



FORMULA SHEET (2nd PUC)

Subject: Physics

Chapter: All Chapters

Electric Charges and Fields

Electrostatics: Basic Properties

Electric charge (q) is quantized and conserved

Concept	Formula	Meaning of Symbols
Quantization of Charge	$q = \pm ne$	$n = \text{integer}; e = 1.6 \times 10^{-19} \text{ C}$
Coulomb's Law	$F = k$	$q_1 q_2$
Permittivity Constant	$k = \frac{1}{4\pi\epsilon_0} \approx 9 \times 10^9 \text{ Nm}^2 / \text{C}^2$	$\epsilon_0 = \text{Permittivity of free space } (8.854 \times 10^{-12} \text{ F/m})$
Medium Effect	$F_{med} = \frac{F_{noc}}{K}$	$K = \text{Dielectric constant (Relative permittivity } \epsilon_r)$

Electric Field Intensity (E)

The electric field is the force per unit test charge.

- ❖ Point Charge: $E = \frac{kq}{r^2}$
- ❖ Superposition Principle: $E_{net} = E_1 + E_2 + \dots + E_n$

Field Due to Charge Distributions

- ❖ Infinite Line Charge: $E = \frac{\lambda}{2\pi\epsilon_0 r}$ ($\lambda = \text{Linear charge density}$)
- ❖ Infinite Sheet of Charge: $E = \frac{\sigma}{2\epsilon_0}$ ($\sigma = \text{Surface charge density}$)
- ❖ Uniformly Charged Ring (at distance x on axis):

$$E = \frac{kqx}{(R^2 + x^2)^{3/2}}$$



(Where R is the radius of the ring)

Electric Dipole

❖ A system of two equal and opposite charges separated by a small distance ($2a$).

Property	Formula	Details
Dipole Moment	$p = q \times (2a)$	Direction: Negative to Positive charge
Field on Axial Line	$E_{axial} = \frac{2kp}{r^3}$	Valid for $r \gg a$; Direction parallel to p
Field on Equatorial Line	$E_{eq} = \frac{kp}{r^3}$	Valid for $r \gg a$; Direction opposite to p
Torque on Dipole	$\tau = p \times E$	$\tau = pE \sin \theta$
Potential Energy	$U = -p \cdot E$	$U = -p \cdot E \cos \theta$

Electric Flux and Gauss's Law

Flux (ϕ) measures the number of field lines passing through a surface.

$$\text{Electric Flux: } \Phi = \int E \cdot dA = EA \cos \theta$$

$$\text{Gauss's Law: } \Phi_{net} = \frac{q_{enclosed}}{\epsilon_0}$$

Application: Spherical Shell (Radius R , Charge (Q))

$$\text{Outside } (r > R); E = \frac{kQ}{r^2}$$

$$\text{On Surface } (r = R); E = \frac{kQ}{R^2}$$

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

Important Constants & Units

- ❖ Charge (q): Coulomb (C)
- ❖ Electric Field (E): N/C or V/m
- ❖ Linear Charge Density (λ): C/m
- ❖ Surface Charge Density (σ): C/m²
- ❖ Volume Charge Density (ρ): C / (m³)



Electric Potential and Capacitance

Electric Potential (V)

- ✓ Due to a point charge:
 $V = (1 / 4\pi\epsilon_0) \times (q / r)$
- ✓ Relation between electric field and potential:
 $E = -dV/dr$
- ✓ Potential due to a system of point charges:
 $V = \Sigma (1 / 4\pi\epsilon_0) \times (q_i / r_i)$
- ✓ Potential at a distance r from an electric dipole:
On axial line: $V = (1 / 4\pi\epsilon_0) \times (p \cos\theta / r^2)$
On equatorial line: $V = 0$

2. Potential Energy (U)

- ✓ Potential energy of two point charges:
 $U = (1 / 4\pi\epsilon_0) \times (q_1 q_2 / r)$
- ✓ Potential energy of a dipole in an electric field:
 $U = -p \cdot E = -pE \cos\theta$

3. Capacitance (C)

- ✓ Definition:
 $C = q / V$
- ✓ Parallel plate capacitor (air):
 $C = \epsilon_0 \times (A / d)$
- ✓ With dielectric:
 $C = K\epsilon_0 \times (A / d)$
- ✓ Cylindrical capacitor:
 $C = (2\pi\epsilon_0 L) / \ln(b/a)$
- ✓ Spherical capacitor:
 $C = 4\pi\epsilon_0 \times (ab / (b - a))$

4. Combination of Capacitors

- ✓ Series:
 $1 / C_{eq} = 1 / C_1 + 1 / C_2 + \dots$
- ✓ Parallel:
 $C_{eq} = C_1 + C_2 + \dots$

5. Energy Stored in a Capacitor

- ✓ General formula:
 $U = \frac{1}{2} C V^2 = \frac{1}{2} q^2 / C = \frac{1}{2} qV$
- ✓ Energy density (in electric field):
 $u = \frac{1}{2} \epsilon_0 E^2$

6. Effect of Dielectrics

- ✓ When battery remains connected:
 $V = \text{constant}$
 $C \uparrow, q \uparrow, U \uparrow$
- ✓ When battery is disconnected:
 $q = \text{constant}$
 $C \uparrow, V \downarrow, U \downarrow$



Current Electricity

1. **Electric Current:** $I = \frac{Q}{t}$

- ❖ $I \rightarrow$ Current (A)
- ❖ $Q \rightarrow$ Charge (C)
- ❖ $t \rightarrow$ time (s)

2. **Drift Velocity:** $v_d = \frac{I}{nqA}$

- ❖ $n \rightarrow$ Number of electrons per unit volume
- ❖ $q \rightarrow$ Charge of electron
- ❖ $A \rightarrow$ Cross-sectional area

3. **Ohm's Law:** $V = IR$

- ❖ $V \rightarrow$ Potential difference
- ❖ $I \rightarrow$ Current
- ❖ $R \rightarrow$ Resistance

4. **Resistance:** $R = \rho \frac{l}{A}$

- ❖ $\rho \rightarrow$ Resistivity ($\Omega\text{-m}$)
- ❖ $l \rightarrow$ Length of conductor
- ❖ $A \rightarrow$ Cross-sectional area

5. **Temperature Dependence:** $R_t = R_0 [1 + \alpha \Delta T]$

- ❖ $\alpha \rightarrow$ Temperature coefficient of resistance

6. **Electrical Power:** $P = VI = I^2R = V^2 / R$

- ❖ $P = VI = I^2R = \frac{V^2}{R}$

7. **Electrical Energy:** $W = Pt = VI t$

8. **Combination of resistors:**

- ❖ Series : $R_{\text{eq}} = R_1 + R_2 + R_3 + \dots$

$$\text{❖ Parallel : } \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

9. Kirchhoff's Current Law

- ❖ KCL: Sum of current at a junction = 0
- ❖ $\sum I_{in} = \sum I_{out}$
- ❖ KVL: Sum of potential differences in a loop = 0

10. EMF & Internal Resistance: $V = E - Ir$

- ❖ $E \rightarrow$ EMF of cell
- ❖ $r \rightarrow$ Internal resistance

11. Cells in Series and Parallel:

- ❖ Series : $E_{total} = E_1 + E_2 + \dots$
- ❖ $r_{total} = r_1 + r_2 + \dots$
- ❖ Parallel: $E_{total} = \frac{E}{n}$ (identical cells)
- ❖ $r_{total} = \frac{r}{n}$

❖

12. Wheatstone Bridge:

$$\text{❖ } \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

13. Meter Bridge:

$$\text{❖ } \frac{R_1}{R_2} = \frac{l_1}{l_2}$$

14. Potentiometer:

$$\text{❖ } \frac{E_1}{E_2} = \frac{l_1}{l_2}$$

15. Conductivity and Mobility:

$$\text{❖ } \sigma = \frac{1}{\rho}$$

$$\sigma = np\mu$$



Moving Charges and Magnetism

1. Lorentz Force (Force on a Moving Charge in Magnetic and Electric Fields)

- $F = q(E + v \times B)$
- Where q = charge, v = velocity vector, B = magnetic field, E = electric field
- Magnetic force magnitude: $F = qvB \sin \theta$
- Force direction given by the right-hand rule; zero if velocity and magnetic field are parallel or antiparallel.

2. Magnetic Field due to a Moving Point Charge

$$B = \frac{\mu_0 qv \times \hat{r}}{4\pi r^2}$$

- μ_0 = permeability of free space, r = distance from charge to point, \hat{r} = unit vector from charge to point.

3. Biot-Savart Law (Magnetic Field due to a Current Element)

$$dB = \frac{\mu_0}{4\pi} \frac{idl \times \hat{r}}{r^2}$$

- I = current, dl = length element of wire, \hat{r} = unit vector from element to point, r = distance.

4. Magnetic Field on Axis of Circular Coil of Radius R carrying current I

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

- x = distance from the center along the axis.

5. Magnetic Field due to Long Straight Current-Carrying Wire

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

- r = perpendicular distance from wire to point.

6. Force on a Current-Carrying Conductor of Length l in a Magnetic Field

$$F = Il \times B$$

- I = current, l = vector length of conductor.

7. Force between Two Parallel Current-Carrying Conductors

$$\frac{F}{\ell} = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{d}$$

- d = distance between conductors, I_1, I_2 = currents.

8. Cyclotron Frequency (Frequency of Circular Motion of Charged Particle in Magnetic Field)

$$v_c = \frac{qB}{2\pi m}$$

- m = mass of particle.



9. Torque on a Current Loop in a Magnetic Field

$$\tau = NIAB \sin \theta$$

- N = number of turns, A = area of loop, θ = angle between normal to loop and B .

10. Magnetic Dipole Moment of Current Loop

$$m = NIA$$

11. Magnetic Flux

- $\Phi = BA \cos \theta$

Conversion of Galvanometer to Voltmeter

- Voltmeter Range: V (desired voltage range)
- Series resistance R connected with galvanometer:

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

Where V = maximum voltage range, I_g = galvanometer current for full scale deflection, G = galvanometer resistance.

Galvanometer Basics

- Current for full scale deflection:
- $I_g = k \times N$
- Where k = figure of merit (current per division), N = total number of divisions.
- Resistance of galvanometer: G .
- **Conversion of Galvanometer to Ammeter**
- Ammeter Range: I (desired max current)
- Shunt resistance S connected in parallel with the galvanometer:

$$S = \frac{I_g \times G}{I - I_g}$$

Where I_g = Galvanometer full scale deflection current, G = galvanometer resistance.



Magnetism and Matter

Magnetic Dipole

- Magnetic dipole moment (M):
- $M = m \cdot 2l$
- where m = pole strength, $2l$ = distance between poles.
- Unit: Am²
- Torque on a dipole in uniform magnetic field (B):
- $T = MB \sin \theta$
- Potential energy of dipole:
- $U = -M \cdot B = -MB \cos \theta$

Magnetisation & Susceptibility

- Magnetisation (M):

$$M = \frac{\text{Magnetic Moment}}{\text{Volume}}$$

Magnetic susceptibility (χ):

$$M = \chi H$$

- where H = magnetic field intensity.

Relative permeability:

$$\mu_r = 1 + \chi$$

Magnetic Intensity & Flux Density

- Magnetic flux density:
- $B = \mu_0(H + M)$
- In free space:
- $B = \mu_0 H$
- In material:
- $B = \mu H$, $\mu = \mu_r \mu_0$

Magnetic Materials

- Diamagnetic: $\chi < 0$ $\mu_r < 1$ (weak repulsion).



- Paramagnetic: $\chi > 0$ $\mu_r > 1$ (weak attraction).
- Ferromagnetic: $\chi \gg 1$ $\mu_r \gg 1$ (strong attraction).

Magnetic Dipole in a Magnetic Field

- Field on axial line of a dipole:

$$B_{axial} = \frac{\mu_0}{4\pi} \cdot \frac{2M}{r^3}$$

Field on equatorial line of a dipole:

$$B_{eq} = \frac{\mu_0}{4\pi} \cdot \frac{M}{r^3}$$

Gauss's Law in Magnetism

$$\nabla \cdot B = 0 \quad \text{or} \quad \oiint B \cdot dA = 0$$

No magnetic monopoles.

Magnetic Properties of Substances (Quick Recall)

- Diamagnetic - repelled by field (e.g., Bi, Cu).
- Paramagnetic - weakly attracted (e.g., Al, Pt).

Ferromagnetic - strongly attracted, permanent magnetism (e.g., Fe, Co, Ni).



Electromagnetic Induction

Magnetic Flux and Faraday's Laws

Magnetic flux (ϕ) represents the total magnetic field passing through a given area.

Concept	Formula	Meaning of Symbols
Magnetic Flux	$\phi = B.A = BA\cos\theta$	B : Magnetic field; A : Area; θ : Angle between B and normal to area
Faraday's Law	$\varepsilon = -N \frac{d\phi}{dt}$	ε : Induced EMF; N : Number of turns; $d\phi/dt$ Rate of change of flux
Induced Current	$I = \frac{\varepsilon}{R}$	R : Resistance
Induced Charge	$\Delta q = \frac{n\Delta\phi}{R}$	Δq : Total charge flown (independent of time)

Lenz's Law: The negative sign in Faraday's law indicates that the direction of induced EMF always opposes the change in magnetic flux that produced it (Conservation of Energy).

Motional EMF

- ❖ EMF induced due to the motion of a conductor in a magnetic field.
- ❖ Straight Rod (Length l): $\varepsilon = Bvl$ (When B , v , l are mutually perpendicular)
- ❖ General Vector Form: $\varepsilon = \int (\mathbf{v} \times \mathbf{B}) \cdot d\mathbf{l}$
- ❖ Rotating Rod (Length l , angular velocity ω):
- ❖ $\varepsilon = \frac{1}{2} B\omega l^2$
- ❖ Rotating Disc (Radius R): $\varepsilon = \frac{1}{2} B\omega R^2$ (between center and rim)



Self and Mutual Induction

Inductance is the property of a coil to oppose changes in current

Property	Formula	Details
Self Induction	$\phi = LI \text{ and } \varepsilon = -L \frac{dI}{dt}$	L : Self-inductance (Unit: Henry, H)
Inductance (Solenoid)	$L = \mu_o n^2 Al = \frac{\mu_o N^2 A}{l}$	n : Turns per unit length; N : Total turns
Mutual Induction	$\phi_2 = MI_1 \text{ and } \varepsilon_2 = -M \frac{dI_1}{dt}$	M : Mutual inductance between two coils
Coupling Coefficient	$M = K \sqrt{L_1 L_2}$	K : Coupling constant ($0 \leq K \leq 1$)
Energy in Inductor	$U = \frac{1}{2} LI^2$	Energy stored in the magnetic field

Growth and Decay in LR Circuits

- ❖ For a circuit with an inductor (L) and resistor (R) connected to a battery (V):
- ❖ Time Constant: $\tau = \frac{L}{R}$ (Time taken to reach 63.2% of max current)
- ❖ Growth of Current: $I = I_0 (1 - e^{-t/\tau})$
- ❖ Decay of Current: $I = I_0 e^{-t/\tau}$
- ❖ Magnetic Energy Density: $u_B = \frac{B^2}{2\mu_o}$

Eddy Currents & AC Generator

- ❖ Eddy Currents: Circulating currents induced in bulk pieces of metal.
- ❖ AC Generator EMF: $\varepsilon = NBA A \omega \sin(\omega t)$
- ❖ Peak EMF: $\varepsilon_o = NBA \omega$ (where $\omega = 2\pi f$)



Alternating Current

(AC) Definition

Formula:

$$i = I_o \sin(\omega t + \phi)$$

Where:

i = Instantaneous current (Amps, A)

I_o = Maximum (peak) current (Amps, A)

ω = Angular frequency ($2\pi f$, rad/s)

t = Time (seconds, s)

ϕ = Phase angle (radians)

Instantaneous Voltage in an AC Circuit

Formula:

$$v = V_o \sin(\omega t + \phi)$$

Where:

v = Instantaneous voltage (Volts, V)

V_o = Maximum (peak) voltage (Volts, V)

Relationship Between RMS and Peak Values

Formula:

$$I_{rms} = \frac{I_o}{\sqrt{2}}, V_{rms} = \frac{V_o}{\sqrt{2}}$$

Where:

I_{rms} = Root mean square (RMS) current (Amps, A)

V_{rms} = Root mean square (RMS) voltage (Volts, V)

I_o = Peak current (Amps, A)

V_o = Peak voltage (Volts, V)

Average Power in an AC Circuit

Formula:

$$P = I_{rms} V_{rms} \cos \phi$$

Where:

P = Average power (Watts, W)



I_{rms} = RMS current (Amps, A)

V_{rms} = RMS voltage (Volts, V)

ϕ = Phase angle between current and voltage (radians)

Explanation:

The power in an AC circuit is a product of the RMS values of current and voltage, and the cosine of the phase angle between them.

Impedance in an AC Circuit

Formula:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Where:

Z = Impedance (Ohms, Ω)

R = Resistance (Ohms, Ω)

X_L = Inductive reactance (Ohms, Ω)

X_C = Capacitive reactance (Ohms, Ω)

Inductive Reactance

Formula:

$$X_L = \omega L = 2\pi fL$$

Where:

X_L = Inductive reactance (Ohms, Ω)

L = Inductance (Henrys, H)

f = Frequency (Hertz, Hz)

ω = Angular frequency ($2\pi f$, rad/s)

Capacitive Reactance

Formula:

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

Where:

X_C = Capacitive reactance (Ohms, Ω)

C = Capacitance (Farads, F)

f = Frequency (Hertz, Hz)



ω = Angular frequency ($2\pi f$, rad / s)

Resonance in an RLC Circuit

Formula:

$$f_o = \frac{1}{2\pi\sqrt{LC}} \text{ Where:}$$

f_o = Resonant frequency (Hertz, Hz)

L = Inductance (Henrys, H)

C = Capacitance (Farads, F)

Explanation:

Resonance occurs when the inductive reactance equals the capacitive reactance. The circuit then exhibits maximum current.

Power Factor

Formula:

$$\text{Power Factor (PF)} = \cos \phi$$

Where:

ϕ = Phase angle between current and voltage (radians or degrees)

AC Voltage in a Resistor (Purely Resistive Circuit)

Formula:

$$V_{rms} = I_{rms} R$$

Where:

V_{rms} = RMS voltage (Volts, V)

I_{rms} = RMS current (Amps, A)

R = Resistance (Ohms, Ω)

AC Voltage in an Inductor (Purely Inductive Circuit)

Formula:

$$V_{rms} = I_{rms} XL$$

Where:

V_{rms} = RMS voltage (Volts, V)

I_{rms} = RMS current (Amps, A)

X_l = Inductive reactance (Ohms, Ω)



AC Voltage in a Capacitor (Purely Capacitive Circuit)

Formula:

$$V_{\text{rms}} = I_{\text{rms}} X_c$$

Where:

V_{rms} = RMS voltage (Volts, V)

I_{rms} = RMS current (Amps, A)

X_c = Capacitive reactance (Ohms, Ω)

Average Power in a Purely Inductive or Capacitive Circuit

Formula: $P = 0$

Explanation:

In a purely inductive or capacitive circuit, the average power is zero because the current and voltage are 90° out of phase, leading to no net energy transfer.

Total Energy in an AC Circuit

Formula:

$$E = \frac{1}{2} C V_{\text{max}}^2$$

Where:

E = Energy stored (Joules, J)

C = Capacitance (Farads, F)

V_{max} = Maximum voltage (Volts, V)

Energy Stored in an Inductor

Formula:

$$E = \frac{1}{2} L I_{\text{max}}^2$$

Where:

E = Energy stored (Joules, J)

L = Inductance (Henrys, H)

I_{max} = Maximum current (Amps, A)



AC Power Consumption in a Resistive-Inductive Circuit (RL Circuit)

Formula:

$$\text{❖ } P = I_{rms} V_{rms} \cos \phi = I_{rms}^2 R$$

❖ Where:

❖ P = Power consumption (Watts, W)

❖ I_{rms} = RMS current (Amps, A)

❖ V_{rms} = RMS voltage (Volts, V)

❖ ϕ = Phase angle between current and voltage (radians or degrees)

❖ R = Resistance (Ohms, Ω)



Electromagnetic Waves

General Wave Equation

Formula:

$$c = \lambda f$$

Where:

c = Speed of light in vacuum (3×10^8 m/s)

λ = Wavelength of the electromagnetic wave (meters, m)

f = Frequency of the electromagnetic wave (Hertz, Hz)

Explanation:

The speed of light is the product of the wavelength and the frequency of the wave.

Electromagnetic Wave Speed in Medium

Formula:
$$v = \frac{c}{n}$$

Where:

v = Speed of electromagnetic wave in the medium (m/s)

c = Speed of light in vacuum (3×10^8 m/s)

n = Refractive index of the medium (dimensionless)

Explanation:

The speed of electromagnetic waves reduces when they travel through a medium with refractive index n .

Relation Between Electric and Magnetic Fields

Formula:

$$E = cB$$

Where:

E = Electric field of the wave (N/C or V/m)

B = Magnetic field of the wave (Tesla, T)

c = Speed of light in vacuum (3×10^8 m/s)

Explanation:

The electric field and magnetic field in an electromagnetic wave are related by the speed of light.

Energy Density in an Electromagnetic Wave

Formula:
$$u = \epsilon_0 E^2$$

Where:



u = Energy density of the wave (J/m^3)

ϵ_0 = Permittivity of free space ($8.85 \times 10^{-12} C^2/N\cdot m^2$)

E = Electric field (V/m)

Explanation:

This equation gives the energy density of the electromagnetic wave, which is proportional to the square of the electric field.

Poynting Vector (Power Density)

Formula: $S = \frac{1}{\mu_0} EB$

Where:

S = Poynting vector or power density (W / m^2)

Permeability of free space ($4\pi \times 10^{-7} T\cdot m / A$)

E = Electric field (V/m)

B = Magnetic field (Tesla, T)

Explanation:

The Poynting vector represents the power transmitted by an electromagnetic wave per unit area.

Electromagnetic Spectrum

The electromagnetic spectrum includes the following categories (from low to high frequency):

Radio waves: $\lambda > 10^3 m$

Microwaves: $10^3 m > \lambda > 10^{-3} m$

Infrared waves: $10^{-3} m > \lambda > 7 \times 10^{-7} m$

Visible light: $7 \times 10^{-7} m > \lambda > 4 \times 10^{-7} m$

Ultraviolet waves: $4 \times 10^{-7} m > \lambda > 10^{-8} m$

X-rays: $10^{-8} m > \lambda > 10^{-11} m$

Gamma rays: $\lambda < 10^{-11} m$

Energy of a Photon

Formula: $E = hf$

Where:

E = Energy of the photon (Joules, J)

h = Planck's constant ($6.626 \times 10^{-34} J\cdot s$)

f = Frequency of the photon (Hz)



Explanation:

The energy of a photon is directly proportional to its frequency. Photons of higher frequency (like gamma rays) carry more energy.

Relation Between Electric and Magnetic Fields in an Electromagnetic Wave

Formula: $\frac{E}{B} = c$

Where:

E = Electric field (V/m)

B = Magnetic field (T)

c = Speed of light (3×10^8 m/s)

Explanation:

This formula shows that the ratio of the electric field to the magnetic field in an electromagnetic wave is equal to the speed of light.

Magnetic Force on a Charged Particle in an Electromagnetic Wave

Formula: $F_B = qvB \sin \theta$

Where:

F_B = Magnetic force (N)

q = Charge of the particle (Coulombs, C)

v = Velocity of the charged particle (m/s)

B = Magnetic field (Tesla, T)

θ = Angle between the velocity and magnetic field vectors

Wave Equation for Electromagnetic Waves

Formula: $\frac{1}{c^2} \frac{\partial^2 E}{\partial t^2} = \nabla^2 E$
 $\frac{1}{c^2} \frac{\partial^2 B}{\partial t^2} = \nabla^2 B$

Where:

E = Electric field vector (V/m)

B = Magnetic field vector (T)

c = Speed of light (3×10^8 m/s)

t = Time (s)

∇^2 = Laplacian operator (spatial derivative)



Refractive Index of a Material for Light

Formula: $n = \frac{c}{v}$

Where:

n = Refractive index of the material (dimensionless)

c = Speed of light in vacuum (3×10^8 m/s)

v = Speed of light in the material (m/s)

Explanation:

The refractive index n determines how much the speed of light is reduced in a particular medium.

Wave Equation for Electric and Magnetic Fields in Free Space

Formula: $E = E_0 \cos(kx - \omega t)$

$$B = B_0 \cos(kx - \omega t)$$

Where:

E_0 = Maximum electric field amplitude (V/m)

B_0 = Maximum magnetic field amplitude (T)

k = Wave number ($2\pi/\lambda$)

ω = Angular frequency ($2\pi f$)

x = Position along the direction of wave propagation (m)

t = Time (s)



Ray Optics and Optical Instruments

Reflection and Spherical Mirrors

In these formulas, f is the focal length, v is image distance, and u is object distance

$$f = \frac{R}{2}$$

(Where R is the Radius of Curvature)

Focal Length of a Spherical Mirror:

$$f = \frac{R}{2}$$

Mirror Formula:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Linear Magnification (m):

$$m = \frac{h_i}{h_o} = -\frac{v}{u} = \frac{f}{f - u}$$

h_i : Height of image; h_o : Height of object.

$m > 0$: Image is Virtual and Erect.

$m < 0$: Image is Real and Inverted.

Refraction and Snell's Law

Refractive Index (n or μ)

$$n = \frac{c}{v}$$

(Where c is speed of light in vacuum, v is speed in the medium)

Snell's Law:

$$n_i \sin(i) = n_r \sin(r)$$

Apparent Depth:

$$n = \frac{\text{Real Depth}}{\text{Apparent}}$$

Critical Angle (θ_c)



$$\sin(\theta_c) = \frac{n_2}{n_1} \text{ (Where } n_2 > n_1 \text{)}$$

Refraction at Spherical Surfaces and Lenses

Refraction at a Single Spherical Surface:

$$\frac{n_2}{v} = \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Lens Maker's Formula:

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

Lens Formula:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Magnification (m):

$$m = \frac{v}{u} = \frac{f}{f + u}$$

Power of a Lens (P):

$$P = \frac{1}{f \text{ (in meters)}}$$

Prisms

Angle of Deviation (δ):

$$\delta = (i + e) - A$$

(Where i is incident angle, e is emergent angle, and A is prism angle)

Prism Formula (at Minimum Deviation δ_m):

$$n = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Thin Prism Deviation:

$$\delta \approx (n - 1)A$$



Optical Instruments

For these formulas, D represents the Least Distance of Distinct Vision (usually 25 cm).

Simple Microscope

Magnification (M):

$$\text{Image at } D: M = 1 + \frac{D}{f}$$

$$\text{Image at Infinity: } M = \frac{D}{f}$$

Compound Microscope

Magnification (M):

$$M = m_o \times m_e$$

$$\text{Image at } D: M = \frac{v_a}{u_o} \left(1 + \frac{D}{f_e} \right)$$

$$\text{Image at Infinity: } M = \left(\frac{L}{f_o} \right) \left(\frac{D}{f_e} \right) \text{ (Where } L \text{ is the length of the tube)}$$

Astronomical Telescope

Magnification (M):

$$\text{Image at } D: M = \frac{f_o}{f_e} \left(1 + \frac{f_e}{D} \right)$$

$$\text{Image at Infinity (Normal Adjustment): } M = \frac{f_o}{f_e}$$

Length of Telescope (L):



Symbol	Meaning
u	Object distance from the pole/optical center
v	Image distance from the pole/optical center
f	Focal length
R	Radius of curvature
n/μ	Refractive index
A	Angle of the prism
f_o	Focal length of objective lens
f_e	Focal length of eyepiece lens



Wave Optics

Basics of Light Waves

- ❖ Speed of Light: $v = f\lambda$
- ❖ Phase Difference (ϕ) and Path Difference (Δx)
- ❖ $\phi = \frac{2\pi}{\lambda} \Delta x$

Refractive Index and Wavelength:

$$n = \frac{\lambda_{vac}}{\lambda_{med}}$$

Coherent Sources & Interference

When two waves of intensities I_1, I_2 and phase difference ϕ meet:

- ❖ Resultant Intensity (I):
- ❖ $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$
- ❖ If $I_1 = I_2 = I_0$: $I = 4I_0 \cos^2 \left(\frac{\phi}{2} \right)$

Constructive Interference (Bright Fringes):

- ❖ $\phi = 2n\pi$
- ❖ $\Delta x = n\lambda$ (where $n = 0, 1, 2, \dots$)
- ❖ Destructive Interference (Dark Fringes)
- ❖ $\phi = (2n-1)\pi$
- ❖ $\Delta x = (2n-1)\frac{\lambda}{2}$ (Where $n = 1, 2, 3, \dots$)

Young's Double Slit Experiment (YDSE)

Fringe Width (β):

$$\beta = \frac{\lambda D}{d}$$

- ❖ Position of n^{th} Bright Fringe: $y_n = \frac{n\lambda D}{d}$
- ❖ Position of n^{th} Dark Fringe: $y_n = \frac{(2n-1)\lambda D}{2d}$
- ❖ Angular Fringe Width (θ):



$$\theta = \frac{\beta}{D} = \frac{\lambda}{d}$$

Shift due to a thin glass slab (thickness t):

$$\Delta y = \frac{D}{d}(n-1)t$$

Diffraction (Single Slit)

Condition for Minima (Dark Points):

$$a \sin \theta = n\lambda \quad (n = 1, 2, 3, \dots)$$

Condition for Secondary Maxima (Bright Points):

$$a \sin \theta = (2n+1) \frac{\lambda}{2}$$

Width of Central Maximum:

❖ Angular Width: $2\theta = \frac{2\lambda}{a}$

❖ Linear Width: $w = \frac{2\lambda D}{a}$

Resolving Power

❖ Resolving Power of Microscope:

❖ R.P. = $\frac{2n \sin \theta}{\lambda}$

Resolving Power of Telescope:

❖ R.P. = $\frac{1}{\Delta \theta} = \frac{a}{1.22\lambda}$

❖ (Where a is the aperture diameter)

Polarization

❖ Brewster's Law:

❖ $n = \tan(i_p)$

❖ (Where i_p is the polarizing angle)

**Malus's Law:**

$$I = I_0 \cos^2$$

(Where I is transmitted intensity and θ is the angle between polarizer and analyzer)

Symbol	Meaning
λ	Wavelength of light
D	Distance between slits and the screen
d	Distance between the two slits (YDSE)
a	Width of the single slit (Diffraction)
n	Order of fringe (integer) or Refractive Index
I_0	Maximum intensity
Δ_x	Path difference
ϕ	Phase difference
β	Fringe width



Dual Nature and Radiation and Matter

Photoelectric Effect

Einstein's Photoelectric Equation

$$h\nu = h\nu_0 + K_{\max}$$

Symbols:

- h = Planck's constant
- ν = frequency of incident radiation
- ν_0 = threshold frequency
- K_{\max} = maximum kinetic energy of emitted electrons

Maximum Kinetic Energy

$$K_{\max} = \frac{1}{2}mv_{\max}^2$$

Symbols:

- m = mass of electron
- v_{\max} = maximum velocity of photoelectrons

Work Function

- $\phi = h\nu_0$

Symbols

- ϕ = Work function of the metal
- ν_0 = Threshold frequency

Stopping potential

- e = Electric charge
- V_0 = stopping potential

Photon Energy

- $E = h\nu = \frac{hc}{\lambda}$

Symbols

- c = Speed of light



- $\lambda =$ Wavelength of radiation

Momentum of a photon

- $$p = \frac{h}{\lambda} = \frac{E}{c}$$

Wave Nature of Matter (de Broglie Hypothesis)

- de Broglie Wavelength

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

Symbols:

- $p =$ linear momentum of particle

For a particle in motion

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

Symbols:

- $v =$ velocity of particle

de Broglie Wavelength for Accelerated Electrons

(a) Using accelerating potential V :

- $$\lambda = \frac{h}{\sqrt{2meV}}$$

(b) Practical form (in \AA):

- $$\lambda(\text{\AA}) = \frac{12.27}{\sqrt{V}}$$

Relativistic de Broglie Wavelength

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

Symbols:



$$\gamma = \frac{1}{\sqrt{1 - v^2 / c^2}} \text{ (Lorentz factor)}$$

Wave-Particle Duality

- Energy-Wavelength Relation (General)
- $E = pc$

For photons only:

$$E = h\nu = \frac{hc}{\lambda}$$

Heisenberg's Uncertainty Principle

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

Symbols:

- Δx = uncertainty in position
- Δp = uncertainty in momentum

Important Constants

Constant	Symbol	Value
Planck's constant	h	6.626×10^{-34} Js
Electron mass	m_e	9.11×10^{-31} kg
Electronic charge	e	1.602×10^{-19} C
Speed of light	c	3×10^8 * m/s
Planck constant (eV-s)	h	4.14×10^{-15} eV s

Quick Summary for NEET/JEE

- Photon: $E = h\nu$, $p = h/\lambda$
- Photoelectric effect: $K_{\max} = h(\nu - \nu_0)$
- Stopping potential: $eV_0 = K_{\max}$
- de Broglie wavelength: $\lambda = h/p$
- Electrons accelerated by V / $\lambda = \frac{12.27}{\sqrt{V}}$ Å
- Uncertainty Principle: $\Delta x \Delta p \geq \frac{h}{4\pi}$



Atoms

Bohr's Postulates

(a) Quantization of Angular Momentum

$$mvr = nh$$

Symbols:

- ❖ m : mass of electron
- ❖ v : electron speed
- ❖ r : radius of orbit
- ❖ n : principal quantum number (1, 2, 3...)
- ❖ $\hbar = h/2\pi$
- ❖ h : Planck's constant

Radius of Hydrogen-like Atoms

$$r_n = a_o \frac{n^2}{Z}$$

Symbols:

- ❖ $r_n = In$: radius of nth orbit
- ❖ $a_o = 0.529 \text{ \AA}$: Bohr radius
- ❖ Z : atomic number (H:1, He⁺:2, Li²⁺:3...)

Electron Velocity in nth Orbit

$$\begin{aligned} \text{❖ } v_n &= \frac{Ze^2}{2\epsilon_o hn} = \frac{v_o}{n} \\ v_o &\approx 2.18 \times 10^6 \text{ m/s} \end{aligned}$$

Symbols:

- ❖ e : electron charge
- ❖ ϵ_o : permittivity of free space
- ❖ Vn : speed in nth orbit



Energy of Electron in nth Orbit

$$E_n = -\frac{13.6Z^2}{n^2} eV$$
$$E_n = -\frac{me^4Z^2}{8\epsilon_0^2h^2n^2}$$

Symbols:

- ❖ E_n : total energy (KE + PE)
- ❖ 13.6 eV: ionization energy of H atom

Kinetic and Potential Energy

- ❖ $KE_n = -E_n$
- ❖ $PE_n = 2E_n$

Energy Difference Between Two Orbits (Transition Energy)

$$\Delta E = E_f - E_i = 13.6Z^2 \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right) eV$$

Symbols:

- ❖ n_i : initial orbit
- ❖ n_f : final orbit
- ❖ ΔE : emitted/absorbed photon energy

Frequency, Wavelength of Emitted/Absorbed Photon

- ❖ Frequency
- ❖ $h\nu = |\Delta E| \Rightarrow \nu = \frac{|\Delta E|}{h}$

Wavelength

$$\lambda = \frac{c}{\nu}$$

Symbols:

- ❖ ν : frequency
- ❖ λ : wavelength
- ❖ c : speed of light



Rydberg Formula for Hydrogen Spectrum

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

Symbols:

- ❖ $R_H = 1.097 \times 10^7 \text{ m}^{-1}$ Rydberg constant
- ❖ $n_f > n_i$ absorption
- ❖ $n_i > n_f$: emission

Series Limits

- ❖ Lyman: $n_f = 1$
- ❖ Balmer: $n_f = 2$
- ❖ Paschen: $n_f = 3$
- ❖ Brackett: $n_f = 4$
- ❖ Pfund: $n_f = 5$

Ionization Energy

- ❖ Hydrogen-like atom
- ❖ $E_{\text{ion}} = 13.6 Z^2 \text{ eV}$

Orbital Time Period

$$T_n = \frac{2\pi r_n}{v_n}$$

Symbols:

- ❖ T_n time period of revolution

De Broglie Condition (Underlying Bohr Model)

$$2\pi r_n = n\lambda$$

- ❖ $\lambda = \frac{h}{mv}$

Binding Energy of Hydrogen Atom

(Binding energy = energy required to remove electron from ground state)

$$E_b = 13.6 \text{ eV}$$

**Quick Constants (Useful for NEET/JEE)**

Constant	Value
h	$6.626 \times 10^{-34} \text{ js}$
C	$3 \times 10^8 \text{ m / s}$
e	$1.6 \times 10^{-19} \text{ C}$
ϵ_0	$8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$
RH	$1.097 \times 10^7 \text{ m}^{-1}$
a_0	0.529 \AA



Nuclei

Basic Terms

- ❖ A – Mass number = total nucleons
- ❖ Z – Atomic number = number of protons
- ❖ N – Neutron number = $A - Z$
- ❖ m_p m_n m_e – Mass of proton, neutron, electron

Nuclear Size

Nuclear Radius

$$R = R_0 A^{1/3}$$

Symbols:

R - Nuclear radius

$R_0 \approx 1.2$ times 10^{-15} m - Constant

A - Mass number

Nuclear Volume

$$V = \frac{4}{3} \pi R^3 \propto A$$

Nuclear Density

$$\rho = \frac{\text{Mass of nucleus}}{\text{Volume}} \approx \frac{Am_{\text{nucleon}}}{\frac{4}{3}\pi R_0^3 A} = \frac{m_{\text{nucleon}}}{\frac{4}{3}\pi R_0^3}$$

Nuclear density is constant, independent of A

$$\rho \approx 2 \times 10^{17} \text{ kg} / \text{m}^3$$

Mass Defect and Binding Energy

Mass Defect

$$\Delta m = Zm_p + (A - Z)m_n - m_{\text{nucleus}}$$

Binding Energy

$$E_b = \Delta mc^2$$



Binding Energy per Nucleon

$$\frac{E_o}{A}$$

Symbols:

Δm – Mass defect

c – Speed of light = 3×10^8 m / s

E_b – Total binding energy

Radioactivity

Law of Radioactive Decay

$$N(t) = N_o e^{-\lambda t}$$

or $A(t) = A_o e^{-\lambda t}$

Symbols:

- ❖ $N(t)$ - Number of undecayed nuclei at time t
- ❖ N_0 Initial number
- ❖ λ – Decay constant (s^{-1})
- ❖ A – Activity (decays/s)

Decay Rate / Activity

$$A = \lambda N$$

Mean Life

$$\tau = \frac{1}{\lambda}$$

Half-life

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

Half-life

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

Relation

$$\tau = \frac{T_{1/2}}{\ln 2}$$

Decay Chains

General Decay Relation

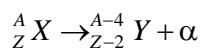
$$\ln \frac{N_o}{N} = \lambda t$$

Successive Decay (A→B→C) (JEE)

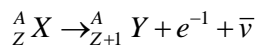
$$N_B = \frac{\lambda_A N_A^0}{\lambda_B - \lambda_A} (e^{-\lambda_A t} - e^{-\lambda_B t})$$

α , β , γ Decays

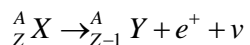
α -decay



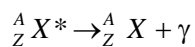
β^- - decay



β^+ -decay



λ -decay



Q-Value of Nuclear Reactions

- ❖ $Q = (m_{\text{initial}} - m_{\text{final}}) c^2$
- ❖ If $Q > 0 \rightarrow$ Exothermic
- ❖ If $Q < 0$ Endothermic



Semiconductor Electronics

Basic Definitions & Constants

- ❖ Energy Band Gap
- ❖ E_g = Energy band gap
- ❖ Silicon (Si): $E_g \approx 1.1$ eV
- ❖ Germanium (Ge): $E_g \approx 0.7$ eV

Intrinsic Carrier Concentration

- ❖ n_i = Intrinsic carrier concentration (electrons = holes in intrinsic semiconductor)

Conductivity & Resistivity

- ❖ Conductivity of Intrinsic Semiconductor
- ❖ $\sigma = n_i e (\mu_e + \mu_h)$

Resistivity

$$\rho = \frac{1}{\sigma}$$

Symbols

- ❖ σ : Conductivity
- ❖ ρ : Resistivity
- ❖ n_i : Intrinsic carrier concentration
- ❖ e : Electron charge = 1.6×10^{-19} C
- ❖ μ_e : Electron mobility
- ❖ μ_h : Hole mobility

Doping & Carrier Concentration

- ❖ n -type Semiconductor
- ❖ $n \approx ND, P = \frac{N_i^2}{N_D}$

p -type Semiconductor

$$\text{❖ } p \approx N_A \quad n = \frac{n_i^2}{N_A}$$

Symbols

- ❖ n : Electron concentration
- ❖ p : Hole concentration
- ❖ N_D : Donor atom concentration
- ❖ N_A : Acceptor atom concentration

Mass Action Law

$$\text{❖ } np = n_i^2$$

p-n Junction Diode

- ❖ Diode Current Equation

$$\text{❖ } I = I_o \left(e^{\frac{V}{\eta V_T}} - 1 \right)$$

Thermal Voltage

$$\text{❖ } V_T = \frac{kT}{e} \approx 26mV \text{ at } 300K$$

Reverse Saturation Current

- ❖ I_0 = Very small ($\sim \mu A$ or nA scale)

Symbols

- ❖ I : Diode current
- ❖ V : Voltage across diode
- ❖ η : Ideality factor (1 for Ge, 2 for Si)
- ❖ V_T : Thermal voltage
- ❖ k : Boltzmann constant

Zener Diode

- ❖ Zener Breakdown Voltage
- ❖ V_z = constant (given)

Load Current in Zener Regulation

$$\diamond I_L = \frac{V_L}{R_L}$$

Zener Current

$$\diamond I_z = I_s - I_L$$

Symbols

- ❖ V_z : Zener voltage
- ❖ R_L : Load resistance
- ❖ I_L : Load current
- ❖ I_s : Source current
- ❖ I_z : Zener current

Rectifiers

- ❖ Half-Wave Rectifier (HWR)

$$\diamond \text{Peak Value} \quad I_o = \frac{V_m}{R_L}$$

$$\diamond \text{RMS Value} \quad I_{rms} = \frac{I_o}{2}$$

$$\diamond \text{Average Value} \quad I_{dc} = \frac{I_o}{\pi}$$

Ripple Factor

$$\gamma = \sqrt{\left(\frac{\pi}{2}\right)^2} - 1 = 1.21$$

Full-Wave Rectifier (FWR)

$$\diamond I_{dc} = \frac{2I_o}{\pi}$$

$$\diamond I_{rms} = \frac{I_o}{\sqrt{2}}$$

Efficiency

$$\text{❖ } \eta = 0.812(81.2\%)$$

Ripple Factor

$$\text{❖ } \gamma = \sqrt{\left(\frac{\pi}{2}\right)^2} = 0.482$$

Symbols

- ❖ V_m : Peak input voltage
- ❖ I_0 Peak current
- ❖ R_L Load resistance
- ❖ I_{dc} Average current
- ❖ I_{rms} RMS current
- ❖ η : Rectifier efficiency
- ❖ γ : Ripple factor
- ❖ Filters (Capacitor input filter)Ripple Factor
- ❖ $\gamma = \frac{1}{4\sqrt{3}fR_L C}$

Symbols

- ❖ f : AC supply frequency
- C : Filter capacitor

