⇒ which law is valid for inertial & non-inertial frame?
↳ 2nd Law of Newton.

⇒ Is force a change in velocity, or is change in velocity a force?
Both statements are true. True w.r.t body in motion. True w.r.t body in rest.

Chapter # 05

Force and motion.

moves, tends to move; stops, tends to stop. It can change the direction, or deform a body. Push or pull acting on an object. Causes acceleration.

Frame of Reference: Frame in which we are observing; in one which Newton's laws hold.

Inertial — $a = 0$ — Earth, train is moving with const. speed. In which Newton 1st Law holds

Non-inertial. — $a \neq 0$

1st Law → Continue its state of rest or uniform motion if no net external force acts on the body. Defines force

Net force = sum of all the forces acting on a body.

Law of Inertia: Property of body due to which it resists a change in its state.

$\boxed{\text{Mass} \propto \text{Inertia}}$ → Not physical quantity.

body's resistance to change in motion.

Newton's 2nd Law: → measures force.

$\xrightarrow{F} \boxed{m} \rightarrow a \quad \xrightarrow{F} \boxed{m_1} \quad \xrightarrow{F} \boxed{m_2}$

$a \propto F$, $a \propto \frac{1}{m}$ } $a \propto \frac{F}{m}$, $F \propto ma$

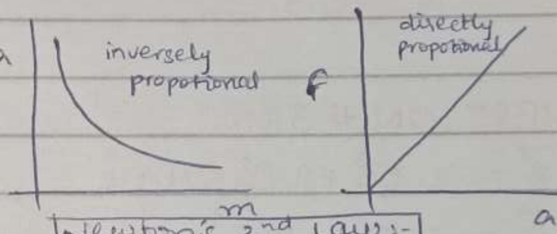
$\boxed{N = 1kg\,ms^{-2}} \leftarrow F = K\,ma$

$\boxed{F = ma}$ (1)

$F_1 = F_2$

$m_1 a_1 = m_2 a_2$

$$\boxed{\frac{m_1}{m_2} = \frac{a_2}{a_1}}$$



Newton's 2nd Law:- Net force on body is equal to the product of the body's mass and its acceleration.

Newton's 3rd Law: To every action (A), there is an equal ~~and~~ reaction (R) but in opposite direction. → Action and Reaction remain in same state, i.e. Newtonian state.

→ A and R act on two different bodies.

→ A and R never cancel each other.

→ A and R are of same nature.

→ A and R act for the same time interval.

Extremely small, extremely large, $\boxed{\text{middle sized objects}}$

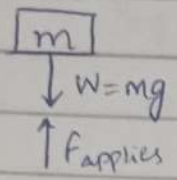
Newton mechanics. speed/velocity → very low.

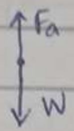
Einstien views will be applicable ⇒ speed/velocity approaches speed of light (c).

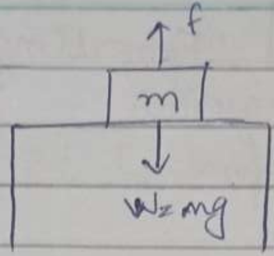
1st Law: If no net force acts on a body ($\vec{F}_{net} = 0$), the body's ~~acceleration~~ velocity cannot change; that is the body cannot accelerate.

2nd Law: The net force on a body is equal to the product of the body's mass and its acceleration $\Rightarrow \boxed{F_{net} = ma}$

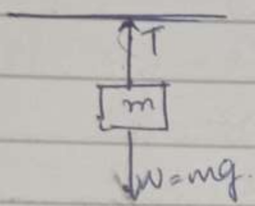
→ FREE BODY DIAGRAM. (FBD)







Tension:



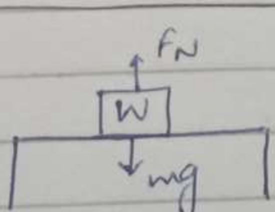
The upward reactional force acting along the string is called tension.

$$F_{net} = T - W$$
$$0 = T - W$$
$$\boxed{T = W} \Rightarrow \text{not moving / at rest.}$$

If it is moving upward:
$$F_{net} = T - W$$
$$ma = T - W$$
$$ma = T - mg$$
apparant weight ← $\boxed{T = ma + mg}$

If it is moving downwards:
$$F_{net} = W - T$$
$$ma = mg - T$$
SI unit ← N ← $\boxed{T = mg - ma}$
$$a = g$$
$$T = \cancel{m}g - \cancel{m}g$$
$$\boxed{T = 0}$$

Normal Reaction Force:



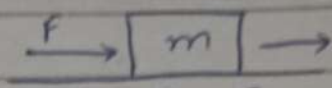
$$F_N = W$$
$$F_N = mg$$

Force of friction

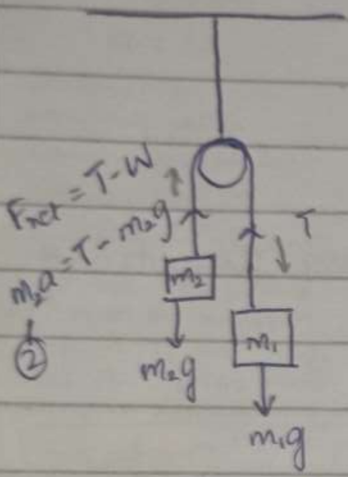
$F_f = \mu mg$

$F_f \rightarrow$ Nature of surface

$\hookrightarrow$ Pressing force.



$F_s > F_0$



$f_{net} = W - T$

$f_{net} = mg - T$

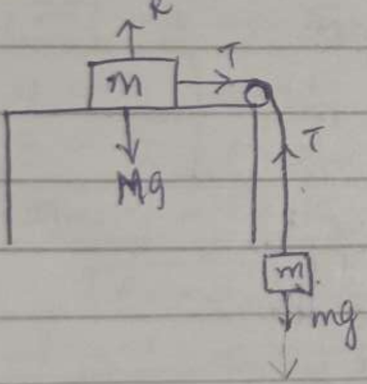
$m_1 a = m_1 g - T$ —①

$m_1 a + m_2 a = m_1 g - m_2 g + \cancel{T} - \cancel{T}$

$a(m_1 + m_2) = g(m_1 - m_2)$

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

$m_1 > m_2$



$f_{net} = T$

$Ma = T$ —①

$f_{net} = mg - T$

$ma = mg - T$ —②

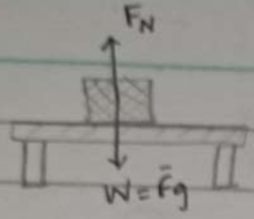
$ma = mg - Ma$

$ma + Ma = mg$

$a(m + M) = mg$

$$\boxed{a = \frac{m}{(m+M)} g}$$

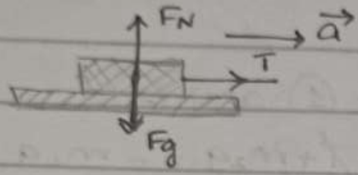
FREE BODY DIAGRAMS (FBD)

① 

$F_{net\,y} = ma_y$

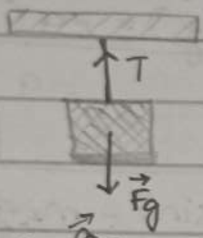
$F_N - W = m(0)$

$F_N = F_g = mg = W$

② 

$F_{net_x} = ma_x$

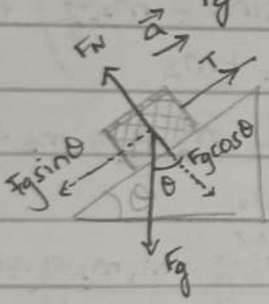
$T = ma_x$

③ 

$F_{net\,y} = ma_y$

$T - F_g = m(0)$

$T = mg$

④ 

$\underline{F_{net\,x}} = ma_x$

$T - mg\sin\theta = m(a) \Rightarrow T - mg\sin\theta = ma$

$T = ma + mg\sin\theta$

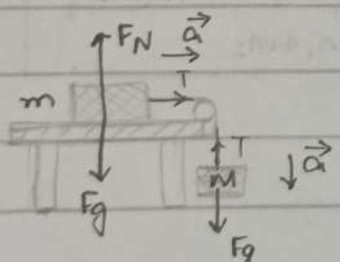
$T = m(a + g\sin\theta)$

$F_{net_y} = ma_y$

$F_N - F_g\cos\theta = m(0)$

$F_N = F_g\cos\theta$

$F_N = mg\cos\theta$

⑤ 

__Body 1:__ $\vec{F}_{net_x} = ma_x$

$T = ma_x$ — ①

$\vec{F}_{net_y} = ma_y$

$\vec{F_N} = \vec{F_g}$

__Body 2:__ $F_{net_y} = Ma_y$

$T - F_g = M(-a)$

$T - Mg = -Ma$

$T = (Mg - Ma)$ — ②

Subtracting ① & ②:

$\cancel{T} - \cancel{T} = ma - Mg + Ma$

$0 = ma - Mg + Ma$

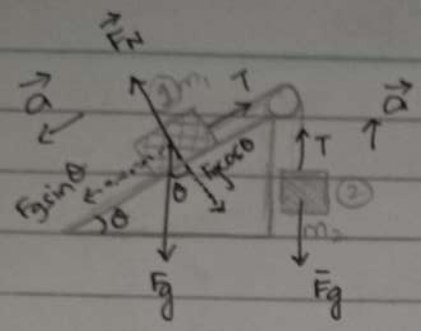
$-Ma - ma = -Mg$

$-(M+m)a = -Mg$

$$\boxed{a = \frac{M}{(M+m)}g}$$

Also, $\boxed{T = \frac{mM}{M+m}g}$

(6)



Body 1:

$\vec{F}_{net\,y} = m_1 a_y$

$\bar{F}_N - \bar{F}_g \cos\theta = m(0)$

$\bar{F}_N - \bar{F}_g \cos\theta = 0$

$\bar{F}_N = \bar{F}_g \cos\theta$

$\bar{F}_{net\,x} = m a_x$

$T - m g \sin\theta = m_1(-a)$

$T - m_1 g \sin\theta = -m_1 a \quad -(1)$

Body 2:

$\vec{F}_{net\,y} = m_2 a_y$

$T - m_2 g = m_2 a \quad -(2)$

Subtracting (1) and (2):

$\cancel{T} - m_1 g \sin\theta - \cancel{T} + m_2 g = -m_1 a - m_2 a$

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

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

Also; $T = m_2\left(\frac{m_1 g \sin\theta - m_2 g}{m_1 + m_2}\right) + m_2 g$

$$T = \frac{m_1 m_2 g \sin\theta - m_2^2 g}{m_1 + m_2} + m_2 g$$

$$T = \frac{m_1 m_2 g \sin\theta - \cancel{m_2^2} g + m_1 m_2 g + \cancel{m_2^2} g}{m_1 + m_2}$$

$$\boxed{T = \frac{m_1 m_2 g \sin\theta + m_1 m_2 g}{m_1 + m_2}}$$

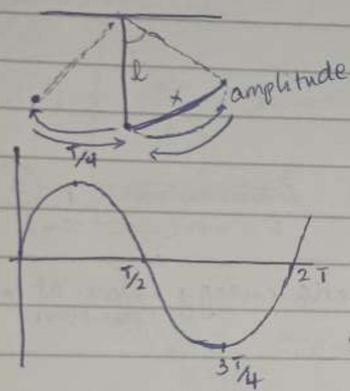
After MIDI

Can a particle, an electron, positron, or quark, execute simple harmonic motion in its nucleus?

CHAPTER # 15:
Oscillations.

2 Definite types of Motion:
→ Mechanical
→ Electrical

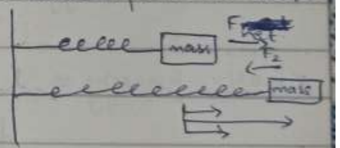
Oscillation — Vibration
↳ To and fro motion of a body about it's mean position.



• Projection along diameter.
• **Phase**: an angle that defines the location while the particle is moving in a circular path.

Simple Harmonic Motion:
Simple → 1-D; Harmonic → sin, cos] Harmonic series

Vector quantities are always measured from its initial point. $F \propto -x$



$F = ma$ ② ⇒ Newton's law

Hooke's law ⇐ $F = -kx$ — ① (k → spring constant)

Equate ① & ②: $-kx = ma$

$a = -\frac{k}{m}x$

$a \propto -x$

$x = x_m \cos(\theta + \phi)$ ⇒ circular motion

$\theta = \omega t$

Displacement equation → $\boxed{x = x_m \cos(\omega t + \phi)}$

$v = \frac{dx}{dt} \rightarrow = \frac{d}{dt}(x_m \cos(\omega t + \phi))$

$v = -x_m (\sin\theta)\, \omega$

$\boxed{v = -x_m \omega \sin(\omega t + \phi)}$ → **Velocity equation**

Q) Calculate the time period of a mass spring system.

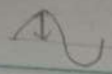
$v_m = -x_m \omega$ $\quad \therefore v = 0$ at extreme position

$\frac{dv}{dt} = a$

$a = -x_m \omega \cos(\omega t + \phi)\omega$

$\boxed{a = -x_m \omega^2 \cos(\omega t + \phi)}$ → **acceleration equation**

Maximum ~~acceleration~~ force can also be written as:- $\boxed{F_m = kx_m = m\omega^2 x_m = ma_m}$



Maximum acceleration of a body:

$\boxed{a = -x_m \omega^2}$

$\therefore (\omega t + \phi) = 0 \Rightarrow \cos 0 = 1$

Maximum velocity of a body: $\boxed{v = -x_m \omega}$

$f = \frac{1}{T}$

$\omega = 2\pi f$

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

$\therefore$ T is independent

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

$\therefore \omega = \sqrt{\frac{k}{m}}$

$\boxed{T = 2\pi \sqrt{\frac{m}{k}}}$

$F = -kx$ — (1) $\quad F = ma$ — (2) $\quad \cancel{F = -\omega^2 max}$ (3)

$F = m(-\omega^2 x_m)$

$\omega = \sqrt{\frac{k}{m}} \Rightarrow \omega^2 m = k$

Energy in SHM:

$\therefore$ Kinetic energy = max. at mean position.

Potential Energy $= U(t) = \frac{1}{2}kx^2$

$= \frac{1}{2}kx^2\cos^2(\omega t + \phi)$

Kinetic Energy $= \frac{1}{2}mv^2$

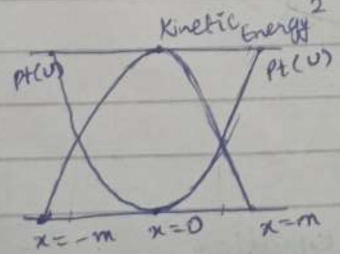
$\therefore v = -x_m \omega \sin(\omega t + \phi)$

$= \frac{1}{2}m x_m^2 \omega^2 \sin^2(\omega t + \phi)$

Total Energy $= \frac{1}{2}Kx_m^2\cos^2(\omega t + \phi) + \frac{1}{2}\underbrace{m x_m^2 \omega^2}_{(\omega^2 m = k)}\sin^2(\omega t + \phi)$

$= \frac{1}{2}kx_m^2(\cos^2(\omega t + \phi) + \sin^2(\omega t + \phi))$

$= \frac{1}{2}kx_m^2$



At $x = 0.7x_m$ (K.E = PE)

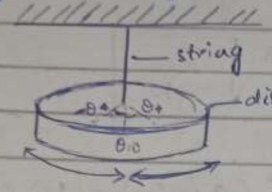
$T = \frac{2\pi}{\omega}$ $\omega = \sqrt{\frac{k}{m}}$

$1.12\,mL^2 \rightarrow$ massless rod

$\Rightarrow$ Dammed Oscillations?

CHAPTER # 15

Angular Simple Harmonic Oscillator:



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

$\boxed{T = 2\pi\sqrt{\frac{I}{K}}}$

Ideal Pendulum

Circular Pendulum.

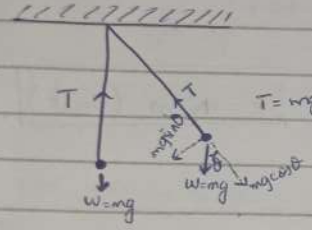
$t \propto \theta$

$t \propto -\theta$

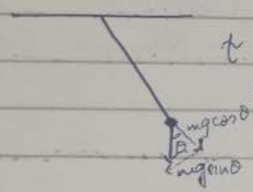
$t = -K\theta$

Kappa

$F = -Kx$



$T = mg\cos\theta \rightarrow$ cancelled.



$t = -lF$

$t = -L\,F_g(y)$

$t = -L\,mg\sin\theta$

θ = is small.

$\sin\theta = \theta$.

$t = -Lmg\theta$ — ①

$t = I\alpha$ — ②

$I\alpha = -Lmg\theta$

alpha → angular acceleration.

$\boxed{\alpha = -\frac{mgL\theta}{I}}$

$\omega = 2\pi f$

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

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

$a = -\omega^2 x$ $\alpha = -\frac{mgL\theta}{I}$

$\omega^2 = \frac{mgL}{I}$

$\boxed{\omega = \sqrt{\frac{mgL}{I}}}$

$\boxed{T = 2\pi\sqrt{\frac{I}{mgL}}}$

→ Resonance ? → transfer of energy maximum
→ Forced angle oscillations ?

CWS Quiz

Simple Pendulum, Time period → $\boxed{T = 2\pi\sqrt{\frac{\ell}{g}}}$
for small angle

Physical Pendulum : Time Period → $\boxed{T = 2\pi\sqrt{\frac{I}{mgh}}}$

Q2) a) $F_{max} = ma_{max}$

$F_{max} = m\omega^2 x_m = (0.12)\cdot(10\pi)^2\cdot(0.085m) = \boxed{10\ N}$

$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.20} = 10\pi$

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

$\boxed{K = N/m \text{ (unit)}}$

Q3) $a_{max} = ?$

$a_{max} = \omega^2 x_{max}$ $\qquad \omega = 2\pi f$

$a_{max} = (2\pi f)^2 x_{max}$

$a_{max} = (2\pi(6.60))^2 \cdot (0.022m)$

$\boxed{a_{max} = 37.8\ ms^{-2}}$

Q4) a) $f = 3.0\ Hz$ $\qquad \omega = \sqrt{\frac{K}{m}}$

$m = \frac{1450kg}{4}$

$m_{each} =$ $\qquad 2\pi f = \sqrt{\frac{K}{m}}$

$(2\pi.(3.0))^2 \times \frac{1450}{4} = K$

$\boxed{K = 1.29 \times 10^5\ Nm^{-1}}$

b) $m_{total} = \frac{((73\times5)+1450)}{8}\ kg =$

$m_{each} = \frac{m_{total}}{4} =$

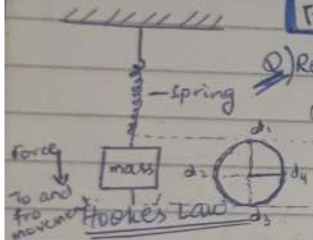
CH # 15 : Oscillations

⇒ Free Oscillation
⇒ Forced Oscillation
⇒ Resonance

* If particles within the nucleus possesses SHM, then all classical physics laws will only be in non-inertial frame of reference.
accelerated frame of reference → inertial frame of reference.
non-accelerated frame of reference → non-inertial frame of reference.

Damping → resisting force, decreases amplitude of body.

$\boxed{\text{FORCED OSCILLATION}}$



Q) Relate circular motion ~~of~~ a mass with a mass connected to a spring.

Radial force → all forces in a circular motion.
~~Displace~~

* If you apply an external force to a system and it moves around a fixed position then in terms of circular motion, their displacement will be in quadrant intervals.

⇒ displacement equation:

$$\boxed{x = x_m \cos(\omega t + \phi)}$$

x_m → maximum displacement ϕ → phase ω → angular velocity
↓
angle between 2 different oscillations.

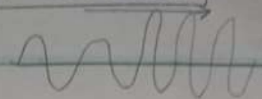
⇒ Velocity equation:

$$\frac{dx}{dt} = -x_m \omega \sin(\omega t + \phi)$$

$$\boxed{v = -x_m \omega \sin(\omega t + \phi)}$$

Assignment # 02: Q1, 2, 3, 4, 5, 7, 9, 10, 11, 13 of Ch # 15. Sample Problem: 15.01

Due on 17th Oct '2022.



⇒ **Acceleration equation:**

$$\frac{dv}{dt} = -x_m \omega^2 \cos(\omega t + \phi)$$

$$\boxed{a = -x_m \omega^2 \cos(\omega t + \phi)}$$

Maximum Velocity of a body: $\boxed{v = x_m \omega}$

Maximum Acceleration of a body: $\boxed{a = x_m \omega^2}$

Newton's Law ⇒ $F = ma$

Hooke's Law ⇒ $F = -kx$ → for restoring force.

Q) Write the time period formula by comparing Newton and Hooke's Law.

$F = -kx$ & $F = ma$ $\qquad a = x_m \omega^2$

$$F = m(x_m \omega^2)$$

$$k \cancel{x_m} = m \cancel{x_m} \omega^2$$

$$\omega^2 = \frac{k}{m}$$

$$\Rightarrow \boxed{\omega = \sqrt{\frac{k}{m}}} \text{ (rad/sec.)}$$

$$\Rightarrow \omega = 2\pi f \qquad \therefore f = \frac{1}{T}$$

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

$$T = \frac{2\pi}{\omega} \qquad \therefore \omega = \sqrt{\frac{k}{m}}$$

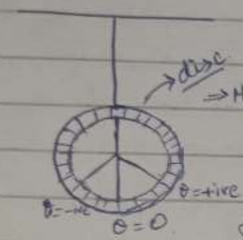
$$\boxed{T = 2\pi \sqrt{\frac{m}{k}}}$$

⇒ **Free Oscillation:** natural frequency of a body/system. If higher energy is provided, then its displacement increases which is known as **resonance**.

Newton's statement ($F=ma$) is second derivative of Hooke's law ($F=-kx$)

Pendulum ① Angular Harmonic Oscillator:

2 types of ~~angul~~ momentum → ① Linear momentum
↳ ② Angular momentum → cross product of position vector $\vec{r}$ and momentum vector $\vec{P}=\vec{r}\times\vec{p}$
↳ 2 types → ① orbital
↳ ② spring



⇒ Harmonic oscillator constant = k = kappa

$F = kx$

$\tau = k_{\kappa}\theta$ → angular displacement x replaced by theta (θ)

torque, spring constant kappa

Torque: Moment of force or turning effect.

Formulas
- Torque (τ) = moment arm × Force —①
  (perpendicular distance)
- τ = moment of inertia (I) × angular acceleration (α) (alpha) —②
- τ = moment ~~of force~~ arm (ℓ) × $\frac{\Delta P}{t}$ → change in moment —③

$T = 2\pi\sqrt{\frac{m}{k}}$

Q) ~~How~~ Calculate Time Period of angular harmonic oscillator.

$T = 2\pi\sqrt{\frac{I}{K_{\kappa}}}$.

$m = I$ → substitution in terms of Hooke's law.

$\tau \propto \theta$

$\tau \propto -\theta$

$\tau = -K_{\kappa}\theta$ (kappa)

$F = -kx$

k replaced by kappa K_{κ}

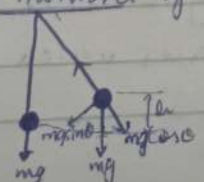
⇓

$$\boxed{T = 2\pi\sqrt{\frac{I}{K_{\kappa}}}}$$ in terms of moment of inertia.

② Circular Pendulum: Revolved complete 360 degrees and then resolved into its components. cos component is cancelled.

The moment of inertia of a circular pendulum is $\boxed{I = \frac{mg\theta}{\ell}}$

$T = mg\cos\theta$ → cancelled.



Ideal pendulum → no turbulence in height.

⇒ Could an ideal pendulum be a simple pendulum or vice versa?

⇒ Quiz on wednesday 19th October '2022. Ch # 15.

③ **Ideal Pendulum:** $I = \frac{mg\theta}{k}$ $T = 2\pi\sqrt{\frac{\theta}{k}} \Rightarrow \boxed{T = 2\pi\sqrt{\frac{I}{k}}}$

④ **Physical / Simple Pendulum:** $T = 2\pi\sqrt{\frac{l}{g}}$

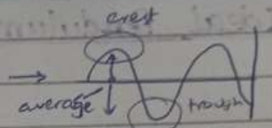
↳ no formula for inertia.

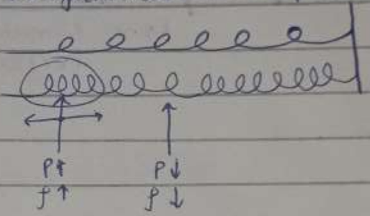
CHAPTER # 16 : WAVES

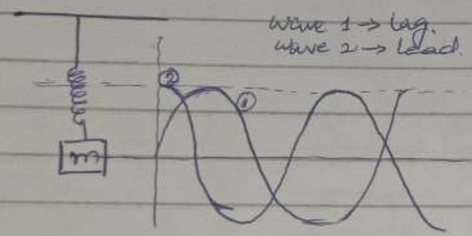
waves : → Disturbance that propagates in a medium.
↳ Transfer of energy.

3 types: → Mechanical [medium required] → Transverse →
→ E.M. Waves (Electromagnetic) [medium not required] → Longitudnal
→ Matter waves

$\lambda = \frac{h}{mv}$







$y(x,t) = y_m \sin(Kx - \omega t)$ ⇒ wave moving towards +ive (rightwards) axis.

position, time

Instantaneous Displacement

angular wave number: $K = \frac{2\pi}{\lambda}$

angular frequency: $\omega = 2\pi f$, $\omega = \frac{2\pi}{T}$

$\boxed{x = x_0 \sin\theta}$

$y(x,t) = y_m \sin(Kx + \omega t)$ ⇒ wave moving towards -ive axis. (leftwards)

$y(x,t) = y_m \sin(Kx + \omega t + \phi)$ → phase difference. ⇒ 2 waves are moving (leftwards) and both have a phase difference.

$y(x,t) = y_m \sin(Kx - \omega t + \phi)$ ⇒ 2 waves are moving (rightwards) and both have a phase difference

> **Prove wave speed:** $Kx - \omega t = \text{constant}$

$$\frac{d}{dt}(Kx - \omega t) = \frac{d}{dt}(\text{constant})$$

$$K\frac{dx}{dt} - \omega = 0$$

$$KV = \omega$$

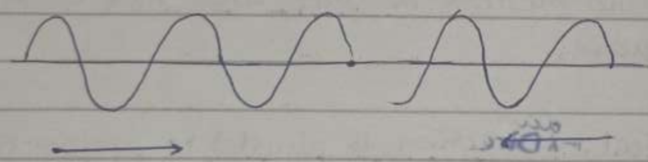
$$V = \frac{\omega}{K} = \frac{2\pi f}{2\pi/\lambda} \Rightarrow \boxed{V = f\lambda}$$

PRINCIPAL OF SUPERPOSITION:

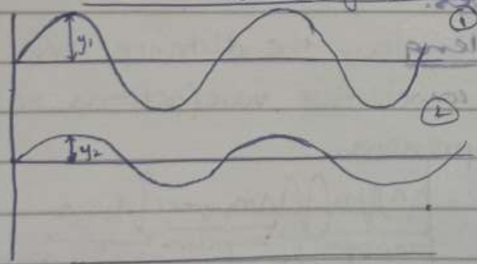
when a certain medium comes in condition of simultaneous

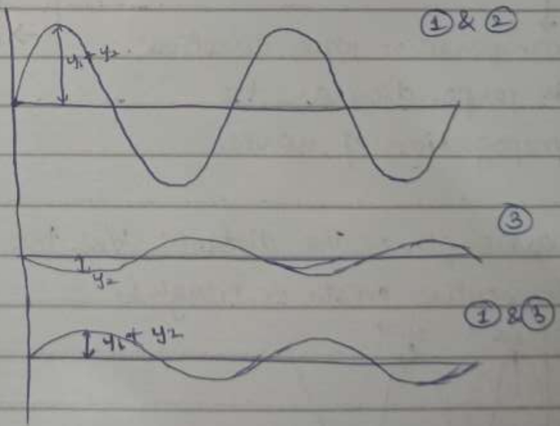
1. Same Nature
2. Same frequency
3. Same medium
4. Same direction

— Interference — Constructive / Destructive



Same Nature of Waves





CHAPTER # 16 : WAVES

Waves: Disturbance in a medium. To and fro motion of waves (SHM). It is transfer of energy.

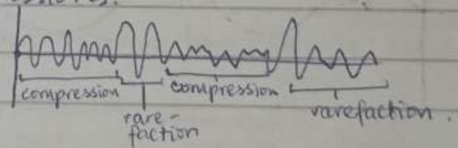
$\boxed{\text{2 types}}$

- → Mechanical :- required medium, e.g. sound.
- → Electromechanical :- not requires medium, e.g. light.

Radio waves → generated by amplification of sound waves.
↳ certain frequency at which radio waves and sound waves frequency are coinciding. We can amplify sound waves to convert them into radio waves. At that, their frequency is known as threshold frequency. ~~At that point~~ Radio waves are used by astronauts in space to communicate as no medium in space and radio waves are example of ~~et~~ E.M waves.

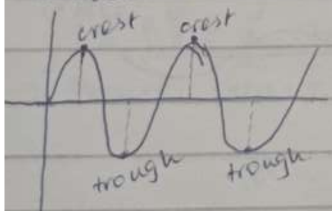
Mechanical ⟶ Longitudinal :- wave Direction is parallel to propogation of waves.

↳ wavelength :- the distance b/w two consecutive rarefactions or compressions.



Transverse :- wave direction is perpendicular to propogation of waves.

→ wavelength :- The distance b/w two consecutive crests or troughs.



Young's Phenomenon: A wave can be a wave and a particle at the same time. Thus, E.M waves do not require a medium.

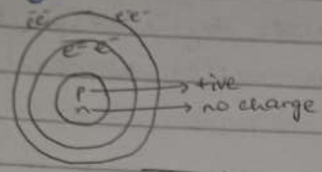
Superposition principle → unification of particles.

$\boxed{20 - 20{,}000 \text{ Hz}}$ → Audible frequency for humans.

Matter waves? According to theory of relativity, atom is divisible, when their particles unify themselves by superposition principle, they generate a wave known as matter waves.

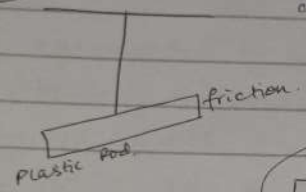
CHAPTER # 11 : COULOMB'S LAW

Charge : → Intrinsic Property.

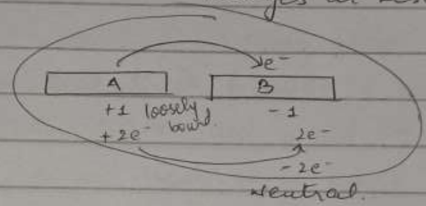


$p = e$ $+ive = -ive$ } Neutral

Charge in the universe is either conserved or neutral.



Electrostatics
↓
charges at Rest.



Charge is Quantized:

$Q = \pm 1e \cdot \pm 2e \cdot \pm 3e \cdot$ —

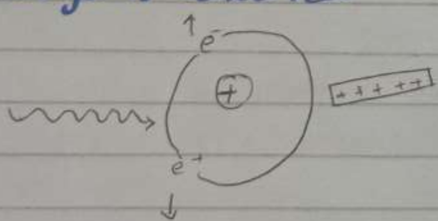
$Q = \pm ne$

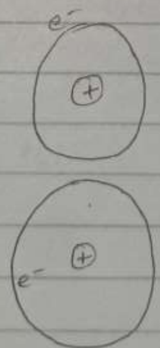
$\boxed{1e = 1.6 \times 10^{-19} C}$

$\frac{1e}{1.6 \times 10^{-19}} = 1C$

$\boxed{1C = 6.25 \times 10^{18} e}$

Charge is Conserved





$\gamma = e^- + e^+$

$e^- + e^+ \rightarrow {}^{1}_{0}\gamma + {}^{1}_{0}\gamma$

${}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{141}_{52}Ba + {}_{40}Kr + 3\,{}^{1}_{0}n$

<u>dipole</u> :- opposite charges of same magnitude separated by a small distance.

$I = \frac{Q}{t} = \frac{ne}{t}$

$t = 20\mu s$

$= 20 \times 10^{-6} s$

$\boxed{Q = It}$

$\boxed{\frac{It}{e} = n}$

q_1 air q_2

q_1 wood q_2

$\boxed{\begin{array}{l} \varepsilon_r > 1 \\ F_{med} < F_{vacuum} \\ \text{Metal} \end{array}}$

$\varepsilon_r = \frac{\varepsilon_{medium}}{\varepsilon_0} \Rightarrow \varepsilon_{med} = \varepsilon_r \varepsilon_0$

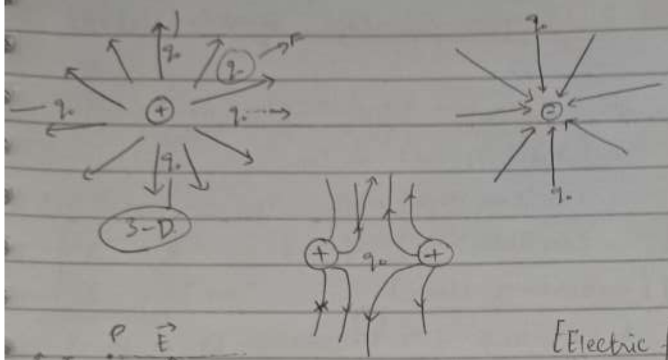
$F_{medium} = \frac{1}{4\pi\varepsilon_{med}} \cdot \frac{q_1 q_2}{r^2}$

$F_{med} = \frac{1}{4\pi\varepsilon_0\varepsilon_r} \cdot \frac{q_1 q_2}{r^2}$

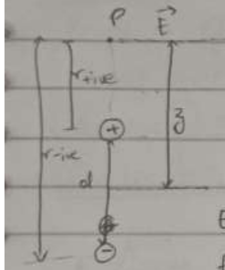
$F_{med} = \frac{F_{vac}}{\varepsilon_r}$

q_1 +ive equal. q_2 -ive

$E = \frac{F}{q_0} = \frac{\left[\frac{Kqq_0}{r^2}\right]}{q_0} = \boxed{\frac{Kq}{r^2} = E}$ (Electric field)



[Electric field due to an electric dipole - DERIVATION]



$r_{+ive} = z - \frac{1}{2}d$

$r_{-ive} = z + \frac{1}{2}d$

$E = E_{+ive} + E_{-ive}$

$E = \frac{Kq}{r_{+ive}^2} + \frac{K(-q)}{r_{-ive}^2}$

$E = \frac{Kq}{r_{+ive}^2} - \frac{Kq}{r_{-ive}^2}$

in terms of z.

$E = \frac{Kq}{(z - \frac{d}{2})^2} - \frac{Kq}{(z + \frac{d}{2})^2}$

$E = \frac{Kq}{z^2(1 - \frac{d}{2z})^2} - \frac{Kq}{z^2(1 + \frac{d}{2z})^2}$

$E = \frac{Kq}{z^2}\left[\frac{1}{(1 - \frac{d}{2z})^2} - \frac{1}{(1 + \frac{d}{2z})^2}\right]$

$E = \frac{Kq}{z^2}\left[\left(1 - \frac{d}{2z}\right)^{-2} - \left(1 + \frac{d}{2z}\right)^{-2}\right]$

$$\boxed{E = \frac{1}{2\pi\varepsilon_0} \cdot \frac{\vec{p}}{z^3}}$$

$= \frac{Kq}{(z - \frac{d}{2})^2}$

$= \frac{Kq}{z^2(1 - \frac{d}{2z})^2}$

$\therefore (1+x)^n = 1 + nx + N.T$

$$E = \frac{Kq}{z^2}\left(\frac{2d}{z}\right)$$

$$E = \frac{1}{2\cancel{4}\pi\varepsilon_0}\frac{q}{z^3}\cancel{2}d$$

$$E = \frac{1}{2\pi\varepsilon_0}\frac{qd}{z^3}$$

$$\boxed{qd = \text{dipole moment } (\vec{P})}$$

→ Transition temperature?
chemically pure water is an insulator.

→ Super conductors: zero resistance, pure conductors, e.g. ~~chemically pure water~~, aluminium, etc. ↳ in its purest form.

→ Conductors: large no. of e^- free to move
→ Non-conductors: insulators — e^- not free to move
→ Semi-conductors: intermediate conductors b/w conductors and insulators → e.g. silicon & germanium.

CHAPTER # 21 : Electrostatics

Grounding: providing a conducting path b/w charged object and ground (via conductors) neutralizes the object. Flow of charges

$1C = 1 AS$
coulomb · Ampere · second

Electric charge: (1) intrinsic property of matter. It is also a property of a particle.

Charge on body defined → charge with reference to one on particle.

(1) electron (e^-) → position (e^+) (anti particle)

(2) Proton → anti-proton (anti particle)

$^{238}U \rightarrow {}^{234}Th + {}^{4}He$
Uranium · thorium
Radioactive decay of nuclei. Charge is conserved.

$e^- + e^+ \rightarrow \gamma + \gamma$ (annihilation)
$\gamma \rightarrow e^- + e^+$ (pair production)
(gamma rays)
— Conservation of charge examples

* Net electric charge of any isolated system is always conserved.

Property of charge → (2) it is quantized. (3) Charge is conserved.

Total charge on body ↳ $Q = ne$ $\boxed{e = 1.6 \times 10^{-19}\ C}$ ⇒ magnitude of charge of electron & proton.
= elementary charge

Ampere's Law → charge also exists outside the surface.

⇒ **Coulomb's Law** $\boxed{F = \frac{K q q_0}{r^2}}$ → difference lies in point charge and test charge. ⇒ Electrostatic force $F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q q_0}{r^2}$

A charge or field described with reference to other charges →

Point charge → Reference charge (q)

Test charge → (q_0)

Shell theorem and gravitational force law.

q · r · q_0
F_1 · F_2

→ if direction of force ⇒ representation will be: F_{12} = Net coulomb's Force.

← → if direction of force ⇒ representation will be: F_{21} = Net Coulomb's Force.

$\boxed{k = 9 \times 10^9\ Nm^2C^{-2}}$ → electrostatic constant or Coulomb's law constant.

$K = \frac{1}{4\pi\varepsilon_0}$ ⇒ permitivity of free space ↳ medium b/w 2 charges.

Coulomb's law is only valid when there is a medium.

$\frac{\varepsilon_M}{\varepsilon_0}$ = Dielectric constant. (ε_M → medium)

$\boxed{\varepsilon_0 = 8.85 \times 10^{-12}\ C^2N^{-1}m^{-2}}$

* Charge can not be written in decimal form. It is quantized.

⇒ Newton's Law: Gravitational force ⇒ $\boxed{F = \frac{G m_1 m_2}{r^2}}$
r → separation b/w both particles.

Newton's law of gravitation: $F = \frac{G M m}{r^2}$, G is gravitational constant: $6.67 \times 10^{-11}\ Nm^2kg^{-2}$

proton
elementary charge

the surface.

ies in
arge and test ⇒

Electrostatic force

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q \cdot q_0}{r^2}$$

to other charges →

n
= Net Coulom

ation
F_{21} = Net Cou

⇒ permitivity
↳ medium b/w

Shell theorem & gravitational force law:-

⇒ A shell of uniform charge attracts or repels a charged particle outside shell as if shell's charge is concentrated at its center.

⇒ If charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell.

=> ...well theory 1&2 ?

Electric current formula -> derivative of charge

1. $K = \dfrac{1}{4\pi \varepsilon_0 \varepsilon_r}$

$\varepsilon_0 = 8.6 \times 10^{-12}\ C^2 N^{-1} m^{-2}$

Ke

2. $Q = ne$ ($e \Rightarrow$ elementary charge) $\boxed{e = 1.602 \times 10^{-19} C}$

3. $F = \dfrac{K q_0 q}{r^2}$

4. (Relative Permitivity) $\varepsilon_r = \varepsilon_0$ (Relative permitivity of free space) $\times$ D (Dielectric constant)

5. $\dfrac{\varepsilon_M}{\varepsilon_0}$ = Dielectric constant.

6. $I = \dfrac{dq}{dt}$

7. $\cancel{\varepsilon_r = \varepsilon_0}$ $K = \dfrac{1}{4\pi\varepsilon_0}$ $\boxed{K = 9 \times 10^9\ Nm^2 C^{-2}}$

=

direction directly away from the point charge if q is +ive and towards the point charge if q is -ive.

$\vec{E} = \frac{F}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q q_0}{r^2} \times \frac{1}{q_0}$ (electric field intensity)

$\boxed{E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}}$ $\boxed{\text{Unit} = N/C}$ ⇒ due to a point charge

q_0 — reference charge
— test charge

CHAPTER #22

Electric Field

⇒ (E) Electric field intensity stronger/larger when field lines are close together and small when they are far apart.

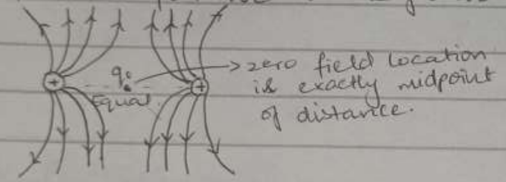
Electric field:- Charge experiences electrostatic force in this region.

⇒ Conventional flow of a charge is from positive to negative.

Zero field location: (depends on nature and magnitude of charge).

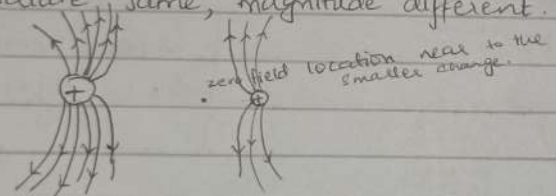
⇒ Same in nature and size (magnitude). — Case ①.

two ~~positive~~ charges of equal and same magnitude and ~~#~~ nature (positive - positive or negative - negative).



⇒ Electric field vector would be tangent to the field lines through that point.

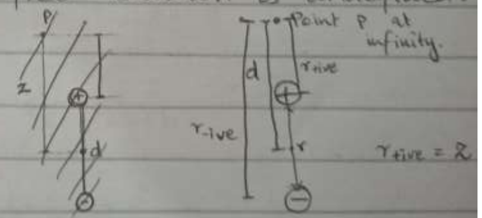
⇒ Nature same, magnitude different. — Case ②



⇒ Nature different, whatever the magnitude is. — Case ③

⊕ Infinity ⊖

Q) Calculate $\vec{E}$ of a dipole where zero field location is undefined.
(→ Case ③ applies here)

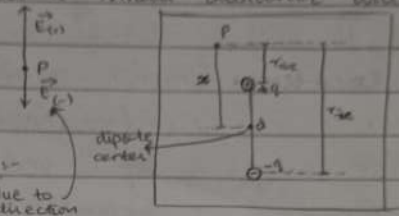


zero field of charges?
→ Calculate electric field intensity of 2 charges?
→ Dipole question (binomial)

Principle of Superposition – unification of particles

Q) Calculate the intensity of dipole $(\vec{E})$ by binomial theorem.
(Two opposite charges placed at a small distance will maintain a dipole)

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$



Principle of Superposition Applied:-

$$E = E_{+ive} + (-E_{-ive})$$ → minus sign due to opposite direction

$$E = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r^2_{+ive}} \cancel{+} - \frac{1}{4\pi\varepsilon_0}\frac{|(-q)|}{r^2_{-ive}}$$

$r_{+ive} = x - \frac{1}{2}d$

$r_{-ive} = x + \frac{1}{2}d$

$$E = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r^2_{+ive}} \cancel{+} - \frac{1}{r^2_{-ive}}\right)$$

$$E = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{\left(x-\frac{d}{2}\right)^2} - \cancel{+}\frac{1}{\left(x+\frac{d}{2}\right)^2}\right)$$

$$E = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{x^2}\right)\left[\frac{1}{\left(1-\frac{d}{2x}\right)^2} - \cancel{+}\frac{1}{\left(1+\frac{d}{2x}\right)^2}\right]$$

Binomial Theorem :-
$(1+x)^n = 1 + nx +$ neglected terms

$$E = \frac{q}{4\pi\varepsilon_0 x^2}\left[\left(1-\frac{d}{2x}\right)^{-2} - \cancel{+}\left(1+\frac{d}{2x}\right)^{-2}\right]$$

Apply binomial theorem:-

$$E = \frac{q}{4\pi\varepsilon_0 x^2}\left[\left[1+(-\cancel{2})\left(-\frac{d}{\cancel{2}x}\right)\right] \cancel{+} - \left[1+(-\cancel{2})\left(\frac{d}{\cancel{2}x}\right)\right]\right]$$

$$E = \frac{q}{4\pi\varepsilon_0 x^2}\left[\left[1+\frac{d}{x}\right] - \left[1-\frac{d}{x}\right]\right]$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{x^2}\left[\cancel{1}+\frac{d}{x} - \cancel{1} + \frac{d}{x}\right]$$

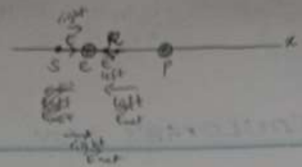
$$E = \frac{1}{\cancel{2}\cancel{4}\pi\varepsilon_0}\cdot\frac{q}{x^2}\cdot\left[\frac{\cancel{2}d}{x}\right]$$

$\therefore \vec{P} = qd.$ → unit: Coulomb meter
(dipole moment)

$$E = \frac{1}{2\pi\varepsilon_0}\cdot\frac{qd}{x^3}$$

$fm = 10^{-15} m$

$nm = 10^{-9} m$

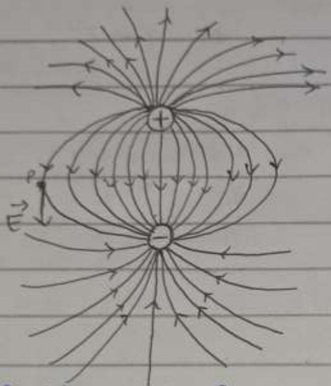


$\vec{F} = q\vec{E}$ → if q is proton ⇒ +ive the $\vec{E}$ would be -ive and vice versa.

↳ direction of $\vec{E}$ depends on sign of charge ⇒ -ive or +ive.

$$\boxed{\vec{E} = \frac{1}{2\pi\varepsilon_0} \cdot \frac{\vec{p}}{z^3}}$$

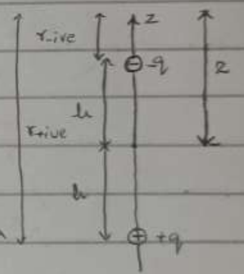
$\vec{p}$ → direction taken to be from -ive to +ive end of dipole. Use this direction of to specify orientation of dipole.



⇒ Both point charges equal in magnitude.

⇒ Electric field vector is tangent to the field line through the point.

Sample Problem 22.02:



$\vec{E} = \frac{1}{2\pi\varepsilon_0} \cdot \frac{\vec{p}}{z^3}$ $\quad \vec{p} = qd$. $\quad d = 2h$.

$z_1 = 30\,km = 30 \times 10^3 m$

$z_2 = 60\,km = 60 \times 10^3 m$.

$q = 200C$

$h = 6\,km = 6.0 \times 10^3 m$

At z_1: $\vec{E} = \frac{1}{2\pi\varepsilon_0} \cdot \frac{q(2h)}{z^3}$

$$\vec{E} = \frac{1}{2\pi\varepsilon_0} \cdot \frac{(200C)(2)(6.0 \times 10^3 m)}{(30 \times 10^3 m)^3}$$

$$\boxed{\vec{E} = 1.6 \times 10^3 NC^{-1}}$$

At z_2: $\vec{E} = \frac{1}{2\pi\varepsilon_0} \cdot \frac{(200C)(2)(6.0 \times 10^3 m)}{(60 \times 10^3 m)^3}$

$$\boxed{\vec{E} = 2.0 \times 10^2 NC^{-1}}$$

If the magnitude of an electric field exceeds certain critical value E_c, air undergoes electrical breakdown where the field removes electrons from the atoms in air. Air begins to conduct electric current as free e^- propelled into motion by field. They collide w/ atoms in their path causing these atoms to emit light.

Electrical breakdown and Sparking

Path taken by free e^- called sparks.

Line/Linear charge density: $\lambda = \frac{q}{L} = \frac{q}{r\theta}$ (Cm^{-1})

Surface charge density: $\sigma = \frac{q}{\pi r^2}$ (circle)

$\sigma = \frac{q}{4\pi r^2}$ (sphere) (Cm^{-2})

Volume charge density: $\rho = \frac{q}{\frac{4}{3}\pi r^3}$ (sphere) (Cm^{-3})

Charge distribution for any metal is only on the surface.

CH # 21 : COULOMB'S LAW

Sample Problems:-

②

$$\vec{F_1} + \vec{F_2} = 0$$

$$\vec{F_1} = -\vec{F_2}$$

$$F_1 = F_2$$

$$\frac{1}{4\pi\epsilon_0} \cdot \frac{q q_0}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q q_0}{r^2}$$

$$\cancel{\frac{1}{4\pi\epsilon_0}} \cdot \frac{\overset{4}{\cancel{8}} q \cancel{q_0}}{x^2} = \cancel{\frac{1}{4\pi\epsilon_0}} \cdot \frac{\overset{1}{\cancel{2}} q \cancel{q_0}}{(x-L)^2}$$

$$\frac{4}{x^2} = \frac{1}{(x-L)^2}$$

$$\frac{(x-L)^2}{x^2} = \frac{1}{4}$$

$$\left(\frac{x-L}{x}\right)^2 = \frac{1}{4}$$

$$\frac{x-L}{x} = \sqrt{\frac{1}{4}}$$

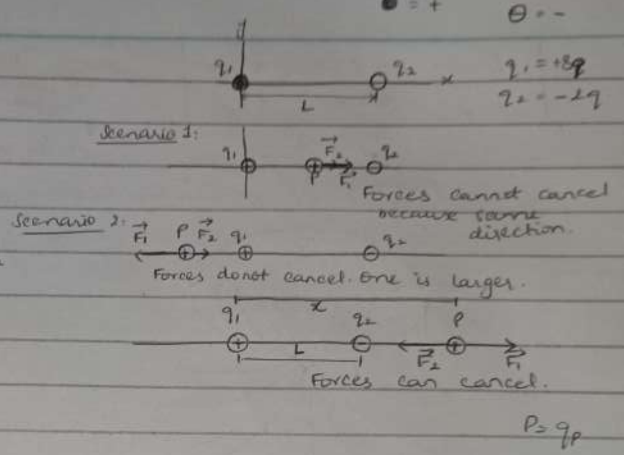
$$\frac{x-L}{x} = \frac{1}{2}$$

$$2(x-L) = x$$

$$2x - 2L = x$$

$$2x - x = 2L$$

$$\boxed{x = 2L}$$ unstable equilibrium.



∴ If proton displaced leftwards, F_1 and F_2 both increase but q_2 being closer than q_1 makes F_2 increase more and net force will drive the proton further leftwards. If the proton is displaced rightwards, F_1 and F_2 both decrease but F_2 decreases more, net force will drive the proton further rightward.

∴ In an equilibrium, if proton is displaced slightly, it returns to the equilibrium position.

$\Rightarrow$ electrically isolated and grounding?

3. a) $F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q q_0}{r^2}$

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\left(\frac{Q}{2}\right)\left(\frac{Q}{2}\right)}{a^2}$

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{4a^2}$

$\boxed{F = \frac{1}{16\pi\varepsilon_0} \cdot \left(\frac{Q}{a}\right)^2}$

b) q_1 becomes 0. Thus, electrostatic force is zero again.

4. a) $F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q q_0}{r^2}$

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\cancel{q}(e)(e)}{r^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{r^2}$

$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(1.602\times10^{-19})}{(4.0\times10^{-15})}$

$\boxed{F = 14N}$

b) $F = \frac{GmM}{r^2} = \frac{G(m)(m)}{r^2}$

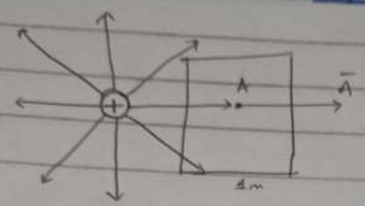
$F = \frac{Gm_p^2}{r^2}$

$F = \frac{(6.67\times10^{-11})(1.67\times10^{-27})^2}{(4.0\times10^{-15})^2}$

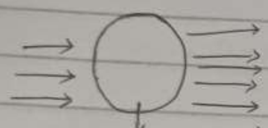
$\boxed{F = 1.2\times10^{-35} N}$

CHAPTER # 23

Gauss's Law



$\Phi_e \rightarrow$ no. of field lines passing through area.



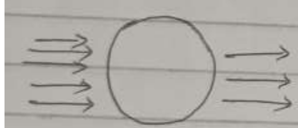
$\boxed{\text{flux} = 1}$

$\Phi_e = E \cdot A$

$= EA\cos\theta$

$\theta = 0$

source exists because flux in < flux out. $\Phi_e = EA$ (max)



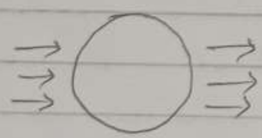
$\boxed{\text{flux} = -\text{ive}}$

$\theta = 90°$

$\boxed{\Phi_e = 0}$

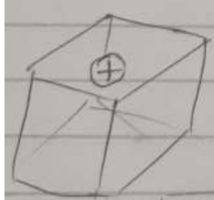
sink exists because flux in > flux out.

~~source~~ lines ~~flux~~ being absorbed



$\boxed{\text{flux} = 0}$

$\boxed{\Phi_e = E \cdot A}$ – for single phase



→ flux formula = sum of flux passing through all phases.

$\boxed{\Phi_e = \Sigma E \cdot A}$ → for multiple phases.

$\boxed{\Phi_e = \oint E \cdot dA}$ → for irregular and multiple phases.

when Σ reduced to very small then integration.

* Gauss's Law is used to calculate Electric field intensity due to charge distribution.

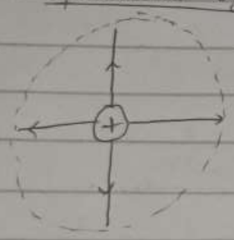
$$\boxed{\phi_e = \frac{q_{enclosed}}{\varepsilon_0}}$$

charge enclosed.

$$\frac{q_{enclosed}}{\varepsilon_0} = \oint E \cdot dA$$

$$\boxed{q_{enclosed} = \varepsilon_0 \oint E \cdot dA}$$

① Spherical Symmetry.



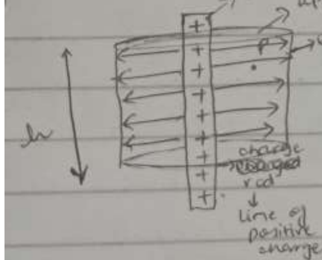
$$q_{en} = \varepsilon_0 \oint E\, dA$$

$$q_{en} = \varepsilon_0 E \oint dA$$

$$q_{en} = \varepsilon_0 E \; 4\pi r^2 \qquad \rightarrow \text{Area of sphere } 4\pi r^2.$$

$$\boxed{E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}}$$

② Cylindrical Symmetry



$$q_{en} = \varepsilon_0 \oint E \cdot dA$$

$$q_{en} = \varepsilon_0 E \oint dA$$

$$q_{en} = \varepsilon_0 E \; 2\pi r h.$$

$$\lambda \cancel{h} = \varepsilon_0 E \; 2\pi r \cancel{h}$$

$$\lambda = \varepsilon_0 E \; 2\pi r$$

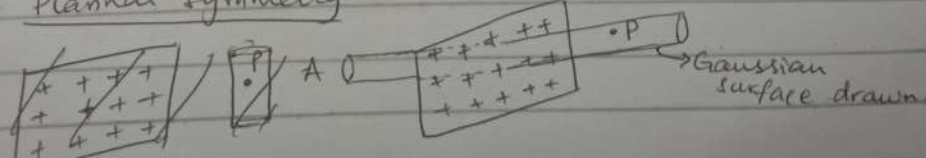
$$\boxed{E = \frac{\lambda}{2\pi r \varepsilon_0}}$$

λ → line charge density
↓
charge per unit length.

$$\lambda = \frac{q}{h}$$

$$q = \lambda h$$

③ ~~Plan~~ Plannar Symmetry



curved surface doesnot contribute $\Rightarrow$ charge doesn't pass through it.

surface charge density $\Rightarrow \sigma = \dfrac{q}{A}$

$$q_{en} = \sigma A$$

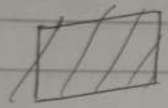
$$q_{en}\ \varepsilon_0 \oint E \cdot dA$$

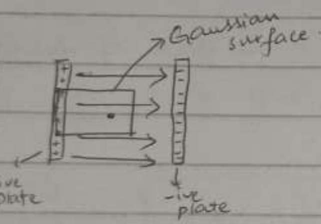
$$\sigma A = \varepsilon_0 \left(EA + EA \right)$$ $\rightarrow$ integration finished because only 2 phases left.

$$\sigma \cancel{A} = \varepsilon_0 (2E\cancel{A})$$

$$\boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

$$\boxed{E = \frac{\sigma}{2\varepsilon_0}\ \hat{r}}$$





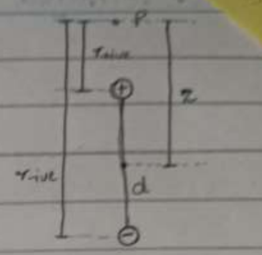
$$q_{en} = \varepsilon_0 \oint E \cdot dA$$

$$\sigma \cancel{A} = \varepsilon_0 (E\cancel{A})$$

$$\boxed{E = \frac{\sigma}{\varepsilon_0}}$$

CHAPTER 22 DERIVATION:

Electric field due to an electric dipole:



Applying Principle of superposition:-

$$E = E_{(+)} + (-E_{(-)})$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{|q|}{r_{+ive}^2} - \frac{1}{4\pi\varepsilon_0}\frac{|-q|}{r_{-ive}^2}$$

$$r_{+ive} = z - \frac{1}{2}d$$

$$r_{-ive} = z + \frac{1}{2}d$$

$$E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r_{+ive}^2} - \frac{q}{r_{-ive}^2}\right]$$

$$E = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(z-\frac{1}{2}d)^2} - \frac{q}{(z+\frac{1}{2}d)^2}\right]$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot q\left[\frac{1}{(z-\frac{1}{2}d)^2} - \frac{1}{(z+\frac{1}{2}d)^2}\right]$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot q\cdot\frac{1}{z^2}\left[\frac{1}{(1-\frac{d}{2z})^2} - \frac{1}{(1+\frac{d}{2z})^2}\right]$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{z^2}\left[\left(1-\frac{d}{2z}\right)^{-2} - \left(1+\frac{d}{2z}\right)^{-2}\right]$$

Applying Binomial Theorem:-

$$(1+x)^n = 1 + nx + (N.T)$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{z^2}\left[\left(1+(-\cancel{2})\left(-\frac{d}{\cancel{2}z}\right)\right) - \left(1+(-\cancel{2})\left(\frac{d}{\cancel{2}z}\right)\right)\right]$$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{z^2}\left[\cancel{1} + \frac{d}{z} - \cancel{1} + \frac{d}{z}\right]$$

$$E = \frac{1}{\cancel{4}_2\pi\varepsilon_0}\cdot\frac{q}{z^2}\left[\frac{\cancel{2}d}{z}\right]$$

$$\boxed{E = \frac{1}{2\pi\varepsilon_0}\cdot\frac{qd}{z^3}}$$

qd = Dipole moment ($\vec{P}$)

$$\boxed{E = \frac{1}{2\pi\varepsilon_0}\cdot\frac{\vec{P}}{z^3}}$$

• Derive formula of $\bar{E}$ from Gauss's Law:

By Applying Gauss's Law:-

$\therefore \phi = \frac{1}{\varepsilon_0} \times q_{enclosed}$

$q = \varepsilon_0 \times$ total flux

$q = \varepsilon_0 \times \bar{E} \cdot \bar{A}$

$q = \varepsilon_0 \times \bar{E} \cdot (4\pi r^2)$

$\phi = \bar{E} \cdot \bar{A}$

Surface Area of sphere is $4\pi r^2$

Rearranging:-

$$\boxed{\bar{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}} \Rightarrow \boxed{E = \frac{kq}{r^2}}$$

Applications of Gauss's Law:-

(i) A charged isolated conductor:

$\sigma = \frac{Q_{enclosed}}{A}$

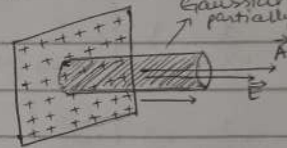
$Q_{enclosed} = \sigma A$

$\phi = \frac{1}{\varepsilon_0} \cdot Q_{enclosed}$

$\bar{E} \cdot \cancel{\bar{A}} = \frac{1}{\varepsilon_0} \cdot \sigma \cancel{\bar{A}}$

$$\boxed{\bar{E} = \frac{1}{\varepsilon_0} \cdot \sigma}$$ (conducting surface)

$\phi = \bar{E} \cdot \bar{A}$



=> Surface charge density is charge per unit area.

=> Gaussian surface is an imaginary surface and no charge is deposited on it.

(ii) Cylindrical Symmetry:

① $\phi = \frac{1}{\varepsilon_0} \times q_{enclosed}$

$\frac{1}{\varepsilon_0} \times q_{enclosed} = E \cdot A$

$\frac{1}{\varepsilon_0} \cdot \lambda \cancel{h} = E \cdot (2\pi r \cancel{h})$

$$\boxed{\bar{E} = \frac{\lambda}{2\pi\varepsilon_0 r}}$$

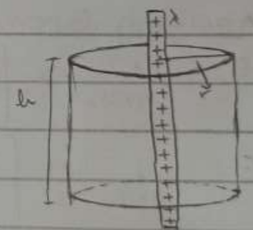
$\phi = E \cdot A$

② $q = \varepsilon_0 \times \phi$

$\lambda h = \varepsilon_0 \times \bar{E} \cdot A$

$\lambda \cancel{h} = \varepsilon_0 \times \bar{E} \cdot (2\pi r \cancel{h})$

$$\boxed{\bar{E} = \frac{\lambda}{2\pi\varepsilon_0 r}}$$



$\lambda = \frac{q}{h}$

$q = \lambda h$

$A = 2\pi r h$

CHAPTER # 23

Flux: No. of field lines passing through a surface, held perpendicular to that surface.

Φ (flux) $= \bar{E} \cdot \bar{A}$ → electric field intensity, → surface area. $\therefore E = \frac{kq}{r^2}$

$\Phi = \int E \cdot dA$

$\Phi = E \cdot \int dA$

Gauss's Law: (invalid for open symmetry. only explains closed symmetry). Flux of any closed surface is constant times total enclosed charge. To Calculate Electric field intensity due to charge distribution.

$$\Phi = \frac{1}{\varepsilon_0} \times Q_{enclosed}$$

Q) Derive the formula for $\bar{E}$ from Gauss's Law: (Sample Problem 3) (Pg 666 of book)

By using Gauss's Law :-

$q = \varepsilon_0 \times$ total flux

$q = \varepsilon_0 \times \bar{E} \cdot \bar{A}$

$q = \varepsilon_0 \times \bar{E} \cdot (4\pi r^2)$

surface area of sphere $= 4\pi r^2$

$E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2}$

$$\boxed{E = k\frac{q}{r^2}}$$

Applications of Gauss's Law:

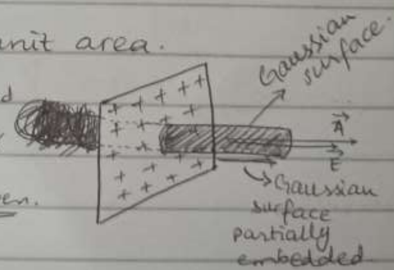
(i) A charged isolated conductor:

Surface charge density is charge per unit area.

↳ $\sigma = \frac{Q}{A}$ $\quad \Phi = \bar{E} \cdot \bar{A}$ $\quad \Phi = \frac{1}{\varepsilon_0} \cdot Q_{enclosed}$

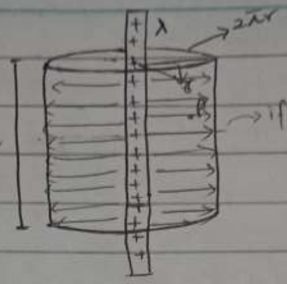
$Q_{enclosed} = \sigma A$ $\quad \bar{E} \cdot \cancel{\bar{A}} = \frac{1}{\varepsilon_0} \cdot \sigma \cancel{\bar{A}}$

$\Rightarrow \bar{E} = \frac{\sigma}{\varepsilon_0}$ $\quad \boxed{\bar{E} = \frac{\sigma}{\varepsilon_0}}$ Proven.



Gaussian Surface :- Charge not deposited on this surface.
↳ Imaginary surface.

(ii) Cylindrical Symmetry:



→ if surface distributed then $\boxed{\frac{\sigma}{2\pi\varepsilon_0}}$

$\phi = \bar{E} \cdot \bar{A}$

$\phi = EA\cos\theta$

$\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$

$\phi = \frac{1}{\varepsilon_0} \times q$

$q = \varepsilon_0 \times \phi$

$\lambda h = \varepsilon_0 \times E.A$

$\lambda \cancel{h} = \varepsilon_0 \times \bar{E} \times (2\pi r \cancel{h})$

$\boxed{\bar{E} = \frac{\lambda}{2\pi\varepsilon_0 r}}$

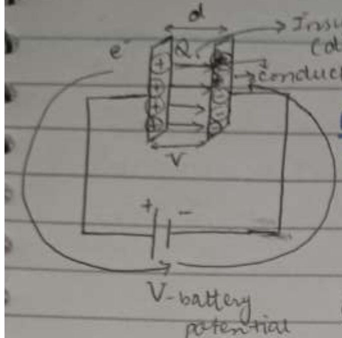
line charge density $= \frac{q}{L}$

$\lambda = \frac{q}{h}$

$q = \lambda h$

Area $= 2\pi r h$

CH#25 - Capacitance



Parallel Plate Capacitor:

Battery can store charge far as long as the charges on plate are not equal to the battery. After they are equal, capacitance of battery finishes.

Capacitance is ability of battery to store charge.

$Q \propto V$

① $\boxed{Q = CV}$

② $\boxed{C = \frac{Q}{V}}$ → Gauss's Law.

$E = \frac{-\Delta V}{\Delta r}$

$E = \frac{\Delta V}{\Delta r}$

$V = E\Delta r$

③ $\boxed{V = \int E\, dr}$

=> Capacitance does not depend on thickness of plates.

=> Capacitance depends on the facing surface area of the plates.

=> Capacitance is inversely proportional to the distance between plates.

=> $C \propto \varepsilon$, Thus, $\boxed{C = \frac{A\varepsilon_0}{d}}$ ④

for parallel plate capacitor.

⑤ Gauss's Law:-

$\varepsilon_0 \oint E\, dA = Q.$

$\varepsilon_0 E \oint dA = Q$

$\boxed{\varepsilon_0 EA = Q}$

⑥ $V = \int E\, dr$

$V = E \int dr$ → from positive to negative plate so this gives us distance.

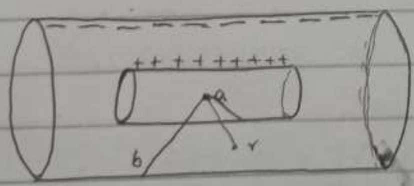
$\boxed{V = Ed}$

⑦ $C = \frac{Q}{V}$

$C = \frac{\varepsilon_0 \cancel{E} A}{\cancel{E} d}$

$\boxed{C = \frac{\varepsilon_0 A}{d}}$ Proven.

Cylindrical Capacitor:



$Q = \varepsilon_0 EA$

$Q = \varepsilon_0 E (2\pi r l)$

$E = \frac{Q}{2\pi\varepsilon_0 r l}$

$$V = \int_{-}^{+} E\,ds = -\frac{q}{2\pi\varepsilon_0 l}\int_b^a \frac{dr}{r}$$

$$V = \frac{q}{2\pi\varepsilon_0 l} \cdot \ln\left(\frac{b}{a}\right)$$

$$C = \frac{q}{V} \Rightarrow \boxed{C = 2\pi\varepsilon_0 \frac{l}{\ln\left(\frac{b}{a}\right)}}$$

$$C = \frac{q}{\frac{q}{2\pi\varepsilon_0 l} \cdot \ln\left(\frac{b}{a}\right)}$$

$$C = 2\pi\varepsilon_0 l \cdot \frac{1}{\ln\left(\frac{b}{a}\right)}$$

$$\boxed{C = 2\pi\varepsilon_0 \cdot \frac{l}{\ln\left(\frac{b}{a}\right)}}$$ Proven.

Induced Current:-

Current transferred by a coil

Produced Current:-

Current is produced by a battery.

Net Current:-

$$I = \frac{Q}{t}$$

$$I = \frac{\Delta Q}{\Delta t}$$

$$\Delta Q = I \cdot \Delta t$$

$$\boxed{Q = I \oint dt}$$

Q) What is meant by current density? → Amount of current passing through per unit area / flow of charge per unit area.

∴ Current density = $\frac{\text{flow of charge}}{\text{Area}}$

$$\boxed{J/\sigma = \frac{Q}{A}}$$

Q) What is meant by resistance and resistivity?

Resistance $\propto$ length of conductor.

Resistance $\propto \frac{1}{\text{Area of a conductor}}$

Resistance $\propto \frac{\text{length}}{\text{Area}}$

Resistance = ρ ~~Res~~ $\frac{\text{length}}{\text{Area}}$

rho is the resistivity.

Current Density and Resistivity :-

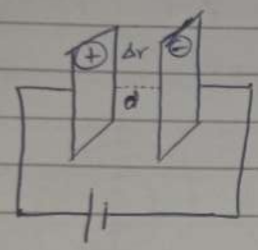
$$\boxed{\rho = \frac{E}{J}}$$

J is current density.
ρ. is resistivity.
E is the electric field.

(Sir Shehroze.)

<u>Capacitance</u>: Ability of battery to store charge.

Q) Define capacitance of a parallel plate capacitor through Gauss's Law.



$C \propto \alpha$

<u>Factors</u>:- 1) $C \propto \varepsilon_0$

2) $C \propto \frac{1}{d}$.

3) $C \propto$ Area (facing)

4) $C \not\propto$ Thickness of plates.

<u>Gauss's Law</u>:- $\Phi = \frac{1}{\varepsilon_0} \times Q_{enclosed}$.

$Q_{en} = \varepsilon_0 \times \Phi$

$Q_{en} = \varepsilon_0 \times \oint E \cdot dA$

$Q = \varepsilon_0 E \cdot \oint dA$

$Q = \varepsilon_0 E A$

$Q = CV$

$V = \int E\,dr$ → from +ive to −ive plate

$V = E \int_{-}^{+} dr$

$V = Ed$

(Electric field is the −ive gradient of Electric potential).

$\therefore E = -\frac{\Delta V}{\Delta r}$

$\Delta V = E \cdot \Delta r$

$\boxed{\Delta V = E \cdot d}$

$C = \frac{Q}{V}$

$C = \frac{(\varepsilon_0 \cancel{E} A)}{(\cancel{E} d)}$

$\boxed{C = \frac{\varepsilon_0 A}{d}}$

⇒ For a cylindrical capacitor :-

$A = 2\pi r \cdot h.$

$A = 2\pi r L.$

$C = \frac{Q}{V}$ $\quad\quad \therefore Q = \varepsilon_0 E A \quad\quad \therefore V = E.d$

$Q = \varepsilon_0 E (2\pi r L) \quad\quad V = E.L$

$C = \frac{\varepsilon_0 \cancel{E}\, 2\pi r \cancel{L}}{\cancel{E} \cdot \cancel{L}}$

$$\boxed{C = \varepsilon_0 (2\pi r)}$$

Q) Hall's effect and how can you define Hall's effect for n no. of charges per unit volume?
Q) Time period, radius?
Q) You have a moving conductor so calculate time period.

Radius: $F_c = \frac{mv^2}{r}$

magnetic force towards centre / centripetal force

$F_c = F_B$

$\frac{mv^{\cancel{2}}}{\cancel{r}} = q\cancel{v}B$

$\frac{mv}{r} = qB$

$$\boxed{r = \frac{mv}{qB}}$$

Time Period: In order to calculate time period, divide circumference by speed.

$s = vt$

$t = \frac{s}{v}$

time = $\frac{\text{circumference}}{\text{speed}}$

$t = \frac{2\pi r}{v}$ $\qquad \therefore r = \frac{mv}{qB}$

$t = \frac{2\pi}{\cancel{v}} \times \frac{m\cancel{v}}{qB}$

$$\boxed{t = \frac{2\pi m}{qB}}$$

Frequency: $f = \frac{1}{t}$ $\quad \therefore \boxed{f = \frac{qB}{2\pi m}}$

Angular velocity: $\omega = 2\pi f$

$\omega = \cancel{2\pi} \times \frac{qB}{\cancel{2\pi} m}$

$$\boxed{\omega = \frac{qB}{m}}$$

Q) How can we define force on a moving conductor?

$F = qv_dB$ $\qquad \therefore t = \frac{s}{v}$

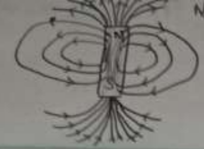
current has been generated due to movement of conductor.

$I = \frac{q}{t}$ $\quad \therefore q = I \times t$

$q = I \times \frac{s}{v}$

$q = I \times \frac{L}{v_d}$

$\therefore F = \frac{IL}{\cancel{v_d}} \times \cancel{v_d} B \Rightarrow \boxed{F = ILB}$ $\qquad \boxed{F = ILB \sin\theta}$



Magnetic field around a bar magnet.

(Sir Shehroze)

CH. 28 : Magnetic Fields

$F_B \Rightarrow$ SI unit = Tesla (T) = $\frac{\text{newton}}{(\text{coulomb})\left(\frac{\text{meter}}{\text{second}}\right)}$

1 tesla = 10^4 Gauss.

~~Define resistivity in terms of~~

Magnetic Field: Force on a charged particle.

$F_B = q\,(\vec{v} \times \vec{B})$ → direction of force dependent on $\vec{v} \times \vec{B}$ → magnetic field → speed of charged particle

if q is +ive, then F_B in direction of $\vec{v} \times \vec{B}$, else opposite.

[magnitude + direction]

Direction of force through right-hand-rule

★ $F_B = qvB\sin\theta$ → angle between vectors v and B. [magnitude only]

Q) Describe Hall effect of a charged particle on surface of a conductor.

distance ↓ force ↑
distance ↑ force ↓

Lorentz effect.

$F_E = F_B$ (force due to electric field = force due to magnetic field)

$\cancel{q}E = \cancel{q}vB$

$E = vB$ (v → drift speed) ∴ ★ $E = v_d B$ ⇒ $v_d = \frac{E}{B}$

∴ Relation b/w electric field and magnetic field.

Surface charge density → flow of charged particles.

$J = ne \times v_d$

$J = \frac{I}{A}$ ∴ $\frac{I}{A} = nev_d$

drift velocity ← $v_d = \frac{I}{Ane}$ (I → current; n → no. of charges per unit volume)

$v_d = \frac{I}{l \times d \times n \times e}$

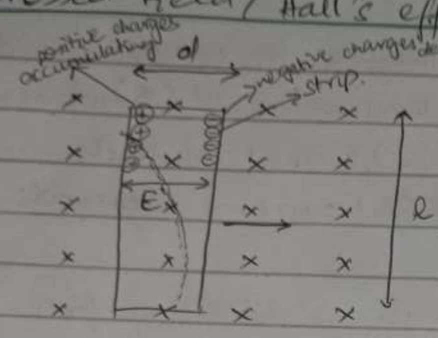
$\frac{E}{B} = \frac{I}{l \times d \times n \times e}$

$E = \frac{I}{l \times d \times n \times e} \times B$

$nE = \frac{IB}{lde}$

★ $\boxed{n = \frac{IB}{ldEe}}$ ⇒ $\boxed{\textbf{Hall's Effect}}$:- no. of charge particles on the surface of a conductor which helps in the distribution of charges.

Crossed Field / Hall's effect.



Hall potential.

$$\boxed{E = \frac{V_H}{d}} \quad (1)$$

electric force — magnetic force

$$\vec{F_E} = \vec{F_B}$$

$$eE = evB$$

$$E = vB$$

$$i = ne V_d A$$

drift velocity — $V_d = \frac{i}{neA}$ — current; $\frac{i}{A} \rightarrow J$

no. of charges per unit volume.

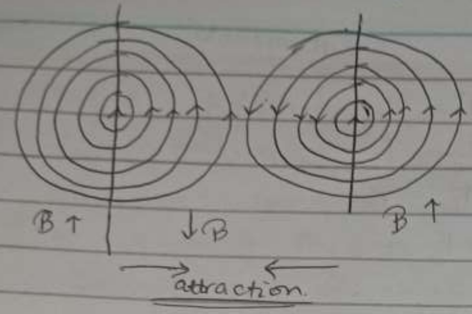
$$\boxed{E = \frac{iB}{neA}} \quad (2)$$

$$\frac{V_H}{d} = \frac{iB}{neA}$$

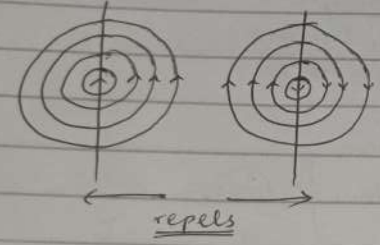
$$\frac{V_H}{\cancel{d}} = \frac{iB}{nel\cancel{d}}$$

$$\boxed{n = \frac{iB}{V_H e l}}$$

Ch 28: Magnetic Fields



- • magnetic Field (B) outward
- × magnetic Field (B) inward
- ⊙ (I) current inwards
- ⊗ (I) current outwards



Magnetic force is deflecting force.
It will only change the direction.
Speed will remain constant.
No work done. ~~s = vt~~

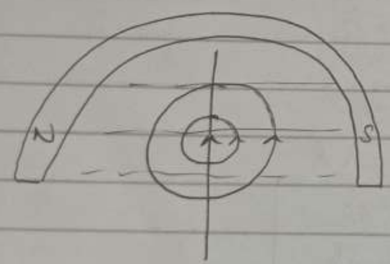
force due to magnetic field $\boxed{qV \times B}$

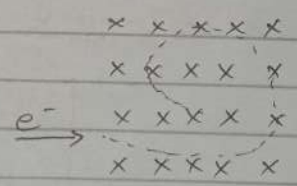
$F_B = qVB\sin\theta$ $\quad V \parallel B$

$F = eVB\sin\theta$ $\quad V$ anti parallel

$F = -eVB\sin\theta$ $\quad V \perp B$

$F = max.$





→ right hand rule shows that force will be upward.

$V \rightarrow$ moving.

$F = ILB\sin\theta$

$\boxed{F = IL \times B}$

$s = vt$

$2\pi r = vT$ $\quad e^-, e^+$

$\boxed{T = \frac{2\pi r}{v}}$

centripetal force

$F_B = F_c$

kinetic energy

$eVB = \frac{mv^2}{r} = \frac{2\,mv^2}{2r}$

$= \frac{2K.E}{r}$

$r = \frac{mv}{eB} = \frac{P}{eB}$ $\quad \boxed{r \propto \frac{m}{e}}$

$\mu_0 = 4\pi \times 10^{-7}$ T.m/A

Q) Magnetic field in terms of Ampere's Law

permeability :- measure of ability of a material to support formation of a magnetic field within itself. It's the degree of magnetization that a material obtains in response to an applied magnetic field.

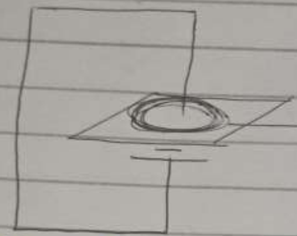
⊙ i inwards, $\vec{B}$ outwards
⊗ i outwards, $\vec{B}$ inwards •

CH 29: Ampere's Law

Ampere's Law:

Change in magnetic field produces current in that surface.

Amperian loop:



When we flow charge within a charged surface, the charged object will attain a specific shape (usually spherical) is an amperian* loop.

permeability ~~of free space~~ constant

Q) Define Ampere's law with its mathematical law.

(mui)

used for closed path.

Line Integral $\oint B.ds$ of any closed path is μ_0 times current enclosed in it.

$$\oint B.ds = \mu_0 I_{enclosed}$$

Q) Magnetic field in terms of Ampere's Law:

$$B \oint ds = \mu_0 I$$

$$B(2\pi r) = \mu_0 I$$

$$\boxed{B = \frac{\mu_0 I}{2\pi r}}$$

[Magnetic field outside a long straight wire carrying conductor]

Right Hand Rule: If charges and thumb are parallel to each other, then $\vec{B}$ will be positive. If charges and thumb are anti-parallel to each other, then $\vec{B}$ will be negative. If charged particles and thumb are perpendicular to each other or the charged particles are outside the surface, then $\vec{B}$ will be zero.

Q) Find the force on a current carrying conductor in terms of $\vec{B}$.

Force on a current carrying conductor: $F = ILB\sin\theta$

$\therefore B = \frac{\mu_0 I}{2\pi r}$

$$F = IL \cdot \left(\frac{\mu_0 I}{2\pi r}\right)\sin\theta$$

$$\boxed{F = \frac{I^2 \mu_0 L}{2\pi r}\sin\theta}$$

[magnetic field inside a long straight wire carrying conductor] :-

$$\oint \vec{B} \cdot d\vec{s} = B \oint ds = B(2\pi r)$$

$$i_{enc} = i \cdot \frac{\pi r^2}{\pi R^2}$$

$$B(2\pi r) = \mu_0 I$$

$$B = \mu_0 \left(i \cdot \frac{\pi r^2}{\pi R^2} \right) \cdot \frac{1}{2\pi r}$$

$$B = \left[\frac{\mu_0 I}{2\pi R^2} \right] r$$