frac{4}{3}\pi r^3(\rho-\sigma)g}_{6\pi\eta r v_1}$$

$q = ne$ → Quantization.

$n$: no. of electrons (more no. of e ⇒ more charge)

$e$: charge one = $1.6\times10^{-19}C$

$6\pi\eta r v_1$ (remains same under both cases)

$$qE = 6\pi\eta r(v_1+v_2)$$

$$\boxed{q = \frac{6\pi\eta r(v_1+v_2)}{E}}$$

$$\boxed{q = \frac{6\pi\eta}{E}\sqrt{\frac{9}{2}\frac{\eta v_1}{(\rho-\sigma)g}}\,(v_1+v_2)}$$

Condition → 2

When drop remains stationery → viscous force will be zero. so,

$$W = F_{es}$$

$$mg = neE = e\frac{V}{d}$$

$$\boxed{q = \frac{6\pi\eta}{E}\sqrt{\frac{9}{2}\frac{\eta v_1}{(\rho-\sigma)g}}\,(v_1-v_2)}$$ → when oil drop moves downward even after applying electric field (i.e. electric field might be weak)

# Motion of electron beam in uniform electric field:

electrons → negatively charged → so, attracted towards +ve plate

Electric field → +ve to −ve

motion of $e^-$ → −ve to +ve

When electron beam is allowed to enter horizontally ... b/w the plates in electric field,

horizontal velocity → remains unaltered throughout the motion

vertical velocity → initially zero and (For $e^-$) accelerates opposite to the direction of electric field.

vertical acceleration,

$$\boxed{a = \frac{F_{es}}{m_e} = \frac{e \times E}{m_e} = \frac{e \times V}{m_e \times d} = \left(\frac{e}{m_e}\right) \times \frac{V}{d}}$$

→ For electron beam $F_{es} = \underline{n}eE$

Equation of motion after time t,

$$x = vt + \frac{1}{2}\underbrace{a_x}_{0} t^2$$

$$\boxed{x = vt}$$ → horizontal distance covered at time t

For same time t

$$y = \underbrace{u_y}_{0} t + \frac{1}{2} a_y t^2$$

$$\boxed{t = \frac{x}{v}} \quad \boxed{y = \frac{1}{2} a t^2} \quad (1)$$

→ Vertical distance covered at time t due to acceleration provided by electrostatic force.

deflection of beam from original direction.

If the plates each of length D are separated by the distance d and potential difference of V is applied.

For, $x = D \Rightarrow t = T$ → time taken to cross the plates.

$$y = \frac{1}{2} a \times T^2$$

$$\boxed{y = \frac{1}{2}\left(\frac{e}{m_e}\right) \times \left(\frac{V}{d}\right) \times \left(\frac{D}{v}\right)^2}$$

If θ is angle of deflection in electric field.

$$\tan\theta = \frac{v_y}{v_x} = \frac{u_y + a_y t}{u_x + a_x t} = \left[\left(\frac{e}{m_e}\right) \frac{V}{d} \times \frac{x}{u}\right]$$

$$\Rightarrow \theta = \tan^{-1}\left(\frac{eV}{mdu^2}\right)x$$

Resultant velocity at any point $v_f = \sqrt{v_x^2 + v_y^2}$

$$v_f = \sqrt{u^2 + \left(\frac{eVx}{mdu^2}\right)^2}$$

$$\boxed{v_{initial} = u}$$

Gain in $K.E. = (K.E.)_f - (K.E.)_i$

$$= \frac{1}{2}m\left[u^2 + \left(\frac{eV}{mdu^2}\right)^2\right] - \frac{1}{2}mu^2$$

$$= \frac{1}{2} m \frac{e^2V^2}{md^2u^2}$$

From ①,

$$y = \frac{1}{2}\left(\frac{eV}{md}\right) \times \left(\frac{x}{u}\right)^2 = \left(\frac{eV}{2mdu^2}\right)x^2$$

This equation shows that the motion of the electron in electric fied is parabolic in nature.

But, once electron crosses electric field, its motion will be in a straight line tangent to parabola,

↓ no. force acts to change the velocity.

$\left(\frac{e}{m}\right)$ = specific charge of electron = $1.8 \times 10^{11}\, C\,kg^{-1}$

* Note:(i) If electron enters midway b/w the plates total deflection after crossing electric field will be $d/2$.

(ii) For electron moving under electric field.

$$\boxed{eV = \frac{1}{2}mv^2}$$

$v \rightarrow$ ~~uniform~~ velocity with which $e^-$ enters the electric field

↳ Applied for Thompson's experiment also.

1eV → amount of energy required to move a $e^-$ in a potential difference of 1V.

$x$eV → amount of energy required to move a $e^-$ in a potential difference of $x$V

$\boxed{1eV = 1.6 \times 10^{-19} J}$

i.e. 500 eV ⇒ $\boxed{V = 500V}$

↳ P.d. might change if no. of $e^-$ is changed

## 3) Motion of electron in uniform magnetic field:-

The electron deflects from its original path when it moves in magnetic field. Then,

The magnitude of magnetic force is given by

$$F = \underline{B}e\underline{v}\sin\theta$$

$\vec{F}_m = q(\vec{v} \times \vec{B})$

$|\vec{F}_m| = Bqv\sin\theta$

$\theta \rightarrow$ angle b/w $\vec{B}$ and $\vec{v}$

$\vec{B}$ → Magnetic field, $\vec{v}$ → velocity

For electron,

$F = Bev\sin\theta$

(i) When electron enters the field parallelly or antiparallelly i.e. $\theta = 0°$ or $\theta = 180°$

$$\boxed{F = 0}$$

↓

$e^-$ does not experience any magnetic force.

(ii) When electron enters the field perpendicularly i.e. $\theta = 90°$

$F = Bev \sin 90°$

$\boxed{F = Bev} \rightarrow$ maximum force experienced by $e^-$ in magnetic field

Here, Force is always ⊥r to $\vec{v}$ so $e^-$ follows circular path. Thus, magnetic force provides centripetal force to the $e^-$.

i.e. $Bev = \dfrac{mv^2}{r}$

radius of circular path followed by $e^-$ in magnetic field ← $\boxed{r = \dfrac{mv}{Be}}$

$$r = \frac{mr\omega}{Be}$$

angular velocity of $e^-$ ← $\boxed{\omega = \dfrac{Be}{m}}$

$$\boxed{\omega = 2\pi f = \frac{2\pi}{T} = \frac{Be}{m}}$$

$f \rightarrow$ Frequency of revolution of $e^-$

$T \rightarrow$ Time period of revolution of $e^-$ in uniform magnetic field.

(iii) When electron enters at any oblique angle $\theta$.

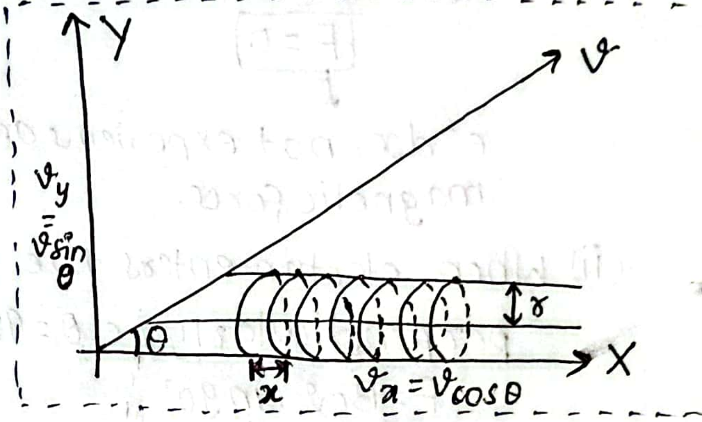
The initial velocity of $e^-$ in magnetic field can be resolved into two components.

The component $v_x (= v\cos\theta)$ tends to move the electron in the direction of magnetic field, whereas

The component $v_y (= v\sin\theta)$, perpendicular to the direction of magnetic field tends to move electron in circular path.

The combined effect makes $e^-$ to move in helical path.

Thus,




$$\frac{m v_y^2}{r} = B e v_y$$

$$\boxed{r = \frac{m v_y}{Be} = \frac{m v\sin\theta}{Be}}$$

radius of helical path

$$T = \frac{\text{Circumference of circle}}{\text{Speed along circle}} = \frac{2\pi r}{v\sin\theta} = \frac{2\pi}{v\sin\theta} \times \frac{m v\sin\theta}{Be}$$

$$\boxed{T = \frac{2\pi m}{eB}}$$

Time period of revolution of $e^-$

$\boxed{\text{Pitch } (x) = \text{horizontal velocity } (v\cos\theta) \times \text{time period } (T)}$

linear distance travelled by the $e^-$ during time period T $\boxed{\text{OR}}$ linear distance b/w two consecutive turns of a helical path.

---

# Cross fields

↳ Region of uniform electric and magnetic field applied simultaneously perpendicular to each other such that such that charge particle entering normally into this region passes undeviated.

This is possible when,

$$qE = Bqv \implies \boxed{v = \frac{E}{B}}$$

$(F_{es}) = (F_m)$

velocity of particle

# Photoelectricity:-

1) Quantum Nature of Light

Energy of each photon $(E) = hf = \frac{hc}{\lambda}$

$f \rightarrow$ frequency of photon
$h \rightarrow$ Planck's constant $= 6.62 \times 10^{-34}$ Js
$c \rightarrow$ velocity of light in vaccum $= 3 \times 10^8$ m/s.
$\lambda \rightarrow$ wave length of photon
↳ tiny packets or bundles of energy emitted or absorbed (∵ energy is emitted or absorbed in discontinuous units)

$$\boxed{f = \frac{c}{\lambda}}$$

For n-photons (quanta), $E = nhf$

* Rest mass of photon is zero it only have dynamic mass (mass in motion) so, its total energy is equal to kinetic energy.

(2) Photoelectric effect
↳ phenomenon of emission of electrons from a material surface when light of suitable wavelength (or frequency) falls upon it.
↳ Evidence of particle nature of light.

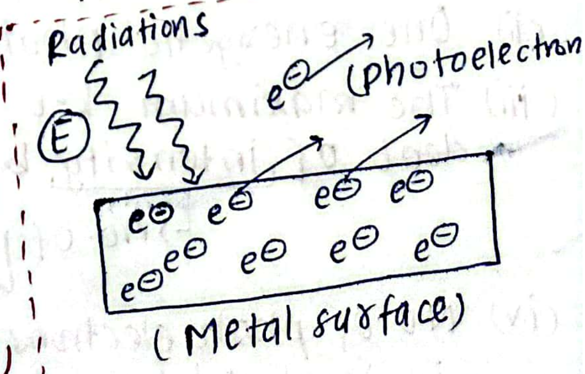
(3) Einstein's equation of photoelectric effect:

$$\boxed{\underbrace{hf}_{\text{energy of incident photon (E)}} = \underbrace{\phi_0}_{\text{Work function}} + \underbrace{\frac{1}{2} m v_{max}^2}_{\text{kinetic energy of ejected photoelectron}}}$$

energy of incident photon (E)

Work function (Minimum amount of energy required to eject out an electron from the surface of material)
↳ property of material (metal)

kinetic energy of ejected photoelectron



* $\boxed{\frac{1}{2} m v_{max}^2 = E_K = e V_s}$ $\boxed{V_s = \frac{E_K}{e}}$ $\boxed{1eV = 1.67 \times 10^{-19} J}$

$m$ → mass of photo-electron

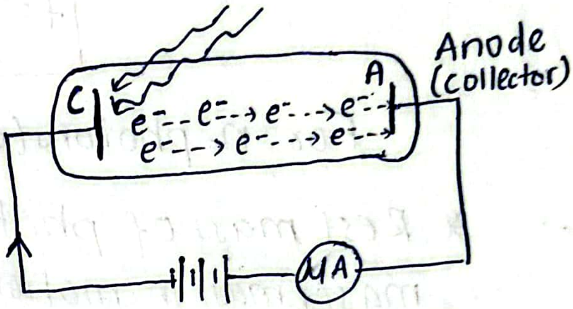
$v_{max}$ → maximum velocity of photoelectron

$e$ → charge of electron

$V_s$ → Stopping potential (The minimum magnitude of negative potential on anode w.r.t. cathode which can stop photocurrent
*At this condition even an $e^-$ of max K.E. fails to reach anode)
↳ depends of frequency of incident radiation and nature of metal.

$\boxed{V_{max} = \sqrt{\frac{2E_K}{m}}}$

$\boxed{\phi_0 = hf_0 = \frac{hc}{\lambda_0}}$




$f_0$ → Threshold frequency: The minimun frequency of an incident light which can eject out the $e^-$s from the surface of metal.

$\lambda_0$ → Threshold wavelength: Longest wavelength of an incident light which can eject out the $e^-$s from the surface of metal.

* For photoelectric effect, $\boxed{\lambda \le \lambda_0 \ \& \ f \ge f_0}$ $\boxed{\& \ hf \ge \phi_0}$

$$K.E_{max} = E - \phi_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$\boxed{\lambda_0 = \frac{c}{f_0}}$$

$$K.E_{max} = E - \phi_0 = hf - hf_0$$

Note:-

(i) Photoelectric effect is instantaneous process.

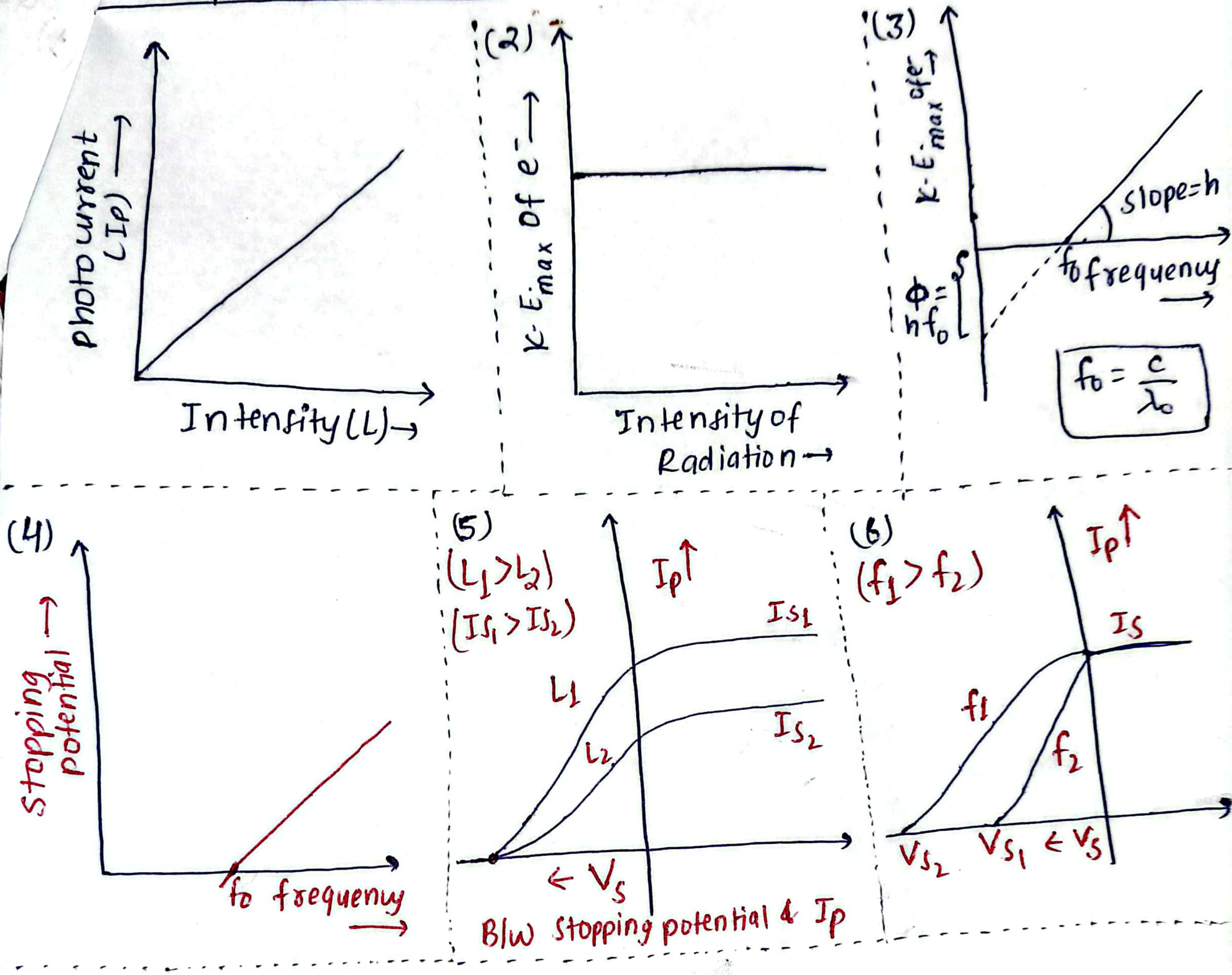
(ii) One energetic photon can liberate only one electron.

(iii) The maximum K.E. of photoelectrons emitted is independent of intensity, but depends upon frequency of light.
↳ no. of photons incident per unit area per unit time.

(iv) No. of photoelectrons emitted only depend upon intensity of incident light but not upon frequency of radiation.

(v) Greater frequency ⟶ more K.E. of photoe⁻ ⟶ larger stopping

## ...me important Relations :-




* Intensity :-

$$I = \frac{Nhf}{At} \qquad N = \text{No. of photo electrons}$$

$$\frac{P}{A} = \frac{Nhf}{At}$$

$$\therefore \text{Power}(P) = \frac{Nhf}{t} = \left(\frac{N}{t}\right)hf = nhf = \frac{nhc}{\lambda}$$

$n \rightarrow$ no. of photoelectrons emitted per second.