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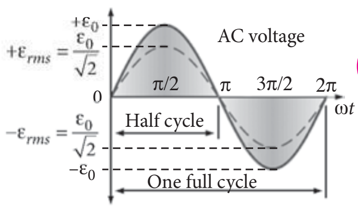
ALTERNATING CURRENT
ELECTROMAGNETIC WAVES

BRAIN MAP
CLASS XII



Alternating Current
Current which changes continuously in magnitude and periodically in direction.

Transformer
- Transformer ratios
  $$\frac{\varepsilon_S}{\varepsilon_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} = k$$
- Efficiency of a transformer,
  $$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\varepsilon_S I_S}{\varepsilon_P I_P}.$$

Step-up transformer, $\varepsilon_S > \varepsilon_P, I_S < I_P$ and $N_S > N_P$.

Step-down transformer, $\varepsilon_S < \varepsilon_P, I_S > I_P$ and $N_S < N_P$.

Alternating voltage
$\varepsilon = \varepsilon_0 \sin \omega t$

Applied across capacitor

Applied across resistor

Applied across inductor

Purely capacitive circuit
Current leads the voltage by a phase angle of $\pi/2$.
$I = I_0 \sin(\omega t + \pi/2)$; $I_0 = \frac{\varepsilon_0}{X_C} = \omega C \varepsilon_0$
where $X_C = 1/\omega C$

Purely resistive circuit
Alternating voltage is in phase with current.
$I = \varepsilon/R = I_0 \sin\omega t$

Purely inductive circuit
Current lags behind the voltage by a phase angle of $\pi/2$.
$I = I_0 \sin(\omega t - \pi/2)$; $I_0 = \varepsilon_0/X_L = \varepsilon_0/\omega L$
where $X_L = \omega L$

Combining LCR in series

Power in ac circuit
Average power (P_{av})
$$P_{av} = \varepsilon_{rms} I_{rms} \cos\phi = \frac{\varepsilon_0 I_0}{2} \cos\phi$$

Series *LCR* circuit
- $\varepsilon = \varepsilon_0 \sin\omega t$, $I = I_0 \sin(\omega t - \phi)$
  Impedance of the circuit: $Z = \sqrt{R^2 + (X_L - X_C)^2}$
- Phase difference between current and voltage is ϕ
  $$\tan\phi = \frac{X_L - X_C}{R}$$
- For $X_L > X_C$, ϕ is +ve. (Predominantly inductive)
- For $X_L < X_C$, ϕ is –ve. (Predominantly capacitive)

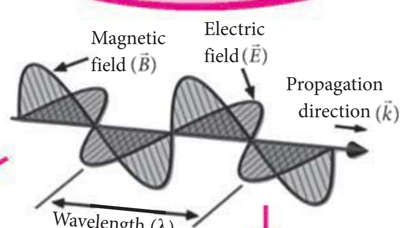
Resonant series *LCR* circuit
When $X_L = X_C$, $Z = R$, current becomes maximum.
Resonant frequency $\omega_r = \frac{1}{\sqrt{LC}}$

Power factor
- **Power factor:** $\cos\phi = \frac{R}{Z}$
- In pure resistive circuit, $\phi = 0°$; $\cos\phi = 1$
- In purely inductive or capacitive circuit
  $$\phi = \pm\frac{\pi}{2};\ \cos\phi = 0$$
- In series *LCR* circuit,
  At resonance, $X_L = X_C$
  $\therefore$ $Z = R$ and $\phi = 0°, \cos\phi = 1$

Quality factor
It is a measure of sharpness of resonance.
$$\therefore\quad Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Electromagnetic Waves
Waves having sinusoidal variation of electric and magnetic field at right angles to each other and perpendicular to direction of waves propagation.

Displacement current
Displacement current arises wherever the electric flux is changing with time.
$I_D = \varepsilon_0 d\phi_E/dt$



Energy density of electromagnetic waves
Average energy density
$$\langle u \rangle = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2}\frac{B_0^2}{\mu_0}$$
Intensity of electromagnetic wave $= \frac{1}{2}\varepsilon_0 E_0^2 c$

Production of electromagnetic waves
- Through accelerating charge
- By harmonically oscillating electric charges.
- Through oscillating electric dipoles.

Maxwell's equations
$\oint \vec{E}\cdot d\vec{S} = \frac{q}{\varepsilon_0}$ (Gauss's law for electrostatics)

$\oint \vec{B}\cdot d\vec{S} = 0$ (Gauss's law for magnetism)

$\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi_B}{dt}$ (Faraday's law of electromagnetic induction)

$\oint \vec{B}\cdot d\vec{l} = \mu_0\left(I + \varepsilon_0 \frac{d\phi_E}{dt}\right)$ (Maxwell-Ampere's circuital law)

AC CIRCUITS

BRAIN MAP

CLASS XII

Series Resonance Circuit

- At resonance : $X_L = X_C \Rightarrow Z_{min} = R$
- Phase difference : $\phi = 0° \Rightarrow \cos\phi = 1$
- Resonant frequency : $\upsilon_0 = \dfrac{1}{2\pi\sqrt{LC}}$

Quality Factor (Q-factor)

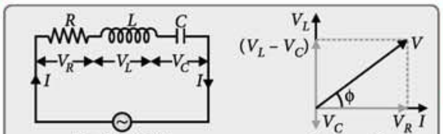
$$\text{Q-factor} = \frac{\text{Resonant frequency}}{\text{Band width}} = \frac{\omega_0}{2\Delta\omega}$$

Parallel Resonance Circuit

- At resonance : $I_C = I_L ; Z_{max} = R$
- Phase difference : $\phi = 0° \Rightarrow \cos\phi = 1$
- Resonant frequency : $\upsilon_0 = \dfrac{1}{2\pi\sqrt{LC}}$

Q-factor of Series Resonant Circuit

$$\text{Q-factor} = \frac{V_L}{V_R} \text{ or } \frac{V_C}{V_R} = \frac{\omega_0 L}{R} \text{ or } \frac{1}{\omega_0 CR} = \frac{1}{R}\sqrt{\frac{L}{C}}$$



Phasor diagram

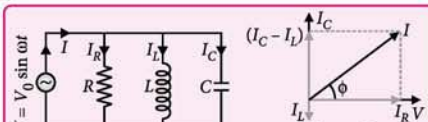
Q-factor of Parallel Resonant Circuit

$$\text{Q-factor} = R\sqrt{\frac{C}{L}}$$

Series *RLC*-Circuit

- Voltage : $V = \sqrt{V_R^2 + (V_L - V_C)^2}$
- Impedance : $Z = \sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}$
- Phase difference :

$$\phi = \tan^{-1}\frac{V_L - V_C}{V_R} = \tan^{-1}\frac{X_L - X_C}{R}$$



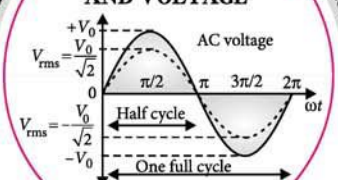
Phasor diagram

Parallel *RLC* Circuits

- Current : $I = \sqrt{I_R^2 + (I_C - I_L)^2}$
- Phase difference : $\phi = \tan^{-1}\dfrac{(I_C - I_L)}{I_R}$
- Impedance : $Z = 1\Big/\sqrt{\left(\dfrac{1}{R}\right)^2 + \left(\dfrac{1}{X_L} - \dfrac{1}{X_C}\right)^2}$

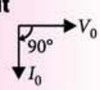
AC VOLTAGE APPLIED TO COMBINED LCR CIRCUITS

ALTERNATING CURRENT AND VOLTAGE

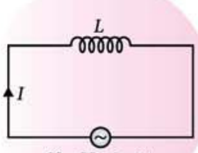


Purely Inductive Circuit

- Voltage : $V = V_0 \sin\omega t$
- Current : $I = I_0 \sin(\omega t - \pi/2)$
- Phase difference : $+(\pi/2)$
- Impedance : $X_L = \omega L$
- Peak current : $I_0 = V_0/X_L$

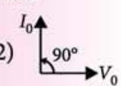


Phasor diagram (Voltage leads current by $\pi/2$)

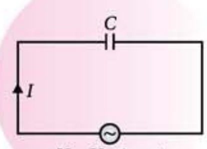


Purely Capacitive Circuit

- Voltage : $V = V_0 \sin\omega t$
- Current : $I = I_0 \sin(\omega t + \pi/2)$
- Phase difference : $-(\pi/2)$
- Impedance : $X_C = 1/\omega C$
- Peak current : $I_0 = V_0/X_C$



Phasor diagram (Current leads voltage by $\pi/2$)

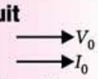


Combined *RL* circuit

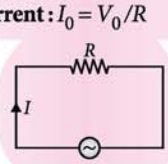
Combined *RC* circuit

Purely Resistive Circuit

- Voltage : $V = V_0 \sin\omega t$
- Current : $I = I_0 \sin\omega t$
- Phase difference : zero
- Impedance : R
- Peak current : $I_0 = V_0/R$

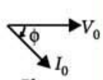


Phasor diagram (Both current and voltage are in same phase)

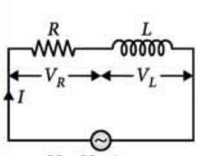


(Series *RL*-Circuit)

- Applied voltage : $V = \sqrt{V_R^2 + V_L^2}$
- Impedance : $Z = \sqrt{R^2 + 4\pi^2\upsilon^2 L^2}$
- Current : $I = I_0 \sin(\omega t - \phi)$
- Phase difference : $\phi = \tan^{-1}\dfrac{\omega L}{R}$
- Power factor : $\cos\phi = \dfrac{R}{\sqrt{R^2 + X_L^2}}$

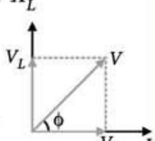


Phasor diagram



$V_R = IR,$

$V_L = IX_L$



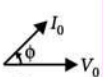
Power in AC Circuit

- Power factor : It may be defined as cosine of the angle of lag or lead (*i.e.*, $\cos\phi$)
- Average power (P_{av}) :

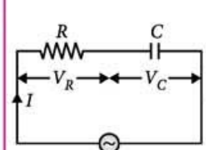
$$P_{av} = V_{rms}I_{rms}\cos\phi = (V_0 I_0/2)\cos\phi$$

(Series *RC*-Circuit)

- Applied voltage : $V = \sqrt{V_R^2 + V_C^2}$
- Impedance : $Z = \sqrt{R^2 + (1/\omega C)^2}$
- Current : $I = I_0 \sin(\omega t + \phi)$
- Phase difference : $\phi = \tan^{-1}(1/\omega CR)$
- Power factor : $\cos\phi = \dfrac{R}{\sqrt{R^2 + X_C^2}}$



Phasor diagram



$V_R = IR,$

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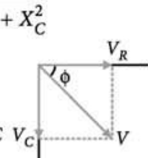

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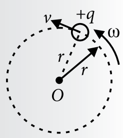
BIOT-SAVART LAW

BRAIN MAP

CLASS XII

Magnetic Field due to a Circulating Charge at Centre



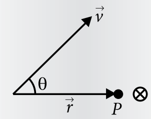
$B_0 = \frac{\mu_0}{4\pi}\frac{q\omega}{r}$

(ω is the angular velocity)

Magnetic Field due to a Moving Charge

$\vec{B} = \frac{\mu_0}{4\pi}\frac{q(\vec{v}\times\vec{r})}{r^3}$

$B = \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2}$



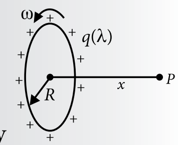
Magnetic Field on the Axis of a Spinning Charged Ring

$B = \frac{\mu_0\omega\lambda}{2}\frac{R^3}{(R^2+x^2)^{3/2}}$

At centre of the ring,

$x = 0;\ B = \frac{\mu_0\omega\lambda}{2}$

λ = linear charge density



Magnetic field at a distance R from the centre of the strip at a right angle to the strip

$B = \frac{\mu_0 I}{2\pi a}\tan^{-1}\left(\frac{a}{R}\right)$

Magnetic Field on the Axis of a Spinning Charged Non-conducting thin Disc

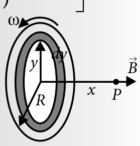
$B = \frac{\mu_0\sigma\omega}{2}\left[\frac{(R^2+2x^2)}{\sqrt{(R^2+x^2)}} - 2(x)\right]$

At the centre,

$x = 0$

$B_{centre} = \frac{\mu_0\sigma\omega R}{2}$

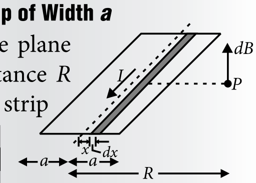
σ = surface charge density



Field due to a Current Carrying Flat Strip of Width *a*

Magnetic field in the plane of the strip at a distance R from the centre of the strip

$B = \frac{\mu_0 I}{4\pi a}\ln\left[\frac{R+a}{R-a}\right]$



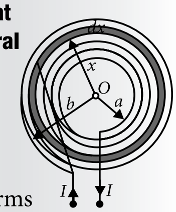
Magnetic Field at the Centre of Spiral

$B = \frac{\mu_0 NI}{2(b-a)}\ln\left(\frac{b}{a}\right)$

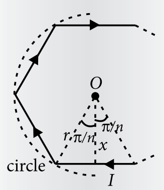
a = inner radius

b = outer radius

N = number of terms



Field due to Regular Polygon at its Centre



$B_{net} = \frac{\mu_0}{2\pi}\frac{nI}{r}\tan\frac{\pi}{n}$

(n = no. of sides of polygon)

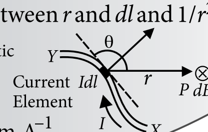
APPLICATIONS OF BIOT-SAVART LAW

BIOT-SAVART LAW

Whenever current is passed through a conductor, a magnetic field is set up around it. Magnetic field at any point was first explained by **Jean Biot (1774- 1862)** and **Felix Savart (1791-1841)**.

If dB is the magnetic field at a point P, at a distance r from element length dl, then according to this law, dB is proportional to current I, dl, sine of angle between r and dl and $1/r^2$.

$dB = k\frac{Idl\sin\theta}{r^2}$ { μ_0 is called magnetic permeability of the medium.



$k = \frac{\mu_0}{4\pi} = 10^{-7}$ T m A^{-1}

Magnetic Field due to Current Carrying Solenoid

$B = \frac{\mu_0 nI}{2}[\sin\alpha + \sin\beta]$

Inside a long solenoid,

$\alpha = \beta = 90°; B = \mu_0 nI.$

At one end of a long solenoid,

$\alpha = 0°, \beta = 90°; B = \mu_0 nI/2.$

Direction of magnetic field

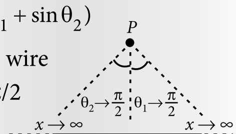
Field due to a Current Carrying Straight Wire

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

- For infinite wire

  $\theta_1 = \theta_2 = \pi/2$

  $B = \frac{\mu_0 I}{2\pi R}$



- At the end of an infinite wire

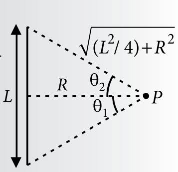
  For $\theta_1 = 0$ and $\theta_2 = \pi/2$; $B = \frac{\mu_0 I}{4\pi R}$

- Field at the perpendicular bisector of a straight wire

  $B = \frac{\mu_0 I}{4\pi R}\frac{2L}{\sqrt{L^2+4R^2}}$

  In this case

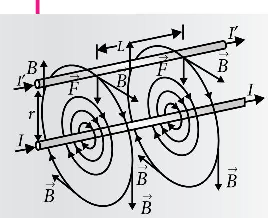
  $\theta_1 = \theta_2$



Force between Current Carrying Parallel Wires

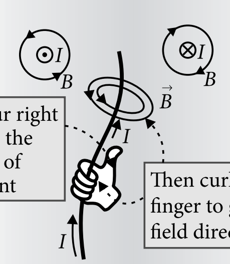
Force per unit length

$\frac{F_{21}}{L} = \frac{F_{12}}{L} = \frac{\mu_0 II'}{2\pi r}$



Right Hand Thumb Rule

Direction of magnetic field because of current carrying wire may be obtained in following way.



Point your right thumb in the direction of the current

Then curl your finger to get the field direction.

BRAIN MAP CLASS XI

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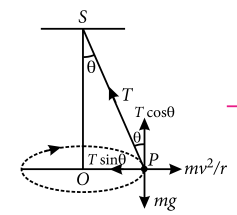
CIRCULAR MOTION

Time period $T = 2\pi\sqrt{\dfrac{l\cos\theta}{g}}$

Linear velocity $v = \sqrt{gr\tan\theta}$

Angular velocity $\omega = \sqrt{\dfrac{g}{l\cos\theta}}$



Conical Pendulum : Tension in the string

$$T = mg\sqrt{1+\left(\frac{v^2}{rg}\right)^2}$$

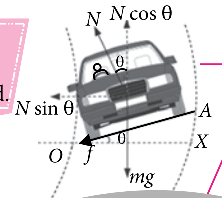
- As $F = \dfrac{mv^2}{r} \neq 0$, Particle is not in equilibrium
- $\tau_{net} = 0$ as central force is involved. *i.e.*, $p \neq$ constant but L = constant

Maximum safe speed on a banked frictional road

$$v = \sqrt{\frac{rg(\mu+\tan\theta)}{1-\mu\tan\theta}}$$

Banking of a road : Optimum speed of a vehicle on a banked road.

$v = \sqrt{rg\tan\theta}$



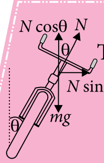
Forces

Centripetal force

$F_c = ma_c = \dfrac{mv^2}{r} = mr\omega^2$

Tangential force, $F_t = ma_t$

Net force, $F_{net} = m\sqrt{a_c^2 + a_t^2}$



Bending of a Cyclist : The cyclist should bend through an angle

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

Dynamics of Circular Motion

Tangential acceleration : $\vec{a}_t = \vec{\alpha}\times\vec{r}$

Centripetal acceleration : $\vec{a}_c = \vec{\omega}\times\vec{v}$

Uniform Circular Motion

A particle moves in a circle at a constant speed.

Kinematics of Uniform Circular Motion

CIRCULAR MOTION

Kinematics of Non-uniform Circular Motion

Non-uniform Circular Motion

Speed of the particle in a horizontal circular motion changes with respect to time.

- **Angular displacement :** It is denoted by θ. SI unit : rad or degree
- **Angular velocity (ω) :**

$$\omega = \underset{\Delta t \to 0}{Lt}\ \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$$

Motion in a Vertical Circle

Body is under the influence of gravity of earth and total mechanical energy is conserved.

Condition of Leaving the Circle

Tension in the string becomes zero before reaching the highest point

if $\sqrt{2gL} < u < \sqrt{5gL}$

Tension at any point on vertical loop :

$$T - mg\cos\theta = \frac{mv^2}{L}$$

Relations between :

- s and $\theta \Rightarrow s = r\,\theta$
- v and $\omega \Rightarrow \vec{v} = \vec{\omega}\times\vec{r}$

Condition of Looping the Loop

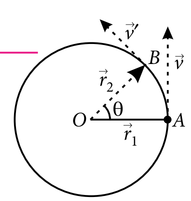
Condition of Oscillations

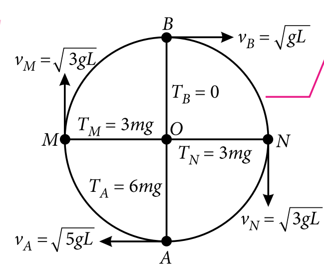
Particle will oscillate if velocity becomes zero the tension in the string is not zero.

$0 < u \leq \sqrt{2gL}$

The particle will complete the circle if

$u \geq \sqrt{5gL}$





BRAIN MAP CLASS XII

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CAPACITOR AND CAPACITANCE

$$K = \frac{\varepsilon\,(\text{Permitivity of medium})}{\varepsilon_0(\text{Permitivity of free space})}$$

Dielectric Constant

Polar dielectric

Permanent dipole moment exist in absence of electric field also.

Non-polar dielectric

Each molecule has zero dipole moment in its normal state.

For linear isotropic dielectric

$\vec{P} = \chi_e\vec{E}$ (χ_e = electrical susceptibility)

- $C' = KC$
- $U = KU_0$
- $Q = KQ_0$
- $E = E_0$
- $V = V_0$

Types of Dielectric

Dielectric is an insulator which transmits electric effect without conducting. If field exceeds the dielectric strength, the dielectric begins to conduct.

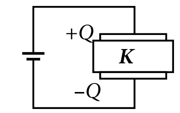
Energy Stored

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

Energy Density

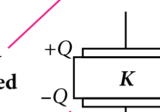
$u = \dfrac{1}{2}\varepsilon_0 E^2$

Parallel Plate Capacitor



Battery Connected

- $C' = KC$
- $Q = Q_0$
- $V = \dfrac{V_0}{K}$
- $U = \dfrac{U_0}{K}$
- $E = \dfrac{E_0}{K}$



Battery Disconnected

Energy Stored

$U = \dfrac{1}{2}QV = \dfrac{Q^2}{8\pi\varepsilon_0 a}$

Energy Density

$u = \dfrac{Q^2}{32\pi^2\varepsilon_0 r^4}$

Spherical Conductor of Radius a

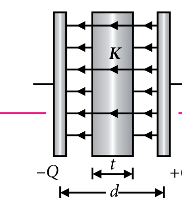
Energy Storage in a Capacitor

Dielectric and its Properties

Capacitors with Dielectrics

CAPACITOR

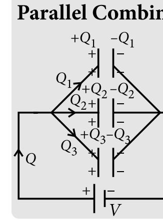
Capacitor is a passive electronic component that stores energy in the form of an electrostatic field. The ratio of charge and the potential it raised is called capacitance.



- **Partially filled dielectric**

$$C' = \frac{\varepsilon_0 A}{d - t + \dfrac{t}{K}}$$

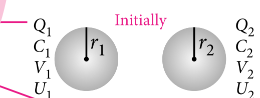
Parallel Combination



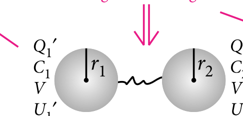
- $Q = Q_1 + Q_2 + Q_3$
- $C_{eq} = C_1 + C_2 + C_3$
- For n identical capacitor $C_{eq} = nC_1$ and $Q' = Q/n$
- Used when high capacity is required at low potential

Combination of Capacitors

Charge Sharing Between Conductors



After connecting through conducting wire



- **New charge**

$Q_1' = Q\left[\dfrac{r_1}{r_1+r_2}\right]$

$Q_2' = Q\left[\dfrac{r_2}{r_1+r_2}\right]$

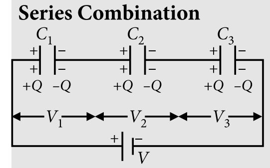
- **Common potential**

$V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$

- **Energy loss**

$\Delta U = \dfrac{C_1C_2}{2(C_1+C_2)}(V_1 - V_2)^2$

Series Combination



- $V = V_1 + V_2 + V_3$
- $\dfrac{1}{C_{eq}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$
- For n identical capacitor $C_{eq} = C/n$ and $V' = V/n$

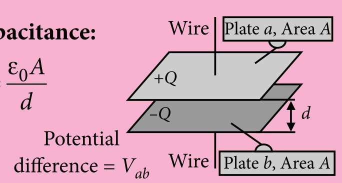
Types of Capacitors and their Capacitances

Parallel Plate Capacitor

It consists of two large plates placed parallel to each other with a separation d.

Capacitance:

$C = \dfrac{\varepsilon_0 A}{d}$



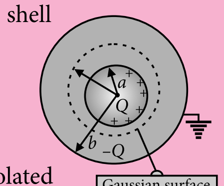
Spherical Capacitor

It consists of two concentric spherical conducting shells of radii a and b, say $b > a$. The outer shell is earthed.

Capacitance:

$C = \dfrac{4\pi\varepsilon_0 ab}{b-a}$

For a single isolated spherical conductor of radius R, $C = 4\pi\varepsilon_0 R$

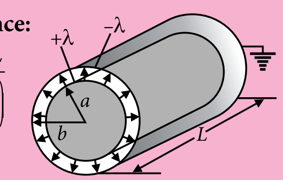


Cylindrical Capacitor

It consists of two coaxial cylinders of radii a and b, say $b > a$ and length L. The outer one is earthed.

Capacitance:

$C = \dfrac{2\pi\varepsilon_0 L}{\ln\left(\dfrac{b}{a}\right)}$



BRAIN MAP

CLASS XI

COLLISION

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CLASSIFICATION OF COLLISON

On the basis of line of impact

HEAD-ON COLLISION
The velocities of the particles are along the same line before and after the collision.

OBLIQUE COLLISION
The velocities of the particles are along different lines before and after the collision.

Head on Inelastic Collision

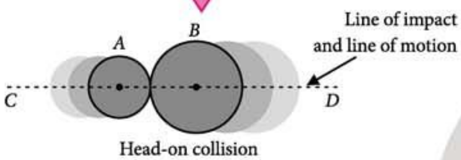
Velocity after collision :

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

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

Loss in kinetic energy :

$$(\Delta K) = \frac{1}{2}\left(\frac{m_1 m_2}{m_1 + m_2}\right)(1-e^2)(u_1 - u_2)^2$$

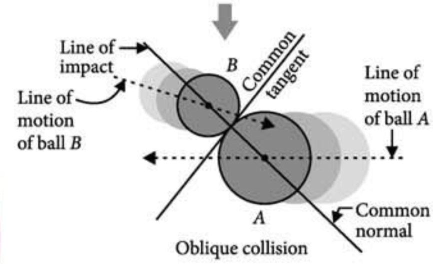


Head-on collision

In Case of Smooth Surfaces

Common normal :
Force is exerted in common normal direction only. Momentum changes in common normal direction.

Common tangent :
$F = 0$
Neither momentum nor velocity changes in common tangent direction.



Oblique collision

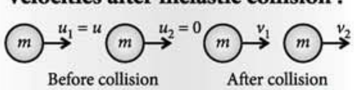
On the basis of kinetic energy

INELASTIC COLLISION
If the kinetic energy after and before collision are not equal, the collision is said to be inelastic.

PERFECTLY INELASTIC COLLISION
If velocity of separation just after collision becomes zero, then the collision is perfectly inelastic.

ELASTIC COLLISION
If the kinetic energy after and before collision is same, the collision is said to be perfectly elastic.

- **Velocities after inelastic collision :**



$$\therefore \frac{v_1}{v_2} = \frac{1-e}{1+e}$$

- **Coefficient of Restitution (e)**

$$e = \frac{\text{Velocity of separation along line of impact}}{\text{Velocity of approach along line of impact}}$$

By substituting $e = 1$, we get $\Delta K = 0$

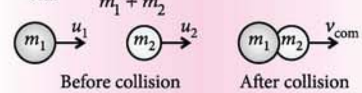
Rebounding of Ball After Collision

- **After first rebound**
  – **Speed :** $v_1 = ev_0 = e\sqrt{2gh_0}$
  – **Height :** $h_1 = e^2 h_0$
- **After n^{th} rebound :**
  – **Speed :** $v_n = e^n v_0$
  – **Height :** $h_n = e^{2n} h_0$
- **Total distance travelled by the ball before it stops bouncing :**
  $H = h_0[(1+e^2)/(1-e^2)]$

Perfectly Inelastic Collision

- **When the colliding bodies are moving in the same direction :**

$$v_{com} = \frac{m_1 u_1 + m_2 u_2}{m_1 + m_2}$$



Loss in kinetic energy

$$\Delta K = \frac{1}{2}\left(\frac{m_1 m_2}{m_1 + m_2}\right)(u_1 - u_2)^2$$

- **When the colliding bodies are moving in the opposite direction :**

$$\therefore v_{com} = \frac{m_1 u_1 - m_2 u_2}{m_1 + m_2}$$

Loss in kinetic energy

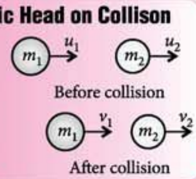
$$\Delta K = \frac{1}{2}\left(\frac{m_1 m_2}{m_1 + m_2}\right)(u_1 - u_2)^2$$

Elastic or Perfectly Elastic Head on Collison

Velocity after collision :

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

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



Special Cases

If projectile and target are of same mass
For $m_1 = m_2 \Rightarrow v_1 = u_1$ and $v_2 = u_1$
i.e., their velocities get interchanged.

If massive projectile collides with a light target
For $m_1 >> m_2 \Rightarrow v_1 = u_1$ and $v_2 = 2u_1 - u_2$
Sub case : For $u_2 = 0$, *i.e.*, target is at rest
$v_1 = u_1$ and $v_2 = 2u_1$

If light projectile collides with a heavy target
For $m_1 << m_2 \Rightarrow v_1 = -u_1 + 2u_2$ and $v_2 = u_2$
Sub case : For $u_2 = 0$, *i.e.*, target is at rest
$v_1 = -u_1$ and $v_2 = 0$, the ball rebounds with same speed.

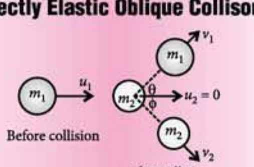
If $m_2 = nm_1$ and $u_2 = 0$
The fractional kinetic energy transferred by projectile

$$\frac{\Delta K}{K} = \frac{4n}{(1+n)^2}$$

Fractional kinetic energy retained by the projectile

$$\left(\frac{\Delta K}{K}\right)_{\text{Retained}} = 1 - \text{fractional kinetic energy transferred by projectile}$$

Perfectly Elastic Oblique Collison



After perfectly elastic oblique collision of two bodies of equal masses, the scattering angle $(\theta + \phi)$ would be 90°.

BRAIN MAP

CLASS XII

DUAL NATURE OF RADIATION AND MATTER

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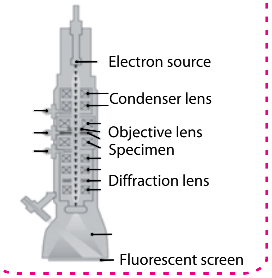
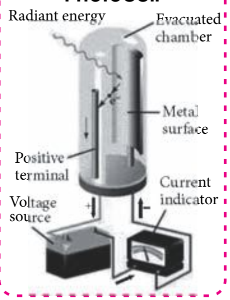
Transmission electron microscope



Photocell



Photoelectric Cell

- An electrical device which converts light energy into electrical energy, is called as photocell or photoelectric cell.
- It works on the principle of photoelectric emission of electrons.

Electron Microscope

- Electron microscope is a device designed to study very minute objects.
- Based on principle of de Broglie wave and the fast moving electrons can be focussed by E or B field in a same way as beam of light is focussed by glass lenses.

de Broglie Wavelength

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

- For electron having K.E. (K) is

$$\lambda = \frac{h}{\sqrt{2mK}}, \text{ here } p = \sqrt{2mK}$$

- For a charged particle accelerated by potential V is

$$\lambda = \frac{h}{\sqrt{2qmV}}, \text{ here } p = \sqrt{2qmV}$$

Application of Photoelectric Effect

Particle Nature of Radiation

DUAL NATURE OF RADIATION AND MATTER

Nature's Love with symmetry arises the matter-wave duality

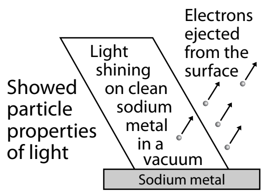
Wave Nature of Matter

Application of de Broglie Waves

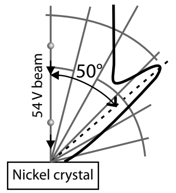
Photoelectric Effect

- The phenomenon of emission of electrons from a metal surface when an electromagnetic wave of suitable frequency is incident on it is called photoelectric effect.

Photoelectric Effect



Davisson-Germer Experiment

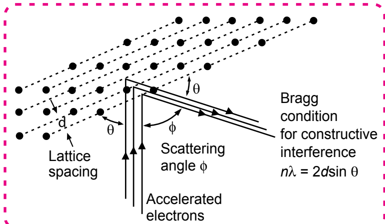


de Broglie Hypothesis

- Due to symmetry in nature, the particle in motion also possesess wave-like properties. And these waves are called matter waves.

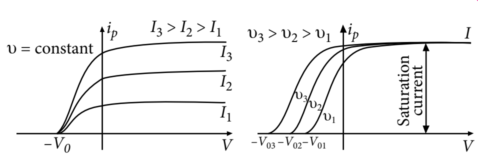
Photoelectric Equation

- $E = K_{max} + \phi_0$, where ϕ_0 = work function,
  E = energy of incident light, K_{max} = maximum K.E. of e^-
  $\Rightarrow\ h\upsilon = \frac{1}{2}mv_{max}^2 + h\upsilon_0 \ \Rightarrow\ \frac{1}{2}mv_{max}^2 = h(\upsilon - \upsilon_0)$



Experimental Study and Conclusion of Photoelectric Effect

- At constant frequency υ and potential V (Photo-current) $i_p \propto I$ (intensity)
- At constant frequency and intensity, the minimum negative potential at which the photocurrent becomes zero is called **stopping potential (V_0).**
- At stopping potential V_0, K_{max} of $e^- = eV_0$
- For a given frequency of the incident radiation, the V_0 is independent of I.
- The V_0 varies linearly with υ.



Davisson and Germer Experiment

- Study of wave nature of electron.
- At a suitable potential V, the fine beam of electrons from electron gun is allowed to strike on the nickel crystal. The electrons are scattered in all directions and following assumptions were made :
  - ➢ Intensity of scattered electrons depends over scattering angle ϕ.
  - ➢ A kink occurs in curve at ϕ = 50° for 54 eV beam.
  - ➢ The intensity is maximum at accelerating voltage 54 V. After this voltage, intensity starts decreasing.
  - ➢ Here, $\theta = \frac{1}{2}(180° - \phi) \ \Rightarrow\ \theta = 65°$ at $\phi = 50°$
    From Bragg's law (particle nature), $\lambda = 2d \sin\theta \ \Rightarrow\ \lambda = 1.65$ Å.
    Also, from wave nature at V = 54 volt, $\lambda = \frac{12.27}{\sqrt{54}} = 1.65$ Å

BRAIN MAP

CURRENT ELECTRICITY

Our society relies heavily on the convenience and versatility of electricity. It powers our microwave, helps light our house, lets us watch TV and so much more. Even it plays a role in the way our heart beats. Muscle cells in the heart are contracted by electricity going through the heart. An electrocardiogram translates the heart's electrical activity into line tracings on paper.

Ohm's Law

- $V = IR$
- Vector form, $\vec{J} = \sigma\vec{E}$, conductivity $\sigma = \frac{1}{\rho}$
- Resistance of a uniform conductor, $R = \frac{\rho l}{A}$
- Conductance, $G = \frac{1}{R}$
- Resistivity or specific resistance, $\rho = \frac{RA}{l}$

  Ohm's law is not valid for semiconductor.

Drift Speed

- Drift speed, $v_d = \frac{eE}{m}\tau$
- Mobility, $\mu_e = \frac{v_d}{E} = \frac{e\tau}{m}$
- Mobility of electron is more than that of hole.
- Current in terms of drift velocity,

  $$I = neAv_d = \frac{ne^2 A\tau E}{m} = neA\mu_e E = neA\mu_e \frac{V}{l}$$
- $\sigma = ne\mu_e$
- In terms of relaxation time τ,

  $$R = \frac{ml}{ne^2\tau A} \text{ and } \rho = \frac{m}{ne^2\tau}$$

Resistors

- Resistance of a resistor with colour code

  R = [(digit 1)(digit 2) Decimal Multiplier ± Tolerance]
- Variation of resistance with temperature,

  $R_T = R_0[1 + \alpha(T - T_0)]$

  Temperature coefficient of resistance, $\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$

  If $T_1 = 0\,°C$ and $T_2 = T\,°C$ then

  $$\alpha = \frac{R_T - R_0}{R_0 \times T} \text{ or } R_T = R_0(1 + \alpha T)$$
- Resistivity of conductor increases with increase in temperature.
- Resistivity of semiconductor decreases with increase in temperature.

Combination of Resistors

- In series, equivalent resistance

  $R_S = R_1 + R_2 + R_3 + ...$
- In parallel, equivalent resistance

  $$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$
- For two resistances in parallel current through the two resistances, $I_1 = \frac{R_2 I}{R_1 + R_2}, I_2 = \frac{R_1 I}{R_1 + R_2}$
- When resistances are connected in series, the current through each resistance is same. In parallel combination voltage is same.

Potentiometer

- Principle : Fall of potential across any portion of the wire, $V \propto l$, $V = Kl$

  Here, $K = \frac{V}{l}$ = potential gradient.
- Comparision of emfs of two cells,

  $$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$
- Internal resistance of a cell

  $$r = R\left(\frac{\varepsilon}{V} - 1\right) = R\left(\frac{l_1}{l_2} - 1\right)$$

  Here, l_1 = balancing length of potentiometer wire corresponding to emf of the cell.

  l_2 = balancing length of potentiometer wire corresponding to potential difference of the cell when a resistance R is connected in series with the cell whose internal resistance to be determined.

Electric Current

- Rate of flow of electric charge (positive)

  $$I = \frac{dQ}{dt} = \oint \vec{J} \cdot d\vec{S}$$
- J is the current density which is the current passing through a cross-section of the wire.
- Dot product of $\vec{J}$ and $d\vec{S}$ shows current is scalar inspite of this we represent current with an arrow.
- In case of an electron revolving in a circle of radius r with speed v, period of revolution of electron is $T = \frac{2\pi r}{v}$.
- Frequency of revolution $\upsilon = \frac{v}{2\pi r}$
- Current in an orbit of a moving electron with velocity v, $I = \frac{e}{T} = \frac{ev}{2\pi r}$

Flow of Charge

- $\Delta Q = I\Delta t$ (Current is constant)

  $= \int I dt$ (Current is a function of time)

  = Area under I-t graph

Kirchhoff's Rules

- **Junction Rule :** At any junction of circuit elements, the sum of currents entering the junction must be equal to the sum of currents leaving it.

  $\Sigma I = 0.$

  It is based on conservation of charge.

  So bending or reorienting the wire does not change the validity of Kirchhoff's junction rule.
- **Loop Rule :** The algebraic sum of changes in potential around any closed loop must be zero.

  $\Sigma\varepsilon = \Sigma IR$

  It is based on conservation of energy.

Sign Convention for Kirchhoff's Rules

- While traversing a closed loop (clockwise or anti clockwise) if negative pole of the cell is encountered first, then its emf is negative, otherwise positive.
- The product of resistance and current in an arm of the circuit is taken positive if the direction of current in that arm is in the same sense as one moves in a closed path and is taken negative if the direction of current in that arm is opposite to the sense as one moves in a closed path.
- This convention depends on your choice. You can go to reverse of this assumption and will get same answer.

Wheatstone Bridge

- In balanced condition,

  $$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$
- It provides a parallel method to determine the value of an unknown resistance.

Meter Bridge

- Resistance of unknown resistor,

  $$R = \frac{Sl_1}{(100 - l_1)}$$
- It is more sensitive if l_1(balance point) is close to 50 cm. This requires a suitable choice of S.

Electrical Energy and Power

- Heat energy developed across a resistor

  $H = I^2Rt$
- Power $P = I^2 R = \frac{V^2}{R}$
- For transmission cable, power loss

  $$P_C = I^2 R_C = \frac{P^2 R_C}{V_C^2}, P = \text{constant}$$

Principle of Bulb

- Resistance of bulb

  $$R = \frac{V^2}{P} \text{ or } R \propto \frac{1}{P}$$
- In parallel $P = P_1 + P_2$
- In series $\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2}$ or $P = \frac{P_1 P_2}{P_1 + P_2}$
- In $R = \frac{V^2}{P}$, V and P are rated values for that bulb.
- In parallel a bulb having more rated power glows more brightly. In series a bulb having less rated power glows more brightly.

Grouping of Batteries

- Series grouping : $I = \frac{\text{net emf}}{\text{net resistance}}$

  If there are n identical batteries of emf ε and internal resistance r, then current through external resistance R (if all batteries are additive in nature) is given by

  $$I = \frac{n\varepsilon}{nr + R}$$

  If polarity of m batteries is reversed, then

  $$I = \frac{(n - 2m)\varepsilon}{nr + R}$$
- Parallel grouping with identical batteries :

  $$I = \frac{\varepsilon_{net}}{R_{net}}$$

  Here, $\varepsilon_{net} = \varepsilon$, R_{net} = Total internal resistance + Total external resistance $= \frac{r}{n} + R$
- Parallel grouping with unidentical batteries :

  $$I = \frac{\varepsilon_{net}}{R_{net}}$$

  Here, $\varepsilon_{net} = \frac{\Sigma(\varepsilon / r)}{\Sigma(1/r)}$ ...(i)

  If any of the battery is oppositely connected, then place negative sign in numerator of eqn. (i) but, no change in denominator.
- Mixed grouping :

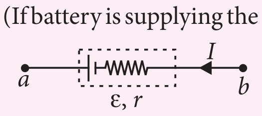
  If there are n rows of identical batteries (ε, r) with m cells in each row. Then, $I = \frac{\varepsilon_{net}}{R_{net}}$

  Here, $\varepsilon_{net} = m\varepsilon$, $R_{net} = \frac{mr}{n} + R$

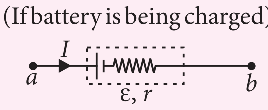
  In this case current through the external resistance is maximum when, $R = \frac{mr}{n}$

Potential Difference across the Terminals of a Battery

- $V = \varepsilon$ (If $I = 0$)
- $V = 0$ (If battery is short circuited)
- $V = \varepsilon - Ir$ (If battery is supplying the energy)



  $V = V_a - V_b = V_{ab} = \varepsilon - Ir$
- $V = \varepsilon + Ir$ (If battery is being charged)



  $V = V_a - V_b = V_{ab} = \varepsilon + Ir$

BRAIN MAP

ELECTROMAGNETIC INDUCTION

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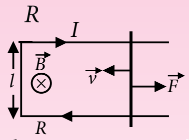
Michael Faraday

A magnetic field can produce an electric field that can drive a current. This link between a magnetic field and the electric field is now known as Faraday's law of induction. The observations by Michael Faraday and other scientists which led to this law were at first just basic science. Today, however, applications of this basic science is everywhere.

Energy Consideration in Motional emf

- Emf in the wire = Bvl
- Induced current, $I = \frac{\varepsilon}{R} = \frac{Bvl}{R}$
- Force exerted on the wire, $F = \frac{B^2l^2v}{R}$



- Power required to move the wire $P = \frac{B^2l^2v^2}{R}$

It is dissipated as Joule heat.

Quantitative idea behind motional emf

Motional emf

- On a straight conducting wire, $\varepsilon = Bvl$
- On a rotating conducting wire about one end $\varepsilon = \frac{B\omega l^2}{2}$

Here, $\vec{B}, \vec{v} (= \omega r \hat{v})$ and $\vec{l}$ are perpendicular to each other.

Special features of induced electric field

Induced Electric Field

- It is produced by change in magnetic field in a region. This is non-conservative in nature.

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt} = -A\frac{dB}{dt} \neq 0$$

- This is also known as integral form of Faraday's law.

A wire moving in B produces emf

Change in flux produces eddy current in a conducting plate

Eddy Current

- The currents induced in surface of bulk pieces of conductors when the magnetic flux linked with the conductor changes are known as Eddy currents. Slotting the conductor reduces the eddy current.
- Applications : Electromagnetic damping, Induction furnace, Electric power meter, Magnetic braking in trains.

MAGNETIC FLUX AND FARADAY'S LAW

- Magnetic flux $\phi_B = \vec{B} \cdot \vec{A} = BA\cos\theta$
- Faraday's Laws : It states that whenever magnetic flux linked with a coil changes, an emf is induced in the coil.

Induced emf, $\varepsilon = -N\frac{d\phi_B}{dt}$

Induced current, $I = \frac{\varepsilon}{R} = N\frac{(-d\phi_B/dt)}{R}$

Induced charge flow, $\Delta Q = I\Delta t = -N\frac{\Delta\phi_B}{R}$

- The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that has produced it.

Direction of induced emf/current is given by Lenz's law

Lenz's Law

- The direction of the induced current is such that it opposes the change that has induced it.
- If a current is induced by an increasing(decreasing) flux, it will weaken (strengthen) the original flux.
- It is a consequence of the law of conservation of energy.

Rotation of coil in B produces motional emf

Electric Generator

- Mechanical energy is converted into electrical energy by virtue of electromagnetic induction.
- Induced emf, $\varepsilon = NAB\omega\sin\omega t = \varepsilon_0\sin\omega t$
- Current, $I = \frac{NBA\omega}{R}\sin\omega t = I_0\sin\omega t$

Magnetic Energy

- Energy stored in an inductor $U_B = \frac{1}{2}LI^2$
- Energy stored in the solenoid, $U_B = \frac{1}{2\mu_0}B^2Al$
- Magnetic energy density, $u_B = \frac{U_B}{V} = \frac{B^2}{2\mu_0}$

Energy stored in the inductor (magnetic field)

Rate of change of current in the coil induces emf

Required inductance can be achieved by

Combination of Inductors

- Inductors in series, $L_S = L_1 + L_2 \pm 2M$
- Inductors in parallel, $L_P = \frac{L_1L_2 - M^2}{L_1 + L_2 + 2M}$
- If coils are far away, then $M = 0$

So, $L_S = L_1 + L_2$ and $L_P = \frac{L_1L_2}{L_1 + L_2}$

Inductance

- Emf induced in the coil/conductor, $\varepsilon = -L\frac{dI}{dt}$
- Coefficient of self induction

$$L = \frac{N}{I}\phi_B = \frac{-\varepsilon}{dI/dt}$$

- Self inductance of a coil $L = \frac{1}{2}\mu_0\pi N^2R$
- Self inductance of a long solenoid $L = \mu_0\mu_r n^2Al = \frac{\mu_0\mu_r N^2A}{l}$
- Mutual inductance, $M = \frac{N_2\phi_2}{I_1} = \frac{-\varepsilon_2}{(dI_1/dt)} = \frac{-\varepsilon_1}{(dI_2/dt)}$
- Mutual inductance of two closely wound circular coils, $M \propto N_1N_2$
- Mutual inductance of two long coaxial solenoids

$$M = \mu_0\mu_r\pi r_1^2 n_1 n_2 l = \frac{\mu_0\mu_r N_1N_2A_1}{l}$$

- Coefficient of coupling, $k = \frac{M}{\sqrt{L_1L_2}}$

For perfect coupling, $k = 1$ so, $M = \sqrt{L_1L_2}$

Growth/decay of current in an inductor

L – R Circuit

- Current growth in L–R circuit $I = I_0(1 - e^{-t/\tau_L})$
- Current decay in L–R circuit $I = I_0(e^{-t/\tau_L})$

Here, τ_L = Time constant = $\frac{L}{R}$

$I_0 = \frac{\varepsilon}{R}$

BRAIN MAP

ELECTROSTATICS

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In dry weather, a spark is produced by walking across certain types of carpet and then bringing one of the fingers near a metal doorknob, or even a person. Multiple sparks can be produced when a sweater or cloth is pulled from the body. It reveals that electric charge is present in our bodies, sweaters, carpets, doorknobs, computers etc. In fact, every object contains a vast amount of electric charge.

Coulomb's Law

- Electric force between two point charges:
$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0 K}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} = -\vec{F}_{21}$$
where $K = 1$ for free space, $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ \mathrm{N\ m^2\ C^{-2}}$
- Coulomb's law agrees with Newton's third law.
- Force on charge q_1 due to remaining charges q_2, q_3, q_4, ... q_n in the region.
$$\vec{F}_1 = \frac{q_1}{4\pi\varepsilon_0}\sum_{i=2}^{n}\frac{q_i}{r_{1i}^2}\hat{r}_{1i}$$
It is a vector sum of all the forces acting on point charge q_1.

Electric Field

- Due to a point charge, $\vec{E} = \frac{\vec{F}}{q_{\text{test}}} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$
- Due to positive charge, electric field is away from the charge and due to negative charge, it is towards the charge.
- Due to charge distribution,

Linear charge, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\sum\frac{\lambda\Delta L}{r^2}\hat{r}$

Surface charge, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\sum\frac{\sigma\Delta S}{r^2}\hat{r}$

Volume charge, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\sum\frac{\rho\Delta V}{r^2}\hat{r}$

Electric Flux and Gauss's Law

- Electric flux through a plane surface area S held in a uniform electric field
$$\Delta\phi_E = \vec{E}\cdot\Delta\vec{S} = E\Delta S\cos\theta$$
- According to Gauss's law, electric flux through a closed surface S is equal to (1/ $_0$) times charge enclosed.
$$\phi_E = \oint\vec{E}\cdot d\vec{S} = \frac{q_{en}}{\varepsilon_0}$$

Applications of Gauss's Law

- Electric field due to a long straight wire of uniform linear charge density $E = \frac{\lambda}{2\pi\,\varepsilon_0 r}$
- Electric field due to an infinite plane sheet of uniform surface charge density , $E = \frac{\sigma}{2\varepsilon_0}$
- Electric field due to two positively charged parallel plates with charge densities $_1$ and $_2$ such that $_1 > {}_2 > 0$,

$E = \frac{1}{2\varepsilon_0}(\sigma_1+\sigma_2)$ (Outside the plates) $E = \frac{1}{2\varepsilon_0}(\sigma_1-\sigma_2)$ (Inside the plates)

- Electric field due to two equally and oppositely charged parallel plates,
$E = 0$ (For outside points), $E = \frac{\sigma}{\varepsilon_0}$ (For inside points)
- Electric field due to a thin spherical shell of charge density and radius R,

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ For $r > R$ (Outside points)

$E = 0$ For $r < R$ (Inside points)

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$ For $r = R$ (At the surface)

where, $q = 4\ R^2$.

- Electric field of a solid sphere of uniform charge density and radius R

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ For $r > R$ (Outside points)

$E = \frac{1}{4\pi\varepsilon_0}\frac{qr}{R^3}$ For $r < R$ (Inside points)

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$ For $r = R$ (At the surface)

where $q = \frac{4}{3}\pi R^3\rho$

Electric Charge

- A physical quantity responsible for electromagnetism. There are only two kinds of charge, positive and negative.
- **Conservation of charge :** The total charge of an isolated system is always conserved.
- **Quantisation of charge :** $Q = ne$
where, $n = \pm1, \pm2, \pm3, ...$ and $e = 1.6\times10^{-19}$ C

Electric Potential

- Work done by an external force (equal and opposite to the electric force) in bringing a unit positive charge from infinity to a point = electrostatic potential (V) at that point.
- Due to a point charge : $V(r) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$
- Potential difference between two points,
$$V_P - V_R = \frac{U_P - U_R}{q} = \frac{W_{RP}}{q}$$
- Potential at a point P, due to system of charges $q_1, q_2, q_3, ...$
$$V_P = V_1 + V_2 + V_3 + ... = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1}+\frac{q_2}{r_2}+\frac{q_3}{r_3}+...\right)$$
It is algebraic sum of the potentials due to the individual charges.

Relation between Field and Potential

- $E = -\frac{dV}{dr}$
- Electric field is in the direction in which the potential decreases steepest.
- Its magnitude is given by the change in the magnitude of potential per unit displacement normal to the equipotential surface at the point.

Electrostatics of Conductors

- At the surface of a charged conductor, electrostatic field must be normal to the surface at every point.
- The interior of a conductor can have no excess charge in the static situation.
- Electrostatic potential is constant throughout the volume of the conductor and has the same value (as inside) on its surface.
- Electric field at the surface of a charged conductor $\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$ where is the surface charge density and $\hat{n}$ is a unit vector normal to the surface in the outward direction.

Potential of Charge Distributions

Charge distribution	Formula
Uniformly charged spherical shell	$V_i = V_s = \frac{Kq}{R} = \frac{\sigma R}{\varepsilon_0}$, $V_o = \frac{Kq}{r}$
Uniformly charged solid sphere	$V_i = \frac{Kq}{R^3}(1.5R^2 - 0.5r^2)$ $V_s = \frac{Kq}{R}$, $V_o = \frac{Kq}{r}$
On the axis of uniformly charged ring	$V = \frac{Kq}{\sqrt{R^2+x^2}}$ At centre, $x = 0\ \therefore\ V = \frac{Kq}{R}$
Infinitely long line charge	$PD = \frac{\lambda}{2\pi\varepsilon_0}\ln\left(\frac{r_2}{r_1}\right)$

Electric Potential Energy

- Electric potential energy of a system of two point charges, $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$
- Electric potential energy of a system of N point charges, $U = \frac{1}{4\pi\varepsilon_0}\sum_{\substack{\text{all pairs}\\(j>k)}}\frac{q_j q_k}{r_{jk}}$

Electric Dipole

- A pair of equal and opposite charges q and $-q$ separated by a small distance $2a$.
- The direction of dipole is the direction from $-q$ to q.
- Dipole moment, $p = q\times 2a$
- Electric Potential, $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$
- Dipole field at an axial point at distance r from the centre of the dipole $E_{\text{axial}} = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2-a^2)^2}$
when $r >> a$ $E_{\text{axial}} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$
- Dipole field at an equatorial point $E_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2+a^2)^{3/2}}$
at distance r from the centre of the dipole is
when $r >> a$ $E_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$
- Torque, $\tau = pE\sin\theta$
- Potential energy of an electric dipole in a uniform electric field, $U = -pE(\cos\ {}_2 - \cos\ {}_1)$

➢ If initially the dipole is perpendicular to the field E, $_1 = 90°$ and $_2 =$, then $U = -pE\cos\theta = -\vec{p}\cdot\vec{E}$

➢ If initially the dipole is parallel to the field E, $_1 = 0°$ and $_2 =$, then $U = -pE(\cos\ - 1) = pE(1 - \cos\ )$

Dielectric and Polarisation

- A dielectric develops a net dipole moment in an external electric field.
- Polarisation = $\frac{\text{net dipole moment}}{\text{volume}}$
For a linear isotropic dielectric, $\vec{P} = \chi_e\vec{E}$
- Surface charge density due to polarisation,
$$\sigma_P = \vec{P}\cdot\hat{n} = P\cos\theta$$

Capacitors and Capacitance

- A capacitor is a system of two conductors separated by an insulator.
- Capacitance, $C = \frac{q}{V_o} = \frac{q}{V_1 - V_2}$
- For a spherical conductor, $C = 4\ {}_0R$
- Energy stored in a charged conductor or capacitor,
$$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}qV$$

Different Types of Capacitors

- Capacity of parallel plate capacitor, $C = \frac{K\varepsilon_0 A}{d}$
- Induced charges, $\sigma_i = \sigma\left(1-\frac{1}{K}\right)$ or $q_i = q\left(1-\frac{1}{K}\right)$
- Capacity of capacitor partially filled with a dielectric, $C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$
- Force of attraction between plates of capacitors, $F = \frac{q^2}{2A\varepsilon_0}$
- Capacity of spherical capacitor, $C = 4\pi\varepsilon_0\left(\frac{ab}{b-a}\right)$
- Capacity of cylindrical capacitor per unit length, $\frac{2\pi\varepsilon_0}{\ln(b/a)}$

Combination of Capacitors

- Capacitors in series : $\frac{1}{C} = \frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}+... = \sum_i\frac{1}{C_i}$
- Capacitors in parallel : $C = C_1 + C_2 + C_3 + ... = {}_i\ C_i$

Van de Graaff Generator

- By means of a moving belt and suitable brushes charge is continuously transferred to the shell and potential difference of the order of several million volts is built up, which can be used for accelerating charged particles.

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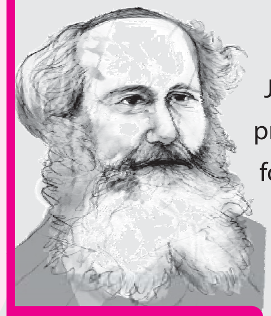
BRAIN MAP

ELECTROMAGNETIC WAVE

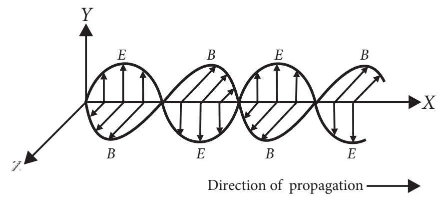


James Clerk Maxwell

James Clerk Maxwell made great strides in helping to understand electromagnetism and produced a unified model of electromagnetism. His research in kinematics and electricity laid foundation for modern quantum mechanics and special relativity.

ELECTROMAGNETIC WAVE

An electromagnetic wave is a wave radiated by an accelerated charge as coupled electric and magnetic field oscillating perpendicular to each other and to the direction of propagation of wave.



Magnitude of $\vec{E}$ and $\vec{B}$ are related as $\frac{E_0}{B_0} = c$

Speed of an electromagnetic wave in free space is given by

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

Ampere's circuital law

The line integral of magnetic field around any closed path in vacuum is equal to μ_0 times the total current passing through that closed path.

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I$$

Properties of electromagnetic waves

- Do not carry any charge.
- Do not deflected by electric and magnetic field.
- Travel with speed of light in vacuum.
- Frequency does not change when it goes from one medium to another, but its wavelength changes.
- Transverse in nature.
- Do not require any material medium for propagation

Electromagnetic spectrum

The orderly distribution of electromagnetic waves in accordance with their wavelength or frequency into distinct groups.

Displacement current

It is the current which is produced when electric field and hence electric flux changes with time.

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

Modified Ampere's law

This law implies the fact that not only a conduction current but a displacement current, associated with a changing electric field, also produces a magnetic field

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 (I_C + I_D)$$

$$= \mu_0 \left(I_C + \varepsilon_0 \frac{d\phi_E}{dt} \right)$$

Maxwell's four equations

1. $\oint_s \vec{E} \cdot \vec{ds} = \frac{q}{\varepsilon_0}$

2. $\oint_s \vec{B} \cdot \vec{ds} = 0$

3. $\oint_c \vec{E} . \vec{dl} = \frac{-d\phi_B}{dt} = -\frac{d}{dt} \oint_s \vec{B} \cdot d\vec{s}$

4. $\oint \vec{B} . \vec{dl} = \mu_0 (I_C + I_D)$

$$= \mu_0 \left(I_C + \varepsilon_0 \frac{d\phi_E}{dt} \right)$$

$$= \mu_0 \left(I_C + \varepsilon_0 \frac{d}{dt} \oint_s \vec{E} \cdot d\vec{s} \right)$$

Uses

Radiowaves
- Used in radio communication

Microwaves
- Radar communication
- Analysis of fine details of molecular and atomic structure.

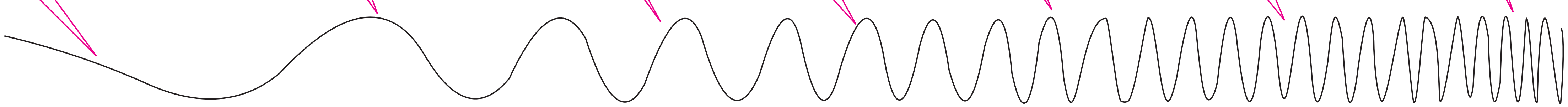
Infrared
- Useful for elucidating molecular structure.
- Useful for haze photography.

Visible light
- Detected by stimulating nerve endings of human retina.
- Can cause chemical reaction.

Ultraviolet
- Can cause many chemical reactions, *e.g.*, the tanning of the human skin.
- Ionize atoms in atmosphere, resulting in the ionosphere.

X-rays
- Penetrate matter (*e.g.*, radiography)
- Ionize gases
- Cause fluorescence
- Cause photoelectric emission from metals

Gamma rays
- In the treatment of cancer and tumours
- To produce nuclear reaction



Radiation Type	Radio	Microwave	Infrared	Visible	Ultraviolet	X-rays	Gamma rays
Wavelength (m)	10^2 to 10^{-1}	10^{-1} to 10^{-3}	10^{-3} to 10^{-6}	8×10^{-7} to 4×10^{-7}	3.5×10^{-7} to 1.5×10^{-7}	10^{-8} to 10^{-11}	10^{-10} to 10^{-14}

BRAIN MAP

CLASS XI

GRAVITATION

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Newton's Law of Gravitation

Gravitational force (F) between two bodies is directly proportional to product of masses and inversely proportional to square of the distance between them.

$$\vec{F} = -\frac{Gm_1m_2}{r^2}\cdot\hat{r}$$

Acceleration due to gravity

- For a body falling freely under gravity, the acceleration in the body is called acceleration due to gravity.
- Relationship between g and G

$$g = \frac{GM_e}{R_e^2} = \frac{4}{3}\pi G R_e \rho$$

where G = gravitational constant

ρ = density of earth

M_e and R_e be the mass and radius of earth

Variation of acceleration due to gravity (g)

Due to altitude (h)

$$g_h = g\left(1 - \frac{2h}{R_e}\right)$$

The value of g goes on decreasing with height.

Due to depth (d)

$$g_d = g\left(1 - \frac{d}{R_e}\right)$$

The value of g decreases with depth.

Due to rotation of earth

$g_\lambda = g - R_e\omega^2\cos^2\lambda$

At equator, $\lambda = 0°$

$g_{\lambda\min} = g - R_e\omega^2$

At poles, $\lambda = 90°$

$g_{\lambda\max} = g_p = g$

Characteristics of gravitational force

- It is always attractive.
- It is independent of the medium.
- It is a conservative and central force.
- It holds good over a wide range of distance.

Gravitational potential

Work done in bringing a unit mass from infinity to a point in the gravitational field.

$$V = \frac{-GM}{r}$$

Kepler's Laws of Planetary Motion

Law of orbits : Every planet revolves around the sun in an elliptical orbit and the sun is situated at one of its foci.

Law of areas : The areal velocity of the planet around the sun is constant

i.e., $\frac{dA}{dt}$ = a constant

Law of periods : The square of the time period of revolution of a planet is directly proportional to the cube of semi major axis of the elliptical orbit.

$$T^2 \propto a^3$$

Gravitational Potential Energy

Work done in bringing the given body from infinity to a point in the gravitational field.

$$U = -GMm/r$$

Escape speed

The minimum speed of projection of a body from surface of earth so that it just crosses the gravitational field of earth.

$$v_e = \sqrt{\frac{2GM}{R}}$$

Earth's Satellite

Types of Satellite

Polar satellilte

- Time period : 100 min
- Revolves in polar orbit around the earth.
- Height : 500-800 km.
- Uses : Weather forecasting, military spying

Geostationary satellite

- Time period : 24 hours
- Same angular speed in same direction with earth.
- Height : 36000 km.
- Uses : GPS, satellite communication (TV)

Orbital speed of satellite

The minimum speed required to put the satellite into a given orbit.

$$v_0 = R_e\sqrt{\frac{g}{R_e + h}}$$

For satellite orbiting close to the earth's surface

$$v_0 = \sqrt{gR_e}$$

Time period of satellite

$$T = \frac{2\pi}{R_e}\sqrt{\frac{(R_e + h)^3}{g}}$$

For satellite orbiting close to the earth's surface

$$T = 2\pi\sqrt{\frac{R_e}{g}} = 84.6 \text{ min}$$

Energy of satellite

- Kinetic energy $K = \frac{GM_em}{2(R_e + h)}$
- Potential energy $U = \frac{-GM_em}{R_e + h}$
- Total energy

$$E = K + U = -\frac{GM_em}{2(R_e + h)}$$

BRAIN MAP

MECHANICAL PROPERTIES OF SOLIDS AND FLUIDS

A solid vertical column can rest on table without external support but a liquid column cannot because it cannot withstand shear stresses

Properties of Solids

Elasticity and Plasticity

- Elasticity is the property of the body by virtue of which it tends to regain its original size and shape, when applied force is removed.
- Plasticity is the inability of a body to regain its original size and shape on the removal of the deforming forces.

Stress and Strain

- Stress is the internal restoring force acting per unit area of a deformed body.
$$\text{Stress} = \frac{\text{Restoring force}}{\text{Area}}$$
- Strain is the ratio of change in configuration to the original configuration.
$$\text{Strain} = \frac{\text{Change in configuration}}{\text{Original configuration}}$$
- According to Hooke's law, within elastic limit stress is directly proportional to strain, that is the extension produced in a wire is directly proportional to the load applied to the wire.
i.e., Stress $\propto$ Strain or Stress = $E \times$ Strain, where E is modulus of elasticity.

Types of Modulus of Elasticity

- Young's modulus, $Y = \frac{\text{Normal stress}}{\text{Longitudinal strain}}$
or $Y = \frac{F/A}{\Delta l / l}$; $\frac{Fl}{A\Delta l}$
- Bulk modulus, $B = \frac{\text{Normal stress}}{\text{Volumetric strain}}$
or $B = \frac{+F/A}{\Delta V / V} = \frac{-FV}{A\Delta V} = \frac{-PV}{\Delta V}$
- Compressibility, $k = \frac{1}{B} = \frac{+BV}{PV}$.
- Modulus of rigidity, G ; $\frac{\text{Shearing stress}}{\text{Shearing strain}}$
or $G = \frac{\theta_s}{\theta} = \frac{F/A}{\Delta x / L} = \frac{FL}{A\Delta x}$

Elastic Potential Energy

- Work done against the internal restoring forces acting between the various particles of the wire when it is stretched, is stored in the form of potential energy in the wire and is known as elastic potential energy,
$$U = \frac{1}{2}F..\Delta L = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume of wire}$$
- Potential energy stored per unit volume of stretched wire,
$$u = \frac{1}{2}..\text{stress} \times \text{strain} = \frac{1}{2} \times \text{Young's modulus} \times (\text{strain})^2$$

Poisson's Ratio

- Poisson's ratio (σ) ; $\frac{\text{Lateral strain}}{\text{Longitudinal strain}}$
$$= \frac{+\Delta R / R}{\Delta L / L} = \frac{-L\Delta R}{R\Delta L}$$

Relations between Y, B, G and σ

- $Y = 3B(1-2\sigma)$
- $Y = 2G(1+\sigma)$
- $\sigma = \frac{3B + 2G}{2G + 6B}$
- $\frac{9}{Y}$; $\frac{1}{B} + \frac{3}{G}$

Properties of Fluids

Pressure

- It is the normal force or thrust exerted by a liquid at rest per unit area of the surface in contact with it. $P = F/A$
- Gauge pressure = Total pressure – atmospheric pressure
$$= P - P_0 = h\rho g.$$
- The pressure is same at all points inside the liquid lying at the same depth in a horizontal plane.

Archimede's Principle

- It states that when a body is immersed wholly or partly in a liquid at rest, it loses some of its weight, which is equal to the weight of the liquid displaced by the immersed part of the body.
Apparent weight = Actual weight –Buoyant force $= W - W'$
(ρ' is density of the liquid) ; $V\rho g - V\rho' g$
$$= V\rho g\left(1 - \frac{\rho'}{\rho}\right) = mg\left(1 - \frac{\rho'}{\rho}\right)$$
- When $W > W'$, the body sinks down.
- When $W = W'$, the body floats completely immersed in the liquid.
- When $W < W'$, the body floats partly immersed.

Fluid in Motion

- **Bernoulli's Theorem :** It states that for the streamline flow of an ideal liquid, the total energy per unit mass remains constant at every cross-section throughout the liquid flow.
$$P\ )\ \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$$
- **Equation of continuity :**
$Av = \text{constant}$
It is a statement of conservation of mass in flow of incompressible fluids.
- **Torricelli's law :**
Velocity of efflux is the velocity with which the liquid flows out of a narrow hole at depth h below the free surface of the liquid.
$$v = \sqrt{2gh + \frac{2(P+P_0)}{\rho}}.$$
- If the hole is open to the atmosphere, then $P = P_0$, so v ; $\sqrt{2gh}$

Capillarity

- The phenomenon of rise or fall of liquid in a capillary tube is called capillarity.
- Ascent formula : Height of the liquid within the capillary tube,
$$h = \frac{2S\cos o}{a\rho g}$$
where a is the radius of the capillary tube.

Viscosity

- Coefficient of viscosity of a liquid is the tangential force required to maintain a unit velocity gradient between two parallel layers of liquid, each of unit area.
$$\eta = \frac{+F}{A\left(\frac{dv}{dx}\right)}$$
where $\frac{dv}{dx}$ is the velocity gradient between two layers of liquid.
- **Poiseuille's formula :** Volume of the liquid flowing per second through a narrow tube, $Q = \frac{v}{8}\frac{Pr^4}{\eta l}$.
- **Stoke's law :** Backward dragging force F on a small spherical body of radius r, moving through a fluid of coefficient of viscosity η, with velocity v is given by $F = 6\pi\eta rv$.
- Terminal velocity, $v_T = \frac{2r^2(\pi + \theta)}{9\eta}g$
- Reynold's number is a number which determines the nature of flow of liquid through a pipe.
$$R = \frac{\pi vd}{\eta}$$

Surface Tension, Surface Energy and Angle of Contact

- **Surface tension(S)** is the property of the liquid by virtue of which the free surface of liquid at rest tends to have minimum surface area.
- **Surface energy** of given liquid surface is defined as the amount of work done against the force of surface tension in forming the liquid surface of given area at a constant temperature.
- **Angle of contact** (θ) is the angle enclosed between the tangents to the liquid surface at the point of contact and the solid surface inside the liquid. It determines whether a liquid will spread on the surface of a solid or it will form droplets on it.

Excess Pressure in Drops

- Excess pressure inside a liquid drop
P ; $\frac{2S}{R}$ (with one free surface)
- Excess pressure inside a soap bubble
P ; $\frac{4S}{R}$ (with two free surface)
- Excess pressure in an air bubble
P ; $\frac{2S}{R}$ (with one free surface)

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BRAIN MAP CLASS XI

NEWTON'S LAWS OF MOTION

OHM'S LAW AND KIRCHHOFF'S RULE

BRAIN MAP CLASS XII

LAWS OF MOTION AND THEIR CONSEQUENCES

Problem Solving Strategies

- *Identify the unknown forces and accelerations.*
- *Draw FBD of bodies in the system.*
- *Resolve forces into their components.*
- *Apply $\Sigma\vec{F} = M\vec{a}$ in the direction of motion.*
- *Apply $\Sigma\vec{F} = 0$ in the direction of equilibrium.*
- *Write constraint relation if exists.*
- *Solve equations $\Sigma\vec{F} = M\vec{a}$ and $\Sigma\vec{F} = 0$.*

Newton's 1st Law

A body continues its state of rest or motion until unless an external force is acted on it.

- Inertia of rest
- Inertia of motion
- Inertia of direction

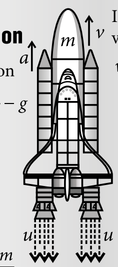
Pseudo Force

For non-inertial frame of reference

$\vec{F}_{ext} + \vec{F}_{Pseudo} = M\vec{a}$

$\vec{F}_{pseudo} = -M\vec{a}_{frame}$

Rocket Propulsion



Acceleration $a = \dfrac{u}{m}\dfrac{dm}{dt} - g$

Instantaneous velocity $v = u\log_e\left(\dfrac{m_0}{m_r}\right) - gt$

Burn out speed $v_{max} = u\log_e\left(\dfrac{m_0}{m_r}\right)$

Thrust $F = -u\dfrac{dm}{dt}$

Newton's 2nd Law

The rate of change of linear momentum of a body is directly proportional to the external force applied on the body in the direction of force.

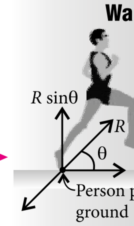
$F = \dfrac{dp}{dt} = ma$

Newton's 3rd Law

To every action there is always an equal and opposite reaction.

$\vec{F}_{AB} = -\vec{F}_{BA}$

Walking



Ground pushes the person (reaction)

Person presses the ground (action)

Horse Cart Type System

For horse cart type system

$a = \dfrac{F_x - f}{M_H + M_{cart}}$ $\begin{cases} F_x = \text{horizontal component of reaction force} \\ f = \text{frictional force} \end{cases}$

FRICTION

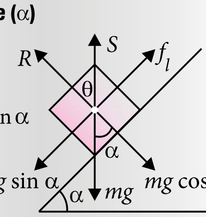
The motion resisted by a bonding between the body and the surface in contact represented by single force called

Angle of Friction (θ) and Angle of Repose (α)

$S = \sqrt{R^2 + f_l^2}$

$\tan\theta = \dfrac{f_l}{R} = \mu_s = \tan\alpha$

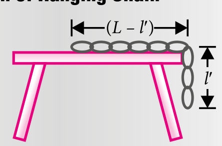
∴ Numerically, $\theta = \alpha$



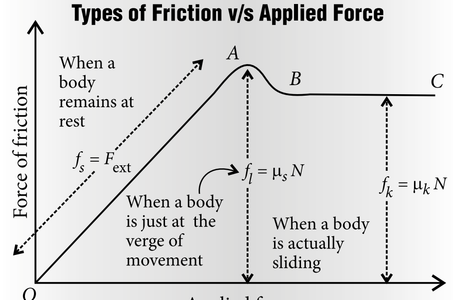
Maximum Length of Hanging Chain

Length of a chain hanging in air

$l' = \dfrac{\mu L}{1+\mu}$

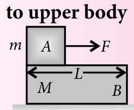


Types of Friction v/s Applied Force

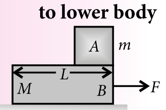


Motion of Two Bodies One Resting on the Other

Force F applied to upper body



Force F applied to lower body



Force applied to upper body:

- **When there is no friction**
  - $a_A = F/m;\ a_B = 0$
  - *A will fall from B after time*

    $t = \sqrt{\dfrac{2L}{a}} = \sqrt{\dfrac{2mL}{F}}$
- **Friction present between A and B ($F < f_l$)**
  - Combined system will move together with $a = F/(M+m)$
- **Friction present between A and B ($F > f_l$)**
  - Relative acceleration

    $a = a_A - a_B = \dfrac{MF - \mu_k mg(m+M)}{mM}$
  - *A will fall from B after time*

    $t = \sqrt{\dfrac{2L}{a}} = \sqrt{\dfrac{2mML}{MF - \mu_k mg(m+M)}}$

Force applied to lower body:

- **When there is no friction**
  - $a_B = F/M$ and $a_A = 0$
  - *A will fall from B (backward) after time t*

    $\therefore\ t = \sqrt{\dfrac{2L}{a}} = \sqrt{\dfrac{2ML}{F}}$
- **Friction present between A and B ($F < f_l$)**
  - Both the bodies will move together

    $a = \dfrac{F}{M+m}$ and $f_l = \mu_s mg$
  - Pseudo force on the body A,

    $F' = ma = \dfrac{mF}{m+M}$
- **Friction present between A and B ($F > f_l$)**
  - Relative acceleration

    $a = a_A - a_B = -\left[\dfrac{F - \mu_k g(m+M)}{M}\right]$
  - *A will fall from B (backward) after time*

    $t = \sqrt{\dfrac{2L}{a}} = \sqrt{\dfrac{2ML}{F - \mu_k g(m+M)}}$

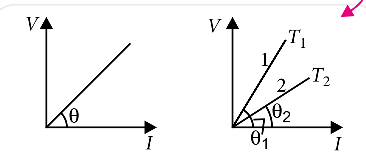
OHM'S LAW

If the physical conditions of the conductor (length, temperature, mechanical strain etc.) remain same, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends *i.e.*, $I \propto V \Rightarrow V = IR$

Basic Features of Ohm's Law

- Vector form of Ohm's law, $\vec{J} = \sigma\vec{E}$

  where conductivity $\sigma = \dfrac{1}{\rho}$ and $\vec{J}$ is the current density.
- Graph between V and I for a metallic conductor



Slope of the line $= \tan\theta = \dfrac{V}{I} = R$

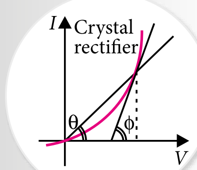
Here $\tan\theta_1 > \tan\theta_2$ so $R_1 > R_2$ *i.e.* $T_1 > T_2$

V-I curve for non-ohmic substance is not linear

- Static resistance

  $R_{st} = \dfrac{V}{I} = \dfrac{1}{\tan\theta}$
- Dynamic resistance

  $R_{dyn} = \dfrac{\Delta V}{\Delta I} = \dfrac{1}{\tan\phi}$

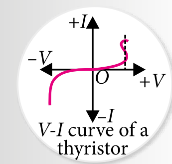


Limitations of Ohm's Law

It is not a universal law that applies everywhere under all conditions. Ohm's law is obeyed by metallic conductors, that too at about normal working temperatures.

Ohm's law is not followed in the following cases

- Materials : Crystal rectifiers, thermistors, thyristors, semi-conductors.
- Conditions :
  - (i) At very high temperatures
  - (ii) At very low temperatures
  - (iii) At very high potential differences.



R is a proportionality constant, known as

Resistance

The property of a substance by virtue of which it opposes the flow of current through it.

$R = \rho\dfrac{l}{A} = \dfrac{m}{ne^2\tau}\cdot\dfrac{l}{A}$

ρ is specific resistance of the material of conductor

Resistivity

It is numerically equal to the resistance of a substance having unit area of cross-section and unit length.

Temperature Dependence

For a conductor

then $R_t = R_0(1 + \alpha t + \beta t^2)$

$R_t = R_0(1 + \alpha t)$ $(\beta \approx 0)$

also for resistivity, $\rho_t = \rho_0(1 + \alpha t)$

$\begin{cases} R_0 = \text{resistance at } 0°\text{C} \\ R_t = \text{resistance at } t°\text{C} \\ \alpha, \beta = \text{temperature co-efficients} \end{cases}$

KIRCHHOFF'S RULE

Junction Rule

At any junction of circuit, the sum of currents entering and leaving must be zero.

$\Sigma I = 0.$

It is based on conservation of charge.

Loop Rule

The algebraic sum of changes in potential around any closed loop must be zero.

$\Sigma\varepsilon - \Sigma IR = 0$

It is based on conservation of energy.

For circuit containing multiple batteries

Grouping of Batteries

Series grouping

For n identical batteries

$I = \dfrac{n\varepsilon}{nr + R}$ $\begin{cases} \varepsilon = \text{emf} \\ r = \text{Internal resistance} \end{cases}$

If polarity of m batteries is reversed

$I = (n - 2m)\varepsilon/(nr + R)$

Parallel grouping

- With identical batteries :

  $I = \dfrac{\varepsilon_{net}}{R_{net}},\ \varepsilon_{net} = \varepsilon,\ R_{net} = \dfrac{r}{n} + R$
- With unidentical batteries :

  $\varepsilon_{net} = \dfrac{\Sigma(\varepsilon/r)}{\Sigma(1/r)},\ I = \dfrac{\varepsilon_{net}}{R_{net}}$

Mixed grouping

- For n rows of identical batteries with m cells in each row. Then,

  $\varepsilon_{net} = m\varepsilon,\ R_{net} = \dfrac{mr}{n} + R,\ I = \dfrac{\varepsilon_{net}}{R_{net}}$

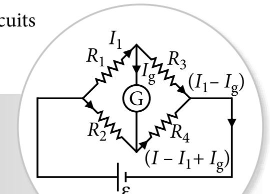
An important application for few circuits

Wheatstone Bridge

- In balanced condition,

  If $\dfrac{R_1}{R_2} = \dfrac{R_3}{R_4}$

  then $I_g = 0$.



Guidelines to applying Kirchhoff's rule

Problem Solving Strategies

- *Distribute current at various junctions in the circuit starting from positive terminal.*
- *Pick a point and begin to walk around a closed loop.*
- *Write down the voltage change for that element according to the sign convention.*
- *By applying KVL, select the required number of loops as many as unknowns are available and apply KVL across each loop.*
- *Solve the set of simultaneous equation to find the unknowns.*

BRAIN MAP

OSCILLATIONS

The world is filled with oscillations in which objects move back and forth repeatedly. We cannot even say 'vibration' properly without the tip of the tongue oscillating.

Simple Harmonic Motion

Differential Equations of SHM

- For linear SHM, $\frac{d^2y}{dt^2}+\omega^2 y=0$
- For angular SHM, $\frac{d^2\theta}{dt^2}+\omega^2\theta=0$

Angular SHM

- Angular displacement,
  $\theta=\theta_0\sin(\omega t+\delta)$
- Torque, $\tau=-c\theta$
- Angular velocity, $\omega=\sqrt{c/I}$
- Angular acceleration, $\alpha=-\frac{c\theta}{I}$
- Time period of oscillation, $T=2\pi\sqrt{\frac{I}{c}}$
- Frequency of oscillation, $\upsilon=\frac{1}{T}=\frac{1}{2\pi}\sqrt{\frac{c}{I}}$

Energy in Angular SHM

- Potential energy, $U=\frac{1}{2}c\theta^2=\frac{1}{2}I\omega^2\theta^2$
- Kinetic energy, $K=\frac{1}{2}I\omega^2$
- Total energy, $E=\frac{1}{2}I\omega^2\theta_0^2$

Characteristics of Linear SHM

- General equation of dispacement of particle executing linear SHM
  $y=A\sin(\omega t+\phi)$
- Time period of SHM, $T=\frac{1}{\upsilon}=\frac{2\pi}{\omega}$
- Velocity, $v=\omega\sqrt{A^2-y^2}$
- Acceleration, $a=-\omega^2 y$

Maximum Velocity and Maximum Acceleration in SHM

- At mean position velocity is maximum
  $v_{max}=A\omega$
- Acceleration is maximum at extreme position
  $a_{max}=-\omega^2 A$

Energy in Linear SHM

- Kinetic energy
  $K=\frac{1}{2}m\omega^2(A^2-y^2)=\frac{1}{2}m\omega^2A^2\cos^2\omega t$
- Potential energy
  $U=\frac{1}{2}m\omega^2y^2=\frac{1}{2}m\omega^2A^2\sin^2\omega t$
- Total energy
  $E=\frac{1}{2}m\omega^2A^2=\frac{2\pi^2mA^2}{T^2}$
- At mean position kinetic energy is maximum, at extreme position potential energy is maximum and total energy is constant at every position during simple harmonic motion.

Dynamics of SHM

- $\vec{F}=-m\omega^2\vec{x}$ or $\vec{F}=-k\vec{x}$
  where, force constant $k=m\omega^2$
- Angular velocity, $\omega=\sqrt{\frac{k}{m}}$
- Time period, $T=2\pi\sqrt{\frac{m}{k}}$
- Frequency, $\upsilon=\frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Simple Pendulum

- Time period $T=2\pi\sqrt{\frac{l}{g}}$
- If the length of simple pendulum is very large, $T=2\pi\sqrt{\frac{1}{g\left(\frac{1}{l}+\frac{1}{R}\right)}}$
- If a simple pendulum oscillates in a non viscous liquid of density σ then its time period $T=2\pi\left[\frac{l}{\left(1-\frac{\sigma}{\rho}\right)g}\right]^{1/2}$ where ρ is the density of suspended mass.
- When a pendulum kept in a car which is sliding down then
  $T=2\pi\sqrt{\frac{l}{g\cos\theta}}$ where θ is the angle of inclination.

Physical Pendulum

- Time period of physical pendulum $T=2\pi\sqrt{\frac{I}{mgd}}$
  where d is the distance from centre of gravity of rigid body to pivoted point.
- Acceleration due to gravity, $g=\frac{8\pi^2 L}{3T^2}$
  $(\because\ d=\frac{L}{2},\ I=\frac{1}{3}mL^2)$

SHM in Spring

- Equation of motion $\frac{d^2y}{dt^2}=\frac{-ky}{m}=-\omega^2 y$
- If the spring is not light but has a definite mass then $T=2\pi\sqrt{\frac{m+\frac{m_s}{3}}{k}}$
- Two bodies of masses m_1 and m_2 are attached through a light spring of spring constant k, the time period of oscillation $T=2\pi\sqrt{\frac{\mu}{k}}$ where $\mu=\frac{m_1m_2}{m_1+m_2}$
- If the mass m attached to a spring oscillates in a non viscous liquid of density σ then $T=2\pi\left[\frac{m}{k}\left(1-\frac{\sigma}{\rho}\right)\right]^{1/2}$ where ρ is the density of suspended mass.
- The force of gravity has no effect on force constant k and time period of oscillating mass.

Oscillations of Loaded Spring Combinations

- For two springs of spring factors k_1 and k_2 connected in parallel, effective spring factor $k=k_1+k_2$ and $T=2\pi\sqrt{\frac{m}{k_1+k_2}}$
- For springs connected in series, $\frac{1}{k}=\frac{1}{k_1}+\frac{1}{k_2}$ or $k=\frac{k_1k_2}{k_1+k_2}$ and $T=2\pi\sqrt{\frac{m(k_1+k_2)}{k_1k_2}}$
- When length of a spring made n times, its spring factor becomes $1/n$ times and hence time period increases $\sqrt{n}$ times.
- When a spring is cut into n equal pieces, spring factor of each part becomes nk and $T=2\pi\sqrt{\frac{m}{nk}}$

Time Period of Different SHMs

- A plank of mass m and area of cross section A is floating in a liquid of density ρ when depressed, it starts oscillating then $T=2\pi\sqrt{\frac{m}{\rho Ag}}$
- In case of water oscillating in U-tube, then $T=2\pi\sqrt{\frac{h}{g}}$
  where h is the height of liquid column in each limb
- A ball of mass m is made to oscillate in the neck of an air chamber having volume V and neck area a then $T=2\pi\sqrt{\frac{mV}{Ba^2}}$
  where B = bulk modulus of elasticity in air.
- A small ball of radius r is rolling down in a hemispherical bowl of radius R, then $T=2\pi\sqrt{\frac{R-r}{g}}$
  where R is the radius of bowl and r is the radius of ball.
- For a body executing SHM in a tunnel dug along any chord of earth $T=2\pi\sqrt{\frac{R_e}{g}}=84.6$ min.
- Time period of torsional pendulum $T=2\pi\sqrt{\frac{I}{C}}$ where $C=\frac{\pi\eta r^4}{2l}$
  where, η = modulus of elasticity of wire, r = radius of wire, l = length of wire

Damped and Forced Oscillations

- The differential equation of damped harmonic oscillator is given by
  $m\frac{d^2x}{dt^2}+b\frac{dx}{dt}+kx=0$
- The displacement of the damped oscillator at any instant t is given by
  $x(t)=Ae^{-bt/2m}\sin(\omega' t+\phi)$
- Angular frequency of the damped oscillation
  $\omega'=\sqrt{\frac{k}{m}-\frac{b^2}{4m^2}}$
  where b is damping constant.
- Mechanical energy of the damped osillator $E(t)$
  $=\frac{1}{2}kA^2e^{-bt/m}$
- The differential equation of forced damped harmonic oscillator is given by
  $m\frac{d^2x}{dt^2}+b\frac{dx}{dt}+kx=F_0\sin\omega_d t$
  where ω_d is the angular frequency of the external force.
- The displacement of the forced damped harmonic oscillator at any instatn t is given by
  $x(t)=A\sin(\omega_d t-\phi)$
  and $\phi=\tan^{-1}\left[\frac{b\omega_d}{m(\omega^2-\omega_d^2)}\right]$
- Amplitude of forced oscillations when driving frequency is far from natural frequency,
  $A=\frac{F_0}{m(\omega^2-\omega_d^2)}$
- When driving frequency is close to natural frequency, *i.e.*, at resonance, $A=\frac{F_0}{\omega_d b}$

BRAIN MAP

OSCILLATIONS

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Class XI

Class XII

SEMICONDUCTOR ELECTRONICS

BRAIN MAP

Periodic Motion

A motion that repeats itself at regular interval of time is called periodic motion. The displacement is represented by a periodic function of time with time period T. *i.e.*, $f(t) = f(t+T) = f(t+2T) = ...$

Oscillatory Motion

If the body is given a small displacement from the position, a force comes into play which tries to bring the body back to the equilibrium point. Such motions are called oscillatory motion.

Simple Harmonic Motion

The motion arises when the force on the oscillating body is directly proportional to its displacement from mean position. Such motion is called simple harmonic motion.

System Excuting SHM

Dynamic of SHM

Charact-eristics of SHM

SHM IN SPRING

- Equation of motion

$$\frac{d^2y}{dt^2} = \frac{-ky}{m} = -\omega^2 y$$

- If the spring is not light but has a definite mass m_s then

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

- Two bodies of masses m_1 and m_2 are attached through a light spring of spring constant k, the time period of oscillation

$$T = 2\pi\sqrt{\frac{\mu}{k}} \quad \text{where } \mu = \frac{m_1 m_2}{m_1 + m_2}$$

SIMPLE PENDULUM

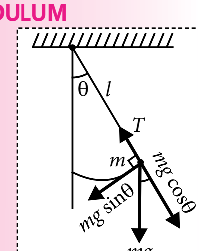
- Time period

$$T = 2\pi\sqrt{\frac{I}{mgl}} = 2\pi\sqrt{\frac{l}{g}}$$

- If the length of simple pendulum is very large,

$$T = 2\pi\frac{1}{\sqrt{g\left(\frac{1}{l}+\frac{1}{R}\right)}}$$

where R is the radius of length of pendulum



Here, $\alpha = -\frac{mgl}{I}\theta$

FORCE LAW IN SHM

- The force acting on a particle of mass m in SHM is
  $\vec{F} = -m\omega^2\vec{x}$ or $\vec{F} = -k\vec{x}$
  where, $k = m\omega^2$ = force constant
- Linear SHM :
  - Angular velocity, $\omega = \sqrt{\frac{k}{m}}$
  - Time period, $T = 2\pi\sqrt{\frac{m}{k}}$
- Angular SHM :
  - Torque, $\tau = -k\theta$
  - Angular velocity, $\omega = \sqrt{k/I}$
  - Angular acceleration, $\alpha = -\frac{k\theta}{I}$
  - Time period, $T = 2\pi\sqrt{\frac{I}{k}}$
  where I = moment of inertia

ENERGY IN SHM

- Linear SHM :
  - Kinetic energy $(K) = \frac{1}{2}m\omega^2A^2\cos^2\omega t$
  - Potential energy $(U) = \frac{1}{2}m\omega^2A^2\sin^2\omega t$
  - Total energy $(E) = \frac{1}{2}m\omega^2A^2$
- Angular SHM :
  - Kinetic energy $(K) = \frac{1}{2}I\omega^2$
  - Potential energy $(U) = \frac{1}{2}k\theta^2 = \frac{1}{2}I\omega^2\theta^2$
  - Total energy $(E) = \frac{1}{2}I\omega^2\theta_0^2$

GENERAL EQUATIONS OF SHM

- Linear SHM:
  - Differential equation $\frac{d^2y}{dt^2} + \omega^2 y = 0$
  - Displacement $y = A\sin(\omega t + \phi)$
  - Velocity, $v = \omega\sqrt{A^2 - y^2}$
  - Acceleration, $a = -\omega^2 y$
- Angular SHM :
  - Differential equation
    $\frac{d^2\theta}{dt^2} + \omega^2\theta = 0$
  - Displacement $\theta = \theta_0\sin(\omega t + \delta)$

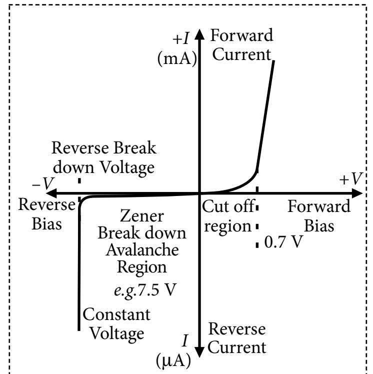
DAMPED AND FORCED OSCILLATIONS

- Damped oscillations
  - Angular frequency $(\omega') = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$
  - Mechanical energy $E(t) = \frac{1}{2}kA^2 e^{\frac{-bt}{m}}$
  - Amplitude $A' = Ae^{-bt/2m}$
    where b is damping constant.
- Forced oscillations
  - When driving frequency ω_d far from natural frequency ω :
    Amplitude $A' = \frac{F_0}{m(\omega^2 - \omega_d^2)}$
  - When driving frequency ω_d closed to natural frequency ω :
    Amplitude $A' = \frac{F_0}{\omega_d b}$

TYPES OF SEMICONDUCTORS

INTRINSIC SEMICONDUCTORS

The pure semiconductors have thermally generated current carriers. Here, $n_e = n_h = n_i$



EXTRINSIC SEMICONDUCTORS

The semiconductor whose conductivity is mainly due to doping of impurity.

***p*-type semiconductor**
- Doped with trivalent atom.
- Here, $n_h >> n_e$

***n*-type semiconductor**
- Doped with pentavalent atom.
- Here, $n_e >> n_h$

SEMICONDUCTOR DIODE

***p–n* junction diode :** A p-type semiconductor is brought into contact with an n-type semiconductor such that structure remains continuous at boundary.

APPLICATIONS OF DIODE

- **Diode as a rectifier**
  - Half wave rectifier
  - Full wave rectifier
- **Zener diode** as a voltage regulator.
- **Photo diode** for detecting light signals.
- **LED:** light emitting diode.
- **Solar cells:** Generates emf from solar radiations.

BIASING CHARACTERSTICS

Forward bias characteristic
- Width of depletion layer decreases
- Effective barrier potential decreases
- Low resistance at junction
- High current flow of the order of mA.

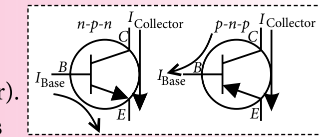
Reverse bias characteristic
- Width of depletion layer increases
- Effective barrier potential increases
- High resistance at the junction
- Low current flow of the order of μA.
- Reverse break down occurs at a high reverse bias voltage.

JUNCTION TRANSISTOR

A semiconductor device possessing fundamental action of transfer resistor.

Junction transistors are of two types
- ***n-p-n* transistor:** A thin layer of p-type semiconductor is sandwiched between two n-type semiconductors.
- ***p-n-p* transistor:** A thin layer of n-type semiconductor is sandwiched between two p-type semiconductors.

There are three configurations of transistors
- CB (Common Base)
- CE (Common Emitter)
- CC (Common Collector).

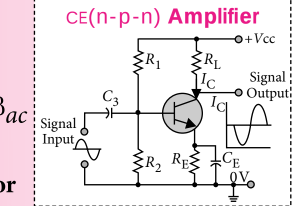


Transistor characteristics
- Input resistance $(r_i)_{(CE)} = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}=\text{constant}}$
- Output resistance $(r_o)_{(CE)} = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B=\text{constant}}$
- Current amplification factor
  $\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}=\text{constant}}$ $\quad \alpha_{ac} = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{V_{CB}=\text{constant}}$

APPLICATIONS OF TRANSISTOR

- **Transistor as an Amplifier**
  - Its operating voltage is fix in active region.
  - Voltage gain,
    $A_v = \frac{V_o}{V_i} = -\beta_{ac}\frac{R_{out}}{R_{in}}$
  - Power gain, $A_p = A_v \times \beta_{ac}$
- **Transistor as a Switch**
- **Transistor as an Oscillator**

CE(n-p-n) Amplifier

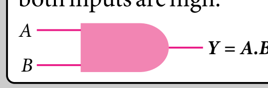


DIGITAL ELECTRONICS AND LOGIC GATES

VARIOUS TYPES OF LOGIC GATE

AND Gate

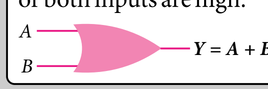
Output is high only when both inputs are high.



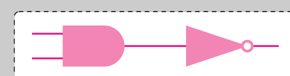
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

OR Gate

Output is high if any one or both inputs are high.

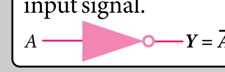


A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

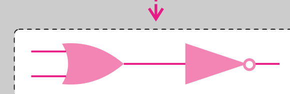


NOT Gate

It just inverts the input signal.



A	Y
0	1
1	0



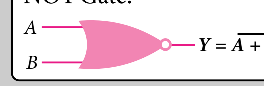
NAND Gate

An AND Gate followed by a NOT Gate.

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

NOR Gate

An OR Gate followed by a NOT Gate.



A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

BRAIN MAP CLASS XI

PROJECTILE MOTION

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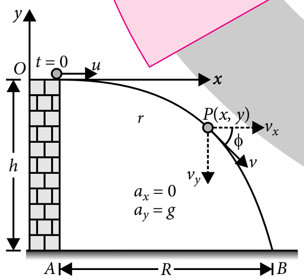
ELECTRIC FLUX AND GAUSS'S LAW

BRAIN MAP CLASS XII

PROJECTILE Motion

A body which is in flight through the atmosphere under the effect of gravity alone and is not being propelled by any fuel is called projectile and its motion is called projectile motion.

Horizontal Projectile Motion



- **Equation of Trajectory**

$$y = \frac{1}{2}\frac{gx^2}{u^2}$$

- **Time of Descent**

$$T = \sqrt{\frac{2h}{g}}$$

- **Horizontal Range**

$$R = u\sqrt{\frac{2h}{g}}$$

- **Instantaneous Velocity**

$$v = \sqrt{u^2 + 2gy} = \sqrt{u^2 + g^2t^2}$$

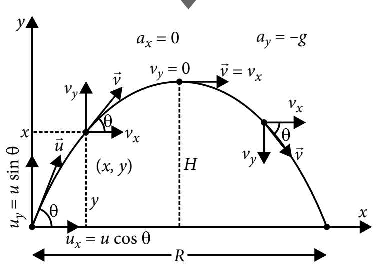
$$\tan\phi = \frac{v_y}{v_x} = \tan^{-1}\left(\frac{gt}{u}\right)$$

Oblique Projectile Motion

- **Equation of Trajectory**

$$y = x\tan\theta - \frac{1}{2}\frac{gx^2}{u^2\cos^2\theta}$$

This represents the parabolic path.



- **Maximum Height**

$$H = \frac{u^2\sin^2\theta}{2g}$$

- **Time of Flight**

$$T = \frac{2u\sin\theta}{g}$$

- **Horizontal Range**

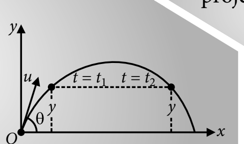
$$R = \frac{u^2\sin 2\theta}{g}$$

- Projectile passing through two different points on same height at time t_1 and t_2

$$y = \frac{gt_1t_2}{2}$$

$$t_2 = \frac{u\sin\theta}{g}\left[1 + \sqrt{1 - \left[\frac{2gy}{u\sin\theta}\right]^2}\right]$$

$$t_1 = \frac{u\sin\theta}{g}\left[1 - \sqrt{1 - \left[\frac{2gy}{u\sin\theta}\right]^2}\right]$$

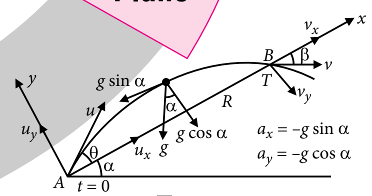


- Ratio of time of flights for projectiles at complimentary angles θ and $90 - \theta$

$$\frac{T_\theta}{T_{90-\theta}} = \tan\theta$$

- For complimentary angles θ and $(90 - \theta)$ range remains unchanged
- Relation between horizontal range and maximum height $R = 4H\cot\theta$
- Range R is n times the maximum height H: $R = nH; \theta = \tan^{-1}[4/n]$
- If $R = H$ then $\theta = \tan^{-1}(4)$ or $\theta = 76°$
- If $R = 4H$ then $\theta = \tan^{-1}(1)$ or $\theta = 45°$

Projectile Motion on an Inclined Plane



- **Time of Flight**

$$T = \frac{2u\sin\theta}{g\cos\alpha}$$

- **Maximum Height**

$$H = \frac{u^2\sin^2\theta}{2g\cos\alpha}$$

- **Horizontal Range**

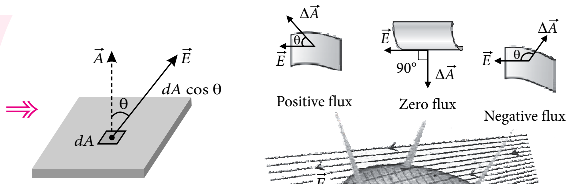
$$R = \frac{2u^2}{g}\frac{\sin\theta\cos(\theta+\alpha)}{\cos^2\alpha}$$

- Maximum range occurs when $\theta = \frac{\pi}{4} + \frac{\alpha}{2}$
- Maximum range along the incline when projectile is thrown upwards $R_{max} = \frac{u^2}{g(1+\sin\alpha)}$
- Maximum range along incline when the projectile thrown downwards $R_{max} = \frac{u^2}{g(1-\sin\alpha)}$

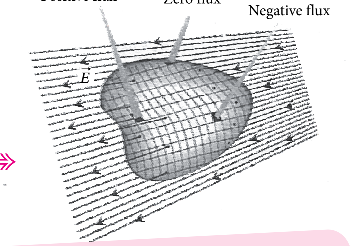
ELECTRIC FLUX

Electric flux is a measure of flow of electric field through a surface. It is equal to the dot product of an area vector and electric field

- Flux of electric field E through any area A: $\phi = EA\cos\theta$ or $\phi = \vec{E}\cdot\vec{A}$
- For variable electric field or curved area $\phi = \int \vec{E}\cdot d\vec{A}$



- For a closed surface outward flux is taken to be positive while inward flux is taken to be negative.



To get a direct connection between the electric flux through closed surface and the total charge inside it.

Problem Solving Strategies

- Select a symmetric gaussian surface as per the charge distribution.
- Calculate total electric charge inside the gaussian surface.
- For uniform charge density, simply multiply it by length, area and volume of surface.
- For non uniform charge density integrate it over the region enclosed the surface.
- Calculate electric field on the gaussian surface as per the given uniform charge distribution.

GAUSS'S LAW

The total flux linked with a closed Gaussian surface is $(1/\varepsilon_0)$ times the charge enclosed by the closed surface *i.e.*,

$$\phi = \oint \vec{E}\cdot d\vec{A} = \frac{1}{\varepsilon_0}(Q_{enc})$$

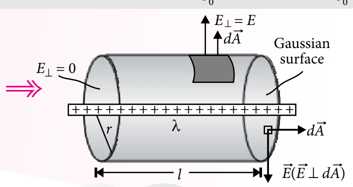
APPLICATIONS OF GAUSS'S LAW

Flux across some definite symmetric closed surfaces

- **Hemispherical body**
  In uniform electric field $\phi_{circular} = -\phi_{curved}; |\phi_{circular}| = \pi R^2 E$
  In non uniform electric field $\phi_{circular} = -\phi_{curved}; |\phi_{curved}| = 2\pi R^2 E$
- **Gaussian Cube**
  Charge kept at corner $\phi_{cube} = \frac{Q}{8\varepsilon_0}$ $\phi_{face} = \frac{Q}{24\varepsilon_0}$ $\phi_{total} = \frac{Q}{\varepsilon_0}$
  Charge kept at centre of face $\phi_{cube} = \frac{Q}{2\varepsilon_0}(5\,faces)$ $\phi_{total} = \frac{Q}{\varepsilon_0}$

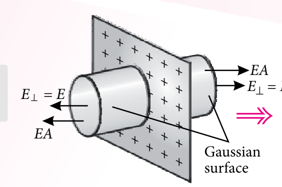
Field of a line charge

$$E_{net} = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{r}$$



Field of an infinite plane sheet of charge

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



Result in field due to a sheet depends only on total charge of the sheet and independent of distribution of charge.

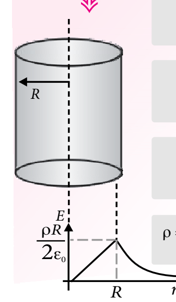
Field due to a long uniformly charged solid cylinder

$$E_{in} = \frac{\rho r}{2\varepsilon_0}$$

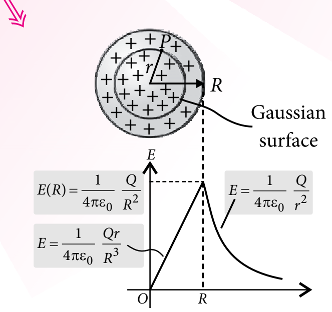
$$E_s = \frac{\rho R}{2\varepsilon_0}$$

$$E_{out} = \frac{\rho R^2}{2\varepsilon_0 r}$$

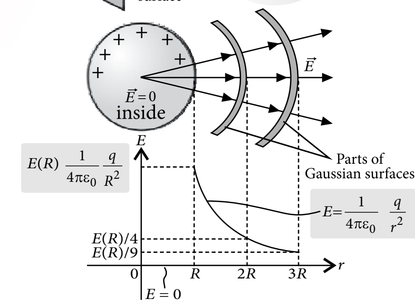
ρ = Volume charge density



Field of a uniformly charged solid sphere and charged conducting sphere



Uniformly charged sphere



Charged conducting sphere

BRAIN MAP

RAY OPTICS

Ray optics describes light propagation in terms of rays. The ray in ray optics is an abstraction or instrument, useful in approximating the paths along which light propagates. The entire field of ray optics deals with tracing back the rays to see their origin.

Formation of images by spherical mirrors

- Mirror formula, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}=\frac{2}{R}$.
- Magnification, $m=\frac{h_2}{h_1}=\frac{-v}{u}=\frac{f}{f-u}=\frac{f-v}{f}$

  m is negative for real image; m is positive for virtual image
  - f and R are negative for a concave mirror and positive for a convex mirror.
  - For a real object u is negative, v is negative for real image and positive for virtual image.

Refraction of light, lateral shift and real and apparent depth

- Refractive index, $\mu=\frac{c}{v}=\frac{\lambda}{\lambda'}$.
- When light travel from medium 1 to 2, ${}^1\mu_2=\frac{\sin i}{\sin r}=\frac{\mu_2}{\mu_1}$.
- $\mu=\frac{\text{Real depth }(x)}{\text{Apparent depth }(y)}$
- Normal shift of image $d=t\left(1-\frac{1}{\mu}\right)$

  where t is the thickness of medium
- Lateral shift $L=t\frac{(\sin(i-r))}{\cos r}$

Refraction from spherical surfaces

- When refraction occurs from rarer to denser medium,

$$\frac{\mu_1}{-u}+\frac{\mu_2}{v}=\frac{\mu_2-\mu_1}{R}$$

- When refraction occurs from denser to rarer medium,

$$\frac{\mu_2}{-u}+\frac{\mu_1}{v}=\frac{\mu_1-\mu_2}{R}$$

- First principal focal length, $f_1=-\frac{\mu_1 R}{\mu_2-\mu_1}$
- Second principal focal length, $f_2=-\frac{\mu_2 R}{\mu_2-\mu_1}$

Lens maker's formula and power of lens

- Lens maker's formula, $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

  where $\mu=\frac{\mu_2}{\mu_1}=\frac{\text{Refractive index of lens material}}{\text{Refractive index of medium}}$
- Power of lens, $P=\frac{1}{f\,(\text{in m})}=\frac{100}{f\,(\text{in cm})}$

Microscope

- Magnifying power of simple microscope when image is formed at infinity, $m=\frac{D}{f}$
- Magnifying power of simple microscope for image formed at D, $m=\left(1+\frac{D}{f}\right)$
- Magnifying power of a compound microscope when image is formed at least distance of distinct vision (D),

$$m=m_0\times m_e=\frac{v_0}{-u_0}\left(1+\frac{D}{f_e}\right)$$

Combination of two lenses

- Focal length F of a combination of two lenses of focal length f_1 and f_2 separated by distance d is,

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2}$$

- If lenses are in contact, $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}$
- Magnification of combination of lenses

  $m=m_1\times m_2\times m_3 \ldots\ldots$
- Power of two lens separated by a distance d is,

  $P=P_1+P_2-d\,P_1P_2.$

Prism

Refraction through prism :

- For refraction through prism,
  - $A+\delta=i_1+e$
  - $r_1+r_2=A$
  - In case of minimum deviation $\delta=\delta_m$, $i_1=e$ and $r_1=r_2$

  $\therefore\ i=\frac{A+\delta_m}{2}$ and $r=\frac{A}{2}$
- $\mu=\frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}$
- Minimum deviation in case of thin prism $\delta=(\mu-1)A$.

Dispersion through prism :

- Angular dispersion $=\delta_V-\delta_R=(\mu_V-\mu_R)A$
- Dispersive power, $\omega=\frac{\delta_V-\delta_R}{\delta}=\frac{\mu_V-\mu_R}{\mu-1}$
- Mean deviation, $\delta=\frac{\delta_V-\delta_R}{2}$

Telescope

- Astronomical telescope :
  - In normal adjustment case, $m=-\frac{f_0}{f_e}$
  - When final image is at the least distance of distinct vision, $m=-\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$
- Terrestrial telescope :
  - In normal adjustment, $m=\frac{f_0}{f_e}$
  - Distance between objective and eye piece $=f_0+4f+f_e$
- Reflecting type telescope, $m=\frac{f_0}{f_e}=\frac{R/2}{f_e}$

Total internal reflection

- Critical angle (i_c) = angle of incidence in denser medium for which angle of refraction is 90° in rarer medium
- Refractive index of denser medium, $\mu=\frac{1}{\sin i_c}$
- Total internal reflection occur when $i>i_c$ and ray must travel from denser to rarer medium.

BRAIN MAP

CLASS XI

THERMAL PROPERTIES OF MATTER

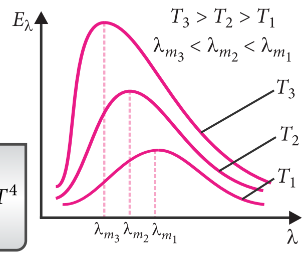
Latent Heat of Fusion (L_f)
Solid $\xrightarrow{Q = mL_f}$ Liquid

Latent Heat of Vapourisation(L_v)
Liquid $\xrightarrow{Q = mL_v}$ Gas

Latent Heat of Sublimation (L_s)
Solid $\xrightarrow{Q = mL_s}$ Gas

$\alpha = \frac{\beta}{2} = \frac{\gamma}{3}$

Wien's Displacement Law
$\lambda_m T = b$ = constant
$b = 2.89 \times 10^{-3}$ m K



Linear Expansion
$L = L_0[1 + \alpha\Delta T]$

Relation between α, β and γ

Superficial Expansion
$A = A_0(1 + \beta\Delta T)$

Volume Expansion
$V = V_0(1 + \gamma\Delta T)$

Stefan's Boltzmann Law
Emissive power, $E \propto T^4 \Rightarrow E = \sigma T^4$
For ordinary body, $E = e\sigma T^4$

CHANGE OF STATE
During the change of phase, temperature remains constant but heat is being supplied to the body.

THERMAL EXPANSION
Increase in configuration of a solid with increasing temperature.

Kirchhoff's Law
Ratio of emissive power to absorptive power at temperature, T is
$\frac{E_1}{A_1} = \frac{E_2}{A_2} = \ldots \left(\frac{E}{A}\right)_{\text{Perfectly black body}}$

Radiation
Heat is transferred without heating the intervening medium.

HEAT
Heat is the form of energy transferred between two or more systems or a system and its surroundings by virtue of temperature difference.

TEMPERATURE
It is defined as the thermal state of the body, which would determine the direction of flow of heat when this body is placed in contact with another body.

HEAT TRANSFER
Transfer of heat from one system to another system arises due to temperature difference.

Convection
Heat is transferred due to actual motion of heated particles.

Applications of Convection
- Formation of trade winds
- Causes monsoons
- Land and sea breezes etc.

Conduction
Heat is transferred without any actual motion of particles of the substance.

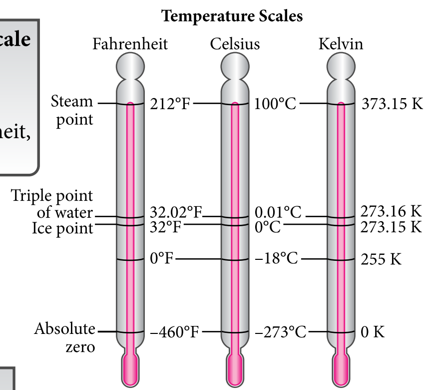
Rate of Heat Flow
$\frac{Q}{t} = \frac{KA(T_1 - T_2)}{d}$; $(T_1 > T_2)$
(K = Coefficient of thermal conductivity)

PRINCIPLE OF CALORIMETRY

It is based on the law of conservation of energy.
Heat lost by one body = Heat gained by other body

THERMOMETRY
A branch of physics which deals with the measurement of temperature, is known as the thermometry.

Conversion of Temperature Scale
$\frac{C}{5} = \frac{F - 32}{9} = \frac{K - 273}{5} = \frac{R}{4}$
where, C = Celsius, F = Fahrenheit, K = Kelvin, R= Reaumur

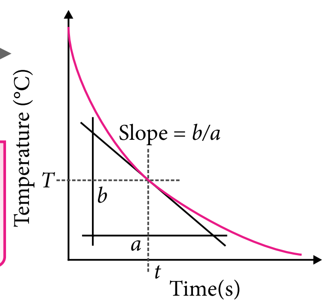


NEWTON'S LAW OF COOLING
The rate of loss of heat by a body is directly proportional to the excess of temperature of the body over surroundings, provided excess is small.

Triple Point of Water
Temperature and pressure at which all the three phases of water exists in equilibrium. $T_3 = 273.16$ K

HEAT CAPACITY
The amount of heat absorbed by a given amount of substance to change the temperature by unity.

Newton's Law of Cooling
Rate of cooling of a body is proportional to the excess temperature of the body over the surroundings
$\frac{dT}{dt} = \frac{-k}{ms}(T_2 - T_1)$



Molar Specific Heat
The amount of heat required to raise the temperature of one mole of a substance by unity. $C = \frac{\Delta Q}{n\Delta T}$

Specific Heat Capacity
The amount of heat required to raise the temperature of 1 g of substance by 1 °C. $s = \frac{\Delta Q}{m\Delta T}$

BRAIN MAP

THERMAL PROPERTIES OF MATTER, THERMODYNAMICS & KINETIC THEORY

Heat and temperature are not the same thing. Temperature of a body is the degree of hotness or coldness whereas heat is a form of energy that flows between two bodies by virtue of temperature difference between

Thermal Properties of Matter

Heat and Temperature

- Heat is a form of energy which produces in us the sensation of warmth.
- Temperature is a relative measure of hotness or coldness of a body.
- $$\frac{T_C+0}{100}=\frac{T_F-32}{180}=\frac{T_K-273.15}{100}=\frac{T_R-0}{80}$$

  where T_C, T_F, T_K and T_R are the temperatures on Celcius, Fahrenheit, Kelvin and Reaumur scales respectively.

Thermal Expansion

- **Coefficient of linear expansion** (α) **:** Increase in length per unit length per unit rise in temperature.
  $$\alpha=\frac{\text{B}L}{L\Delta T}$$
- **Coefficient of area expansion** (β) **:** Increase in area per unit area per unit rise in temperature.
  $$\beta=\frac{\text{B}A}{A\Delta T}$$
- **Coefficient of volume expansion** (γ) **:** Increase in volume per unit volume per unit rise in temperature.
  $$\gamma=\frac{\text{B}V}{V\Delta T}$$
- **Relation between** α, β **and** γ**:** $6\alpha=3\beta=2\gamma$

Important Definitions

- **Specific heat capacity** (c) **:** Amount of heat required to raise the temperature of unit mass of the substance through one degree.
  $$c\;;\;\frac{Q}{m\Delta T}$$
- **Molar heat capacity** (C) **:** Amount of heat required to raise the temperature of one mole of a substance through one degree.
  $$C\;;\;\frac{Q}{n\Delta T}$$
- **Water equivalent** (w) **:** Quantity of water which would be raised through 1°C by the amount of heat required to raise the temperature of the body through 1°C.
  $$w=mc$$
- **Latent heat** (L) **:** Amount of heat required to change the state of a unit mass of a substance without rise in temperature.
  $$L\;;\;\frac{Q}{m}$$
  Latent heat of fusion (L_f) corresponds to solid to liquid phase change whereas latent heat of vapourisation (L_v) corresponds to liquid to gas phase change.

Heat Transfer

- Heat Q that flows across the opposite faces of a rod in time t,
  $$Q\;;\;KA\frac{dT}{dx}t$$
  where A is area of cross-section, $\frac{dT}{dx}$ is temperature gradient and K is coefficient of thermal conductivity.

Newton's Law of Cooling

- Rate of cooling of a body is proportional to the excess temperature of the body over the surroundings

  i.e. $\frac{dQ}{dt}\;;\;-k(T_2-T_1)$

Thermodynamics

First Law of Thermodynamics

- $dQ=dU+dW$

  where dQ is amount of heat which is taken as positive when heat is supplied to a system and negative when heat is drawn from the system

  dU is change in internal energy, taken as positive when temperature increases and negative when temperature decreases,

  dW is amount of work done, taken as positive when work is done by the system and negative when work is done on the system.

Thermodynamic Processes

- **Isothermal :** Temperature constant. $(dQ=dW)$
- **Adiabatic :** No heat flow between the system and surroundings. $(dU=-dW)$
- **Isobaric :** Pressure constant.
- **Isochoric :** Volume constant. $(dQ=dU)$

Adiabatic and Isothermal Processes

- For an adibatic process,

  $PV^{\varepsilon}=$ constant, $TV^{(\gamma-1)}=$ constant,

  $P^{(1-\gamma)}T^{\gamma}=$ constant

  $$W=\frac{nR(T_1+T_2)}{(\gamma-1)}$$
- For an isothermal process,
  $$W\;;\;nRT\ln\frac{V_2}{V_1}$$
- Slope of adiabatic curve $=\gamma$(slope of isothermal curve)

Heat Engine and Refrigerator

- Net work done (W) = Heat absorbed by the source (Q_1) – Heat rejected to the sink (Q_2)
- Efficiency of a heat engine,
  $$\phi=\frac{W}{Q_1}=1-\frac{Q_2}{Q_1}=1-\frac{T_2}{T_1}$$
- Coefficient of performance of a refrigerator,
  $$\upsilon=\frac{Q_2}{Q_1-Q_2}=\frac{T_2}{T_1-T_2}$$

Entropy

- Entropy (S) is the measure of disorder in a system.
  $$\Delta S=\frac{\text{B}Q}{T}.$$
- For irreversible processes, $\Delta S>0$
- For reversible processes, $\Delta S=0$
- Process where $\Delta S<0$ is not possible.

Kinetic Theory

Ideal Gas Laws

- **Boyle's law :** At constant T, $P\propto 1/V$, $PV=$ constant
- **Charles' law :** At constant P, $V\propto T$, $V/T=$ constant
- **Gay-Lussac's law :** At constant V, $P\propto T$, $P/T=$ constant
- **Ideal gas equation :**
  $$PV=nRT=k_BNT.$$

Pressure and Kinetic Energy

- Pressure exerted by an ideal gas
  $$P\;;\;\frac{1}{3}mnv_{\text{rms}}^2=\frac{1}{3}\frac{M}{V}v_{\text{rms}}^2=\frac{1}{3}\rho v_{\text{rms}}^2$$
- Average kinetic energy per molecule of the gas
  $$E\;;\;\frac{1}{2}mv_{\text{rms}}^2=\frac{3}{2}k_B T$$
- Relation between P and E: $PV=\frac{2}{3}E$

Speed of a Gas Molecule

- Most probable speed,
  $$v_{\text{mp}}\;;\;\sqrt{\frac{2k_BT}{m}}=\sqrt{\frac{2RT}{M}}$$
- Average speed,
  $$v_{\text{av}}\;;\;\sqrt{\frac{8k_BT}{\pi m}}=\sqrt{\frac{8RT}{\pi M}}$$
- Root mean square speed,
  $$v_{\text{rms}}\;;\;\sqrt{\frac{3k_BT}{m}}=\sqrt{\frac{3RT}{M}}$$

Relation between C_P, C_V, γ, f and R

- $C_V\;;\;\frac{f}{2}R$
- $C_P\;;\;\frac{f}{2}R+R$
- $\varepsilon\;;\;\frac{C_P}{C_V}$
- $\varepsilon=1+\frac{2}{f}$
- $C_P+C_V=R$

where f is the number of degrees of freedom.

Values of C_P, C_V and γ

- For monoatomic gases
  $$C_V\;;\;\frac{3}{2}R,\;C_P=\frac{5}{2}R,\;\gamma=\frac{5}{3}$$
- For diatomic gases :
  $$C_V\;;\;\frac{5}{2}R,\;C_P=\frac{7}{2}R,\;\gamma=\frac{7}{5}$$
- For triatomic gases (linear molecule)
  $$C_V\;;\;\frac{7}{2}R,\;C_P=\frac{9}{2}R,\;\gamma=\frac{9}{7}$$
- For triatomic gases (non-linear molecule)
  $$C_V\;;\;3R,\;C_P=4R,\;\gamma=\frac{4}{3}$$

Mean Free Path

- Average distance travelled by a gas molecule between two successive collisions
  $$\varphi=\frac{k_BT}{\sqrt{2}\,\pi d^2P}=\frac{1}{\sqrt{2}\,\pi d^2 n}$$

Blackbody Radiation

- **Wein's displacement law :** $\lambda_m T=$ constant
- **Stefan-Boltzmann law :** For a perfect radiator at temperature T, the energy emitted per unit time, $H=A\sigma T^4$

  For a perfect radiator at temperature T, with surroundings at T_S, $H=\sigma A(T^4-T_S^4)$

  For a body with emissivity e, $H=e\sigma A(T^4-T_S^4)$

BRAIN MAP

CHRISTIAAN HUYGENS (1629-1695)

Christiaan Huygens, the first person to explain how wave theory can also account for the laws of geometric optics. He had a very important insight into nature of wave propagation which is known as Huygens' principle. He is known particularly as an astronomer, physicist. His work included early telescopic studies of rings of Saturn and the discovery of its Moon Titan. He also experimented in 1672 with double refraction (birefringence) in Iceland spar.

WAVE OPTICS

An encounter with wave nature of light

Propagation of light wave

Principle of superposition of light waves

Huygens Fresnel principle

Light as a transverse electromagnetic wave

Huygens' Wave Theory

- Every point on a wave-front may be considered as a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wave-front is the tangential surface to all of these secondary wavelets at a later time.
- Laws of reflection and refraction of light can be explained by Huygens wave theory.

Interference of light

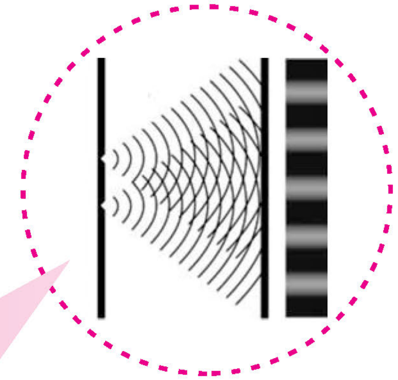
The superposition of two coherent waves resulting a pattern of alternating dark and bright fringes.

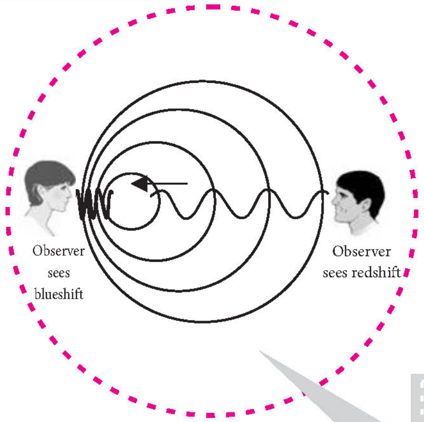
- Young's double slit experiment
  - Resultant intensity $I_R = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$

    for bright fringes, $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$ at $\phi = 0°$ or $2n\pi$

    for dark fringes, $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$ at $\phi = 180°$ or $(2n-1)\pi$

    for $I_1 = I_2 = I_0$; $I_R = 4I_0\cos^2\frac{\phi}{2}$
  - Position of bright fringes $x_n = \frac{n\lambda D}{d}$
  - Position of dark fringes $x_n' = \frac{(2n-1)\lambda D}{2d}$
  - Fringe width $\beta = \frac{\lambda D}{d}$
  - Ratio of slit width with intensity : $\frac{\omega_1}{\omega_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$
- If whole YDSE set up is taken in medium of refractive index μ, as λ changes β also changes $\lambda' = \frac{\lambda}{\mu}$ and $\beta' = \frac{\beta}{\mu}$





Doppler's effect

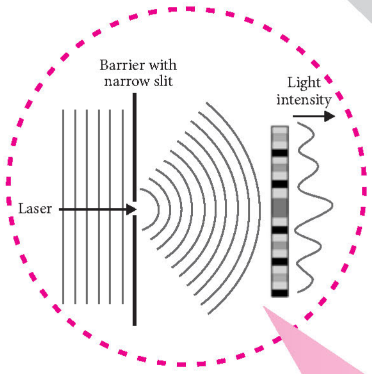
- The apparent frequency received by an observer during relative motion of source and observer is

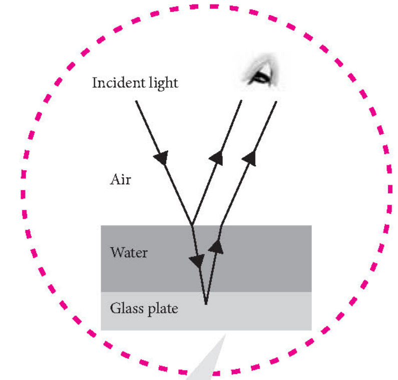
  $\upsilon' = \upsilon\left(1 - \frac{v}{c}\right)$; source moving away from observer

  $\upsilon' = \upsilon\left(1 + \frac{v}{c}\right)$; source approaching the observer

  Doppler shift : $\Delta\upsilon = \pm\frac{v}{c}\times\upsilon$

  $\Delta\lambda = \pm\frac{v}{c}\times\lambda \Rightarrow \lambda' - \lambda = \pm\frac{v}{c}\lambda$





Interference in thin film

- For reflected Light

  Maxima $\rightarrow$ $2\mu t\cos r = (2n+1)\frac{\lambda}{2}$

  Minima $\rightarrow$ $2\mu t\cos r = n\lambda$

  For transmitted light

  Maxima $\rightarrow$ $2\mu t\cos r = n\lambda$

  Minima $\rightarrow$ $2\mu t\cos r = (2n+1)\frac{\lambda}{2}$
- Shift in fringe pattern

  $\Delta x = \frac{\beta}{\lambda}(\mu-1)t = \frac{D}{d}(\mu-1)t$ (t = thickness of film, μ = R.I. of the film)

Diffraction

The spreading of light waves on passing through apertures or by sharp edges.

- Single slit experiment
  - Angular position of n^{th} minima, $\theta_n = \frac{n\lambda}{d}$
  - Angular position of n^{th} maxima $\theta_n' = \frac{(2n+1)\lambda}{2d}$
  - Width of central maximum $\beta_o = 2\beta = \frac{2D\lambda}{d}$
- Ray optics as a limiting case of wave optics
  - Fresnel's distance : distance at which diffraction spread is equal to the size of aperture
  - Size of Fresnel zone $D_F = \frac{d^2}{\lambda}$
- Diffraction at circular aperture $d_F = \sqrt{\lambda D}$
  - Linear spread, $x = D\theta$

    Areal spread, $x^2 = (D\theta)^2$ $\left\{\theta = \frac{1.22\lambda}{d}\right\}$

Resolving Power (R.P.)

The ability to resolve the images of two nearby point objects distinctly.

$$\text{R.P.} = \frac{1}{\text{Limit of resolution}}$$

- R.P. of a microscope = $\frac{1}{d} = \frac{2\mu\sin\theta}{\lambda}$

  θ = Semivertical angle subtended at objective.
- R.P. of a telescope = $\frac{1}{d\theta} = \frac{D}{1.22\lambda}$

  D = diameter of objective lense of telescope.

Polarisation of Light

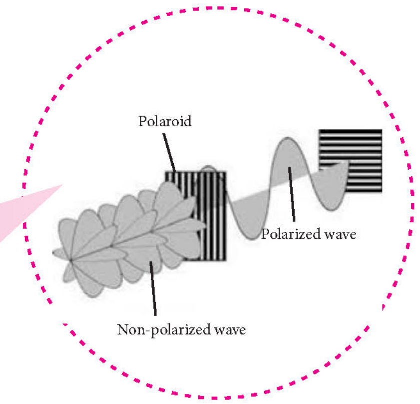
- **Malus Law:** The intensity of transmitted light passed through an analyser is

  $I = I_0\cos^2\theta$

  (θ = angle between transmission directions of polariser and analyser)
- **Brewster's Law:** The tangent of polarising angle of incidence at which reflected light becomes completely plane polarised is numerically equal to refractive index of the medium

  $\mu = \tan i_p$ i_p = Brewster's angle.

  and $i_p + r_p = 90°$



BRAIN MAP
CLASS XI

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THERMODYNAMICS

Thermal Equilibrium
The macroscopic variables such as pressure, temperature, volume, mass, composition, etc., which characterize a system, do not change with time.

Zeroth Law
Two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other.

First Law
Heat supplied to a gas may
(i) raise its internal energy
(ii) enable it to expand and thereby do external work. $dQ = dU + dW$

Second Law
There is no heat engine can have efficiency η equal to 1 or no refrigerator can have coefficient of performance is equal to infinity.

Specific Heat Capacity
$\Delta Q = ms\Delta T = ms(T_f - T_i)$ or $s = \dfrac{\Delta Q}{m\Delta T}$

Molar specific heat capacity, $C = \dfrac{1}{\mu}\left(\dfrac{\Delta Q}{\Delta T}\right)$

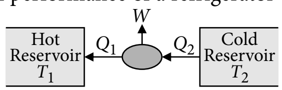
Laws of Thermodynamics

THERMODYNAMICS

Thermodynamic Processes

Refrigerator
The coefficient of performance of a refrigerator is ;

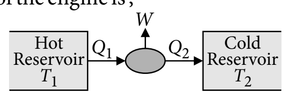
$\alpha = \dfrac{Q_2}{W} = \dfrac{Q_2}{Q_1 - Q_2}$



here, $(Q_1 < Q_2)$

Heat Engine
The efficiency η of the engine is ;

$\eta = \dfrac{W}{Q_1} = 1 - \dfrac{Q_2}{Q_1}$



here $(Q_1 > Q_2)$

State Variables and Equation of State
The relation between the state variables (P, V, T) of the system is called equation of state.

For μ moles of an ideal gas, equation of state is $PV = \mu RT$ and for 1 mole of an ideal gas it is $PV = RT$.

Carnot's Cycle
Isothermal expansion:

$$W_1 = \mu RT_1 \log_e \frac{V_2}{V_1}$$

Adiabatic expansion:

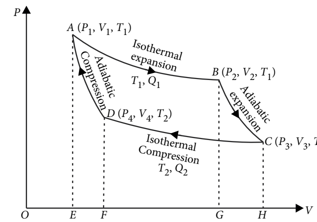
$$W_2 = \mu \frac{R(T_1 - T_2)}{\gamma - 1}$$

Isothermal compression:

$$W_3 = \mu RT_2 \log_e \frac{V_3}{V_4}$$

Adiabatic compression:

$$W_4 = \mu \frac{R(T_1 - T_2)}{\gamma - 1}$$



Net work done during the complete cycle,

$W = W_1 + W_2 + (-W_3) + (-W_4)$

$= W_1 - W_3 =$ Area ABCD

(As $W_2 = W_4$)

Efficiency, $\eta = \dfrac{\text{Work done}}{\text{Heat input}} = \dfrac{W}{Q_1}$

$\eta = 1 - \dfrac{Q_2}{Q_1} = \dfrac{W}{Q_1}$

Relation between Coefficient of Performance and Efficiency of Refrigerator
$$\alpha = \frac{1 - \eta}{\eta}$$

Isothermal Process
Isothermal process : A thermodynamic process in which the temperature remains constant.

- Equation of isothermal process, $PV =$ constant.
- Work done during isothermal process,

  $W = \mu RT \ln\left(\dfrac{V_f}{V_i}\right)$; $W = \mu RT \ln\left(\dfrac{P_i}{P_f}\right)$

- The slope of isothermal curve on a P-V diagram at any point on the curve is given by

  $\dfrac{dP}{dV} = -\dfrac{P}{V}$

Adiabatic Process
Adiabatic Process : A thermodynamic process in which no heat flows between the system and the surroundings.

- Equation of adiabatic process,

  $PV^{\gamma} =$ constant, where $\gamma = C_P/C_V$.

- Work done during adiabatic process,

  $W = \dfrac{(P_iV_i - P_fV_f)}{(\gamma - 1)}$; $W = \dfrac{\mu R(T_i - T_f)}{\gamma - 1}$

- The slope of adiabatic curve on a P-V diagram at any point on the curve is given by

  $\dfrac{dP}{dV} = -\gamma\left(\dfrac{P}{V}\right)$

Isochoric Process
Isochoric (isometric) process : A thermodynamic process in which volume remains constant.

- Equation of isochoric process :

  $\dfrac{P}{T} =$ constant.

- No work is done by the gas in an isochoric process.
- The slope of the isochoric curve on a P-V diagram is infinite.

Isobaric Process
Isobaric process : A thermodynamic process in which pressure remains constant.

- Equation of isobaric process : $\dfrac{V}{T} =$ constant.
- Work done during isobaric process,

  $W = P(V_f - V_i) = \mu R(T_f - T_i)$.

- The slope of the isobaric curve on a P-V diagram is zero.

BRAIN MAP

WAVES

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Class XI

Class XII

COMMUNICATION SYSTEMS

BRAIN MAP

TYPES OF WAVES

Electromagnetic Waves
Waves propagating in form of oscillating electric and magnetic fields.
Do not require medium for propagation.

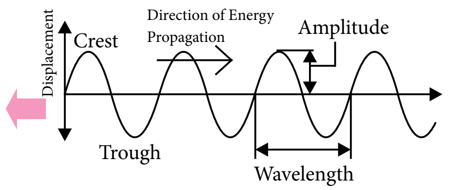
Matter Waves
Waves associative with microscopic particles such as electrons, protons etc. in motion are called matter waves.

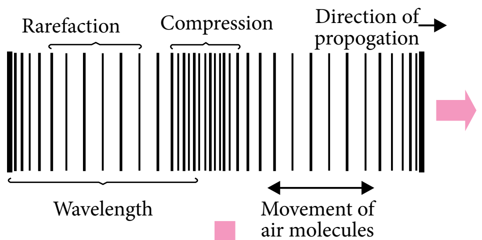
Mechanical Waves
Waves which require a material medium for their propagation are called mechanical waves.

Transverse Waves
The individual particles of the medium oscillate perpendicular to the direction of wave propagation.

Longitudinal Waves
The individual particles of medium oscillate along the direction of wave propagation.

Velocity of Transverse Wave in Solids and Strings
- In solids, $v=\sqrt{\frac{\eta}{\rho}}$
  where η is modulus of rigidity and ρ is density of solids.
- In stretched string, $v=\sqrt{\frac{T}{m}}$
  here, T is tension in string and m is mass per unit length of string.





Velocity of Longitudinal Waves
- In a solid of bulk modulus κ, modulus of rigidity η and density ρ is
  $$v=\sqrt{\frac{\kappa+\frac{4}{3}\eta}{\rho}}$$
- In a fluid of bulk modulus κ and density ρ is
  $$v=\sqrt{\frac{\kappa}{\rho}}$$
- Newton's formula for the velocity of sound in a gas is
  $$v=\sqrt{\frac{\kappa_{iso}}{\rho}}=\sqrt{\frac{P}{\rho}}\ (P=\text{pressure of the gas})$$

WAVE MOTION

Progressive Waves
- **Displacement,** $y=A\sin(\omega t-kx+\phi_0)$
  $$y=A\sin 2\pi\left(\frac{t}{T}-\frac{x}{\lambda}\right)=A\sin\frac{2\pi}{\lambda}(vt-x)$$
- **Phase,** $\phi=2\pi\left(\frac{t}{T}-\frac{x}{\lambda}\right)+\phi_0$
  where ϕ_0 is the initial phase.
- **Phase change:**
  (a) with time $\Delta\phi=\frac{2\pi}{T}\Delta t$
  (b) with position $\Delta\phi=\frac{2\pi}{\lambda}\Delta x.$

Superposition of Waves
Identical waves of same speed superposes in opposite direction

Waves with same speed and different frequency superposes in same direction

Doppler's Effect in Sound
- If v, v_0, v_s and v_m are the velocities of sound, observer, source and medium respectively, then the apparent frequency,
  $$\upsilon'=\frac{v+v_m-v_0}{v+v_m-v_s}\times\upsilon$$
- If the medium is at rest, $(v_m=0)$ then
  $$\upsilon'=\frac{v-v_0}{v-v_s}\times\upsilon$$

Stationary Waves
- Wave formed by the superposition of incident wave and reflected wave is given by $y=\pm 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi t}{T}$
- Position of antinodes: $x=0,\frac{\lambda}{2},\lambda,\frac{3\lambda}{2}$
- Position of nodes: $x=\frac{\lambda}{4},\frac{3\lambda}{4},\frac{5\lambda}{4}...$
- Frequency of vibration of a string fixed at both ends, $\upsilon=\frac{nv}{2L}=\frac{n}{2L}\sqrt{\frac{T}{m}}$
  L = length of string, n = mode of vibration

- **Open organ pipe:**
  Fundamental mode,
  $\upsilon_1=v/2L=\upsilon$ (1st harmonic)
  n^{th} mode, $\upsilon_n=nv/2L$ (n^{th} harmonic and $(n-1)^{th}$ overtone)
- **Closed organ pipe:**
  Fundamental mode,
  $\upsilon_1=v/4L=\upsilon$ (1st harmonic)
  n^{th} mode, $\upsilon_n=(2n-1)\,\upsilon$
  [$(2n-1)^{th}$ harmonic or $(n-1)^{th}$ overtone]

Beats Formation
- **Beat frequency** = Number of beats sec^{-1}
  = Difference in frequencies of two sources.
  $\upsilon_{beat}=(\upsilon_1-\upsilon_2)$ or $(\upsilon_2-\upsilon_1)$
  $\therefore\ \upsilon_2=\upsilon_1+\upsilon_{beat}$
- If prongs of tuning fork is filed υ increases.
- If prongs is loaded with a wax υ decreases.
- **Uses:**
  – For tuning musical instruments
  – For detection of marsh gas in mines
  – For using as a low frequency oscillator.

MODES OF COMMUNICATION

POINT TO POINT COMMUNICATION
Communication takes place over a link between a single transmitter and a receiver.

BROADCAST MODE COMMUNICATION
Large number of receivers corresponding to a single transmitter.

BASIC COMMUNICATION TECHNIQUE

Transmitter
Converts the message signal suitable for transmission.

Communication Channel
A medium that connects a transmitter to a receiver.

Receiver
Retrieves the message signal into original form.

Modulation
Process of variation of some characteristic of a high frequency wave in accordance with the message signal.

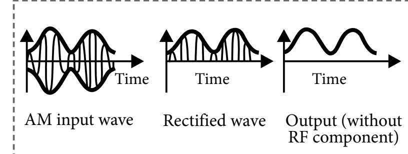
Necessity of Modulation
- *To reduce the size of antenna, need a high frequency carrier wave.*
- *We need high power transmission as $P\propto(1/\lambda)^2$*
- *To avoid the mixing up of signals a band of frequency is allotted to each user for different radio channels.*

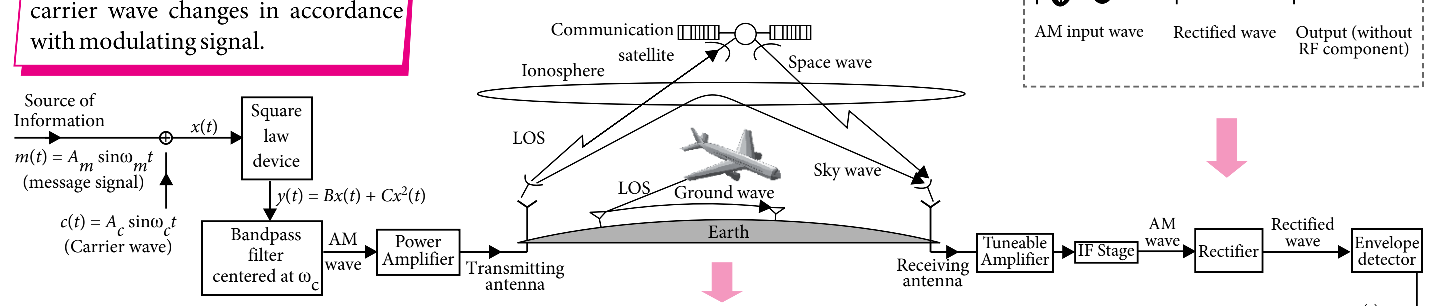
Demodulation
Process of recovering the audio signal from the modulated wave is called demodulation or detection.

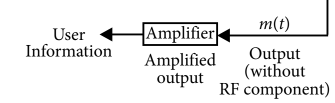
Phase Modulation

Frequency Modulation

Amplitude Modulation
Amplitude of the high frequency carrier wave changes in accordance with modulating signal.

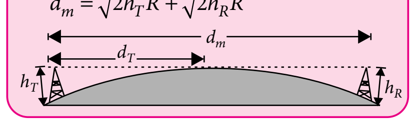






SPACE COMMUNICATION

Space Wave Propagation
A radio wave transmitted from an antenna, directly reaches the receiving antenna by LOS propagation.
- Maximum LOS distance
  $d_m=\sqrt{2h_TR}+\sqrt{2h_RR}$



Range and Application:
- VHF: 30 MHz - 300 MHz
  TV, FM radio, metrology devices
- UHF: 300 MHz - 3 GHz
  TV, aircraft landing systems

Ground Wave Propagation
Here EM wave glides over the earth surface along its curvature from transmitter to receiver placed close to the surface of earth.

Range and Application:
- LF: 30 kHz - 300 kHz
  Long wave radio communication
- MF: 300 kHz - 3 MHz
  AM radio broadcast for local areas

Sky Wave Propagation
The radio wave directed towards the sky and reflected by the ionosphere towards the desired location on the earth.
- Critical frequency $\upsilon_c=9(N_{max})^{1/2}$

Range and Application:
- HF: 3 MHz - 30 MHz
  Short wave radio communication, CB radio

BRAIN MAP

WAVES

Every piece of music you hear, from Hindustani classical to film songs, depends on performers producing waves and your detection of those waves.

Wave Motion

A means of transferring momentum and energy from one point to another without any actual transportation of matter

Transverse and Longitudinal Waves

- A transverse wave is one in which the disturbance occurs perpendicular to the direction of travel of the wave.
- A longitudinal wave is one in which the disturbance occurs parallel to the line of travel of the wave.

Progressive Wave Parameters

- Displacement, $y = A\sin(\omega t + kx)$

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

- Phase, $\phi = 2\pi\left(\frac{t}{T}+\frac{x}{\lambda}\right)+\phi_0$

where ϕ_0 is the initial phase.

- Phase change with time,

$$\Delta\phi = \frac{2\nu}{T}\Delta t.$$

- Phase change with position,

$$\Delta\phi = \frac{2\nu}{\lambda}\Delta x.$$

- Instantaneous particle velocity,

$$u = \frac{dy}{dt} = \frac{2\nu A}{T}\cos 2\pi\left(\frac{t}{T}+\frac{x}{\lambda}\right)$$

- Velocity amplitude,

$$u_0 = \frac{2\nu A}{T} = \omega A$$

- Instantaneous particle acceleration,

$$a = \frac{du}{dt} = -\frac{4\nu^2}{T^2}A\sin 2\pi\left(\frac{t}{T}+\frac{x}{\lambda}\right)$$
$$= -\omega^2 y$$

- Acceleration amplitude,

$$a_0 = \frac{4\nu^2}{T^2}A = \omega^2 A$$

Wave Travelling Along a String

- Speed, $v \; ; \sqrt{\frac{T}{m}}$,

where, T = tension in the string,
m = mass per unit length.

- Average rate at which kinetic energy or potential energy transported $= \frac{1}{4}\frac{\upsilon^2 A^2 T}{v}$
- Average power transmitted along the string by a sine wave

$$P_{av} = \frac{1}{2}\frac{\upsilon^2 A^2 T}{v} = 2\pi^2 mvA^2\upsilon^2$$

Principle of Superposition of Waves

- According to the principle of superposition of waves, when any number of waves interact at a point in a medium, the net displacement of the point at a given time is the algebraic sum of the displacements due to each wave at that instant of time.

Stationary Waves

- The stationary wave formed by the superposition of incident wave and reflected wave is given by

$$y = 2A\sin\frac{2\nu x}{\lambda}\cos\frac{2\pi t}{T}$$

Nodes are formed at the positions

$$x = 0,\ \frac{\varphi}{2},\ \lambda,\ \frac{3\lambda}{2}....$$

and anti nodes are formed at

$$x = \frac{\varphi}{4},\ \frac{3\lambda}{4},\ \frac{5\lambda}{4}...$$

Velocity of Longitudinal Waves

- Velocity of longitudinal waves in a solid of bulk modulus κ, modulus of rigidity η and density ρ is

$$v = \sqrt{\frac{\iota + \frac{C}{3}\eta}{\rho}}$$

- Velocity of longitudinal waves in a long solid rod of Young's modulus Y and density ρ is given by

$$\S\ ;\ \sqrt{\frac{\breve{G}}{\rho}}$$

- Velocity of longitudinal waves in a fluid of bulk modulus κ and density ρ is

$$\S = \sqrt{\frac{\iota}{\rho}}$$

- Newton's formula for the velocity of sound in a gas is

$$v = \sqrt{\frac{\iota_{x\sim}}{\rho}} = \sqrt{\frac{P}{\rho}}.$$

here, P = pressure of the gas

- Laplace formula for the velocity of sound in a gas is

$$v = \sqrt{\frac{\kappa_{ps\,xp}}{\rho}} = \sqrt{\frac{\varepsilon P}{\rho}},$$

- Intensity of sound waves

$$I = \frac{1}{2}\frac{\upsilon^2 A^2\kappa}{v} = \frac{2\pi^2\kappa}{v}A^2v^2 = \frac{P_0^2 v}{2\kappa} = \frac{P_0^2}{2\rho v}$$

Factors Affecting Velocity of Sound through Gases

- Effect of density, $v \cdot \frac{1}{\sqrt{\rho}}$

i.e., $\frac{v_2}{v_1} = \sqrt{\frac{\pi_1}{\rho_2}}$

- Effect of temperature, $v \cdot \sqrt{T}$

$$\frac{v_t}{v_0} = \sqrt{\frac{T}{T_0}} = \sqrt{\frac{273)\ t}{273}}$$

- No change in velocity of sound with change in pressure provided temperature is kept constant.

Doppler's Effect

- If v, v_o, v_s and v_m are the velocities of sound, observer, source and medium respectively, then the apparent frequency,

$$\upsilon' = \frac{v \Leftrightarrow v_m \pm v_o}{v \pm v_m \rightsquigarrow v_s}\times\upsilon$$

- If the medium is at rest, ($v_m = 0$) then

$$\upsilon' = \frac{v \Leftrightarrow v_o}{v \rightsquigarrow v_s}\times\upsilon$$

- Upper sign on v_s (or v_o) is used when source (observer) moves towards the observer (source) while lower sign is used when it moves away.

Organ Pipes

- Open organ pipe
Fundamental mode,

$$\sigma_1 = \frac{v}{2L} = \upsilon \text{ (First harmonic)}$$

Second mode, $\upsilon_2 = 2\upsilon$
(Second harmonic or first overtone)

n^{th} mode, $\upsilon_n = \frac{nv}{2L}$
(n^{th} harmonic or $(n-1)^{th}$ overtone)

- Closed organ pipe
Fundamental mode,

$$\sigma_1 = \frac{v}{4L} = \upsilon \quad \text{(First harmonic)}$$

Second mode, $\upsilon_2 = 3\upsilon$
(Third harmonic or first overtone)
Third mode, $\upsilon_3 = 5\upsilon$
(Fifth harmonic or second overtone)
n^{th} mode, $\upsilon_n = (2n-1)\upsilon$
$[(2n-1)^{th}$ harmonic or $(n-1)^{th}$ overtone$]$

- Laplace correction $e = 0.6r$ (in closed pipe) and $2e = 1.2r$ (in open pipe)

$$\upsilon = n\left[\frac{v}{2(l+1.2r)}\right] \text{ (in open pipe)}$$

$$\upsilon = n\left[\frac{v}{4(l+0.6r)}\right] \text{ (in closed pipe)}$$

Modes of Vibration of Strings

- String fixed at both ends
Frequency of vibration

$$\sigma = \frac{nv}{2L} = \frac{n}{2L}\sqrt{\frac{T}{m}}$$

where L = length of string
n = mode of vibration
Fundamental frequency

$$\sigma_0 = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{T}{m}},$$

Second harmonic or 1st overtone, $\upsilon_2 = 2\upsilon_0$
Third harmonic or 2nd overtone, $\upsilon_3 = 3\upsilon_0$
and so on.

- String fixed at one end
Frequency of vibration

$$\upsilon = \left(n+\frac{1}{2}\right)\frac{v}{2L} = \frac{\left(n+\frac{1}{2}\right)}{2L}\sqrt{\frac{T}{m}}$$

Fundamental frequency,

$$\sigma_0 = \frac{v}{4L} = \frac{1}{4L}\sqrt{\frac{T}{m}}$$

- Law of length
υL = constant
or $\upsilon_1 L_1 = \upsilon_2 L_2$

Beats

- Beat frequency = Number of beats/sec
= Difference in frequencies of two sources.
$\upsilon_{beat} = (\upsilon_1 - \upsilon_2)$ or $(\upsilon_2 - \upsilon_1)$
$\therefore$ $\upsilon_2 = \upsilon_1 \pm \upsilon_{beat}$
- The $\pm$ sign is decided by loading/filing any of the prongs of either tuning fork.
- On loading a fork, its frequency decreases and on filing, its frequency increases.

BRAIN MAP

CLASS XI

WORK AND ENERGY

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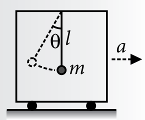
Pendulum Suspended in an Accelerating Trolley

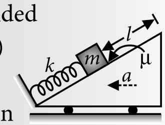
- For a pendulum suspended from the ceiling of a trolley moving with acceleration a, the maximum deflection θ of the pendulum from the vertical is $\theta = 2\tan^{-1}\left(\frac{a}{g}\right)$



Work Energy Theorem for Non-inertial Frames

For a block of mass m welded with light spring (relaxed) When the wedge fitted moves with an acceleration a, block slides through maximum distance l relative to wedge,

$$l = \frac{2m}{k}[a(\cos\theta - \mu\sin\theta) - g(\sin\theta + \mu\cos\theta)]$$



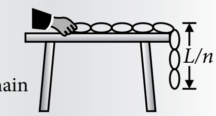
Work Done in Pulling the Chain

$$W = \frac{MgL}{2n^2}$$

{M = Mass of chain

L = Length

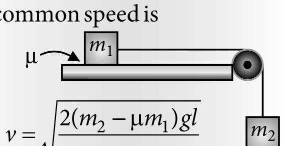
n = Fraction of chain hanged}



Motion of Blocks Connected with Pulley

- Two blocks connected by a string, as shown. If they are released from rest. After they have moved a distance l, their common speed is

$$v = \sqrt{\frac{2(m_2 - \mu m_1)gl}{m_1 + m_2}}$$



Different cases explained using work energy theorem

Nature of Work Done

- Positive work ($0° \le \theta < 90°$)
  Component of force is parallel to displacement
- Negative work ($90° < \theta \le 180°$)
  Component of force is opposite to displacement
- Zero work ($\theta = 90°$)
  Force is perpendicular to displacement

Work Energy Theorem

Work done by a force acting on a body is equal to the change in the kinetic energy of the body. It is valid for a system in presence of all types of forces.

$$W_{\text{total}} = \Delta K$$

Work

Work done by a force (F) is equal to the scalar product of the force and the displacement (S) of the body.

$W = \vec{F}\cdot\vec{S}$ (θ is the angle between F and S)

$W = FS\cos\theta$

Energy

The energy of a body is defined as its capacity for doing work. Energy is a scalar quantity.

Unit and dimensions for both energy and work are same

Dimensions : $[ML^2T^{-2}]$

S.I. Unit : joule (J)

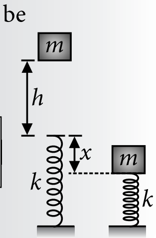
Work Depends on Frame of Reference

With change of the frame of reference (inertial), force does not change while displacement may change. So the work done by a force will vary in different frames.

An Application of Conservation of Energy

- A block of mass m, falling from height h, on a mass less spring of stiffness k.
  - The maximum compression in the spring will be

$$x = \frac{mg}{k}\left[1 + \sqrt{1 + \frac{2kh}{mg}}\right]$$



- If block is released slowly ($h = 0$), maximum compression, $x = \frac{2mg}{k}$
- Work done in bringing the block to stable equilibrium, $W_{ext} = -\frac{m^2g^2}{2k}$

Work Done by Friction

- Work done by static friction is always zero.
- Work done by kinetic friction on the system is always negative.

Work Done by a Spring Force

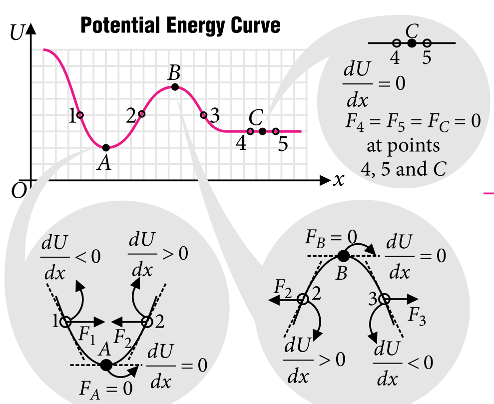
- Work done for a displacement from x_i to x_f

$$W_s = -\frac{1}{2}k\left(x_f^2 - x_i^2\right)$$

Potential Energy

It is the ability of doing work by a conservative force. It arises from the configuration of the system or position of the particles in the system.

Potential Energy Curve



Relation between Conservative Force and Potential Energy

Negative gradient of the potential energy gives force.

$$F = -\frac{dU}{dr}$$