CLASS 12 PHYSICS — FORMULA SHEET

Chapter 1 : Electric Charges and Fields (NCERT)

1.1 Electric Charge — Basic Properties

Concept	Detail / Formula
Quantisation of charge	$q = \pm n e$ (n = integer) ; $e = 1.6 \times 10^{-19}$ C
Conservation of charge	Total charge of an isolated system stays constant
Additivity	Total charge = algebraic sum of individual charges
Like / unlike charges	Like charges repel ; unlike charges attract
1 coulomb	Charge of about 6.25×10^{18} electrons
Charging methods	Friction, conduction, and induction

1.2 Coulomb's Law

Concept	Formula
Coulomb's law (force)	$F = (1/4\pi\varepsilon_0) \times (q_1q_2 \div r^2)$
Coulomb constant	$k = 1/4\pi\varepsilon_0 = 9 \times 10^9$ N m^2 C^{-2}
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}
In a medium	$F_{medium} = F_{vacuum} \div K$ (K = dielectric constant)
Vector form	$F_{12} = k(q_1q_2/r^2)\, \hat{r}_{12}$ (along line joining charges)
Superposition principle	Net force = vector sum of forces due to each charge

1.3 Electric Field (E)

Concept	Formula
Electric field	$E = F \div q_0$ (force per unit positive test charge)
Field due to point charge	$E = (1/4\pi\varepsilon_0) \times (q \div r^2)$
SI unit	N/C or V/m
Direction	Away from +ve charge, toward −ve charge
Field from superposition	$E_{net} = E_1 + E_2 + \ldots$ (vector sum)
Force on a charge in field	$F = qE$

1.4 Electric Dipole

Concept	Formula
Dipole moment	$p = q \times 2a$ (vector, from −q to +q) ; unit C·m
Field on axial line	$E = (1/4\pi\varepsilon_0) \times (2p \div r^3)$ (for $r >> a$)
Field on equatorial line	$E = (1/4\pi\varepsilon_0) \times (p \div r^3)$ (for $r >> a$)
Axial : equatorial ratio	$E_{axial} = 2 \times E_{equatorial}$ (same distance)

Concept	Formula
Torque on dipole	$\tau = p \times E$; $\lvert\tau\rvert = pE \sin\theta$
Potential energy of dipole	$U = -p \cdot E = -pE \cos\theta$
Stable / unstable equilibrium	$\theta = 0°$ stable (U min) ; $\theta = 180°$ unstable (U max)

1.5 Electric Flux & Gauss's Law

Concept	Formula
Electric flux	$\Phi = E \cdot A = EA \cos\theta$; unit N m^2/C
Gauss's law	$\Phi = \oint E \cdot dA = q_{enclosed} \div \varepsilon_0$
Key point	Flux depends only on enclosed charge, not its position
Field of infinite line charge	$E = \lambda \div (2\pi\varepsilon_0 r)$ (λ = linear charge density)
Field of infinite sheet	$E = \sigma \div (2\varepsilon_0)$ (σ = surface charge density)
Field between two sheets	$E = \sigma \div \varepsilon_0$ (opposite charges)
Field of charged shell (outside)	$E = (1/4\pi\varepsilon_0)(q \div r^2)$ (acts as point charge)
Field inside shell	$E = 0$ (no charge enclosed)

1.6 Charge Densities

Type	Definition
Linear charge density (λ)	λ = charge ÷ length (C/m)
Surface charge density (σ)	σ = charge ÷ area (C/m^2)
Volume charge density (ρ)	ρ = charge ÷ volume (C/m^3)

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Coulomb constant	$k = 1/4\pi\varepsilon_0 = 9 \times 10^9$ N·m²/C². Memorise this value.
Charge is quantised	$q = ne$; $e = 1.6 \times 10^{-19}$ C. Charge always comes in whole multiples.
E from a point charge	$E = kq/r^2$; force on a charge $F = qE$.
Dipole fields	Axial = $2kp/r^3$; Equatorial = kp/r^3. Axial is TWICE the equatorial.
Dipole energy	$U = -pE \cos\theta$. Minimum (stable) at $\theta = 0°$, maximum at 180°.
Gauss's law	$\Phi = q\_enclosed/\varepsilon_0$. Pick a symmetric Gaussian surface.
Sheet vs shell	Infinite sheet: $\sigma/2\varepsilon_0$ (independent of distance). Shell inside: $E = 0$.
Torque on dipole	$\tau = pE \sin\theta$; maximum at $\theta = 90°$, zero at 0° and 180°.

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Chapter 2 : Electrostatic Potential and Capacitance (NCERT)

2.1 Electric Potential

Concept	Formula
Electric potential	$V = W \div q_0$ (work done per unit charge from infinity)
SI unit	Volt (V) = J/C ; scalar quantity
Potential due to point charge	$V = (1/4\pi\varepsilon_0) \times (q \div r)$
Potential difference	$V_B - V_A = W_{AB} \div q$
Potential from superposition	$V_{net} = V_1 + V_2 + \ldots$ (algebraic sum, with signs)
Relation E and V	$E = -dV/dr$; $V = -\int E \cdot dr$
Potential due to dipole (axial)	$V = (1/4\pi\varepsilon_0) \times (p \div r^2)$; equatorial $V = 0$

2.2 Equipotential Surfaces & Potential Energy

Concept	Detail / Formula
Equipotential surface	Surface where V is constant ; no work done in moving a charge on it
E is perpendicular to it	Field lines are always normal to equipotential surfaces
PE of two charges	$U = (1/4\pi\varepsilon_0) \times (q_1 q_2 \div r)$
PE of charge in external field	$U = qV$
PE of dipole in field	$U = -pE \cos\theta = -p \cdot E$
Work done	$W = q(V_B - V_A) = \Delta U$

2.3 Conductors & Dielectrics

Concept	Detail
Field inside a conductor	$E = 0$ (electrostatic conditions)
Potential inside conductor	Constant throughout (equal to surface value)
Charge on conductor	Resides entirely on the outer surface
Field just outside surface	$E = \sigma \div \varepsilon_0$ (perpendicular to surface)
Dielectric	Insulator that reduces field by polarisation
Dielectric constant K	$K = E_0 \div E = C_{with} \div C_{without}$
Electrostatic shielding	Field inside a cavity of a conductor is zero

2.4 Capacitance

Concept	Formula
Capacitance	$C = Q \div V$; SI unit Farad (F) = C/V
Parallel plate (vacuum)	$C = \varepsilon_0 A \div d$

Concept	Formula
With dielectric (fills gap)	$C = K \varepsilon_0 A \div d$
Spherical capacitor	$C = 4\pi\varepsilon_0 (ab)/(b - a)$
Isolated sphere	$C = 4\pi\varepsilon_0 R$
Effect of dielectric slab (thickness t)	$C = \varepsilon_0 A \div [d - t(1 - 1/K)]$

2.5 Combination of Capacitors

Arrangement	Formula
Series	$1/C_{eq} = 1/C_1 + 1/C_2 + \ldots$ (charge Q same on each)
Two in series	$C_{eq} = (C_1C_2) \div (C_1 + C_2)$
Parallel	$C_{eq} = C_1 + C_2 + \ldots$ (voltage V same across each)
Series voltage	V splits in inverse ratio of capacitance
Parallel charge	Q splits in direct ratio of capacitance

2.6 Energy Stored in a Capacitor

Concept	Formula
Energy stored	$U = ½ QV = ½ CV^2 = Q^2 \div (2C)$
Energy density	$u = ½ \varepsilon_0 E^2$ (energy per unit volume)
Energy on connecting capacitors	Common $V = (C_1V_1 + C_2V_2)/(C_1 + C_2)$
Energy loss on connection	$\Delta U = ½ [(C_1C_2)/(C_1+C_2)](V_1 - V_2)^2$ (always lost as heat)
Effect of dielectric (battery on)	Q increases, V constant, energy increases
Effect of dielectric (battery off)	Q constant, V decreases, energy decreases

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V from point charge	$V = kq/r$ (scalar — add with signs). $E = kq/r^2$ (vector).
E and V link	$E = -dV/dr$. Field points toward decreasing potential.
Equipotential	No work to move a charge along it ; E is always perpendicular to it.
Capacitor formula	$C = \varepsilon_0 A/d$; add dielectric → multiply by K.
Series vs parallel	Series: add reciprocals (like resistors in parallel). Parallel: just add.
Energy stored	$U = ½CV^2 = ½QV = Q^2/2C$ — three equivalent forms.
Dielectric (battery)	Battery ON → V fixed, Q & U rise. Battery OFF → Q fixed, V & U fall.
Energy density	$u = ½\varepsilon_0 E^2$ (energy stored per unit volume of the field).

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Chapter 3 : Current Electricity (NCERT)

3.1 Electric Current & Drift

Concept	Formula
Electric current	$I = Q \div t$; SI unit ampere (A) = C/s
Instantaneous current	$I = dQ/dt$
Current & drift velocity	$I = n A e v_d$ (n = electron density, A = area)
Drift velocity	$v_d = (eE \div m)\, \tau = (eV) \div (mL)\, \tau$ (τ = relaxation time)
Mobility	$\mu = v_d \div E$; unit $m^2\, V^{-1}\, s^{-1}$
Current density	$J = I \div A = n e v_d = \sigma E$

3.2 Ohm's Law & Resistance

Concept	Formula
Ohm's law	$V = I R$ (at constant temperature)
Resistance	$R = V \div I$; SI unit ohm (Ω)
Resistance & dimensions	$R = \rho L \div A$ (ρ = resistivity, L = length, A = area)
Resistivity	$\rho = (m) \div (n e^2 \tau)$; unit ohm·metre
Conductivity	$\sigma = 1 \div \rho = n e^2 \tau \div m$
Microscopic Ohm's law	$J = \sigma E$
Conductance	$G = 1 \div R$; unit siemens (S)

3.3 Effect of Temperature

Concept	Formula
Resistance vs temperature	$R_T = R_0(1 + \alpha\, \Delta T)$
Resistivity vs temperature	$\rho_T = \rho_0(1 + \alpha\, \Delta T)$
Temperature coefficient α	$\alpha = (R_T - R_0) \div (R_0\, \Delta T)$
Conductors	Resistance INCREASES with temperature (α positive)
Semiconductors / insulators	Resistance DECREASES with temperature (α negative)

3.4 Combination of Resistors

Arrangement	Formula
Series	$R_{eq} = R_1 + R_2 + \ldots$ (same current I through all)
Parallel	$1/R_{eq} = 1/R_1 + 1/R_2 + \ldots$ (same voltage V across all)
Two in parallel	$R_{eq} = (R_1 R_2) \div (R_1 + R_2)$
n equal resistors in series	$R_{eq} = nR$

Arrangement	Formula
n equal resistors in parallel	$R_{eq} = R \div n$

3.5 EMF, Internal Resistance & Cells

Concept	Formula
EMF and terminal voltage	$V = \varepsilon - I r$ (r = internal resistance)
Current in circuit	$I = \varepsilon \div (R + r)$
Internal resistance	$r = (\varepsilon - V) \div I = R[(\varepsilon/V) - 1]$
Cells in series	$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 + \ldots$; $r_{eq} = r_1 + r_2 + \ldots$
Cells in parallel (identical)	$\varepsilon_{eq} = \varepsilon$; $r_{eq} = r \div n$
Terminal voltage (charging)	$V = \varepsilon + I r$

3.6 Kirchhoff's Laws & Power

Concept	Formula / Statement
Kirchhoff's current law (KCL)	$\Sigma I = 0$ at a junction (charge conservation)
Kirchhoff's voltage law (KVL)	$\Sigma V = 0$ around a loop (energy conservation)
Electric power	$P = VI = I^2R = V^2 \div R$
Electrical energy	$W = VIt = I^2Rt$; commercial unit kWh
Heat produced (Joule's law)	$H = I^2R\, t$
Max power transfer	When $R = r$ (external = internal resistance)

3.7 Wheatstone Bridge & Potentiometer

Concept	Formula
Wheatstone balance condition	$P/Q = R/S$ (no current through galvanometer)
Meter bridge	$R \div S = l \div (100 - l)$ (balancing length l)
Potentiometer principle	$V \propto l$ (potential drop proportional to length)
Potential gradient	$k = V \div L$ (volt per unit length)
Comparing EMFs	$\varepsilon_1 \div \varepsilon_2 = l_1 \div l_2$
Internal resistance (potentiometer)	$r = R[(l_1 - l_2) \div l_2]$

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Ohm's law	$V = IR$. Resistance $R = \rho L/A$ — longer/thinner wire → more resistance.
Drift velocity	$I = nAev_d$. Tiny drift speed (about mm/s) but current flows fast (field sets up instantly).
Series vs parallel	Series: add R. Parallel: add reciprocals (R drops below the smallest).
EMF vs terminal V	Discharging: $V = \varepsilon - Ir$. Charging: $V = \varepsilon + Ir$.

Power trio	$P = VI = I^2R = V^2/R$. Pick the form matching your known quantities.
Kirchhoff	KCL = charge conservation (junctions) ; KVL = energy conservation (loops).
Wheatstone	Balanced when $P/Q = R/S$; galvanometer reads zero.
Potentiometer	Measures EMF without drawing current — more accurate than a voltmeter.

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Chapter 4 : Moving Charges and Magnetism (NCERT)

4.1 Force on a Moving Charge

Concept	Formula
Lorentz force	$F = q(E + v \times B)$ (electric + magnetic)
Magnetic force only	$F = q(v \times B)$; $\|F\| = qvB \sin\theta$
Direction	Fleming's left-hand rule (or $v \times B$ for positive charge)
Force is zero when	v parallel to B ($\theta = 0°$ or $180°$)
Force maximum when	v perpendicular to B ($\theta = 90°$): $F = qvB$
Work done by magnetic force	Zero (force always $\perp$ to velocity)

4.2 Circular & Helical Motion of Charge

Concept	Formula
Radius of circular path	$r = mv \div (qB)$
Time period	$T = 2\pi m \div (qB)$ (independent of speed & radius)
Frequency (cyclotron)	$f = qB \div (2\pi m)$
Angular frequency	$\omega = qB \div m$
Helical path	When v has components both parallel & perpendicular to B
Pitch of helix	$p = v_{parallel} \times T = (2\pi m\, v \cos\theta) \div (qB)$

4.3 Cyclotron

Concept	Formula
Cyclotron frequency	$f = qB \div (2\pi m)$
Maximum velocity	$v_{max} = qBR \div m$ (R = radius of dees)
Maximum kinetic energy	$KE_{max} = (q^2B^2R^2) \div (2m)$
Principle	Accelerates ions using high-frequency AC + magnetic field
Limitation	Cannot accelerate electrons (relativistic) or neutral particles

4.4 Biot–Savart Law & Magnetic Fields

Source	Magnetic Field Formula
Biot–Savart law	$dB = (\mu_0/4\pi) \times (I\, dl \times \hat{r}) \div r^2$
μ_0 value	$\mu_0 = 4\pi \times 10^{-7}$ T·m/A
Straight infinite wire	$B = \mu_0 I \div (2\pi r)$
Centre of circular loop	$B = \mu_0 I \div (2R)$
Axis of circular loop	$B = (\mu_0\, I\, R^2) \div [2(R^2 + x^2)^{3/2}]$

Source	Magnetic Field Formula
N-turn coil (centre)	$B = \mu_0 NI \div (2R)$

4.5 Ampere's Circuital Law & Solenoid/Toroid

Concept	Formula
Ampere's law	$\oint B \cdot dl = \mu_0 I_{enclosed}$
Solenoid (inside)	$B = \mu_0 n I$ (n = turns per unit length)
Solenoid (at end)	$B = \mu_0 n I \div 2$
Toroid (inside)	$B = \mu_0 N I \div (2\pi r)$
Outside solenoid/toroid	$B = 0$ (ideal case)

4.6 Force on Current & Between Wires

Concept	Formula
Force on current-carrying wire	$F = I(L \times B)$; $\lvert F \rvert = BIL \sin\theta$
Force between parallel wires	$F/L = (\mu_0 I_1 I_2) \div (2\pi d)$
Nature of force	Same direction currents ATTRACT ; opposite REPEL
Definition of ampere	1 A: wires 1 m apart with force 2×10^{-7} N/m

4.7 Current Loop, Torque & Moving Coil Galvanometer

Concept	Formula
Magnetic moment of loop	$m = N I A$; unit $A \cdot m^2$
Torque on a loop	$\tau = m \times B = NIAB \sin\theta$
Maximum torque	$\tau_{max} = NIAB$ ($\theta = 90°$)
PE of magnetic dipole	$U = -m \cdot B = -mB \cos\theta$
Galvanometer current	$I = (k \div NAB)\ \theta$ (k = torsional constant)
Current sensitivity	$= \theta \div I = NAB \div k$
Voltage sensitivity	$= \theta \div V = NAB \div (kR)$
Ammeter (shunt)	Low resistance in PARALLEL ; $S = (I_g G)/(I - I_g)$
Voltmeter (series R)	High resistance in SERIES ; $R = (V/I_g) - G$

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Lorentz force	$F = q(E + v \times B)$. Magnetic part does NO work (always $\perp$ to v).
Radius & period	$r = mv/qB$; $T = 2\pi m/qB$. Period is INDEPENDENT of speed.
Straight wire	$B = \mu_0 I/2\pi r$ (falls as $1/r$). Loop centre: $B = \mu_0 I/2R$.
Solenoid	$B = \mu_0 nI$ inside (uniform) ; half that at the open end.

Parallel wires	Same direction → attract ; opposite → repel. $F/L = \mu_0 I_1 I_2 / 2\pi d$.
Torque on loop	$\tau = NIAB \sin\theta$; magnetic moment $m = NIA$.
Ammeter vs voltmeter	Ammeter: low R shunt in parallel. Voltmeter: high R in series.
μ_0 value	$\mu_0 = 4\pi \times 10^{-7}$ T·m/A — memorise it.

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Chapter 5 : Magnetism and Matter (NCERT)

5.1 Bar Magnet & Magnetic Dipole

Concept	Formula
Magnetic dipole moment	$m = m_p \times 2l$ (pole strength × magnetic length) ; unit $A \cdot m^2$
Field on axial line	$B = (\mu_0/4\pi) \times (2m \div r^3)$
Field on equatorial line	$B = (\mu_0/4\pi) \times (m \div r^3)$
Axial : equatorial ratio	$B_{axial} = 2 \times B_{equatorial}$
Torque on dipole	$\tau = m \times B = mB \sin\theta$
PE of dipole	$U = -m \cdot B = -mB \cos\theta$
Magnetic length	$2l = (5/6) \times$ geometric length (approx)

5.2 Magnetic Field Intensity & Oscillation

Concept	Formula
Work done rotating dipole	$W = mB(\cos\theta_1 - \cos\theta_2)$
Work (0° to θ)	$W = mB(1 - \cos\theta)$
Oscillation time period	$T = 2\pi \sqrt{(I \div mB)}$ (I = moment of inertia)
Frequency of oscillation	$f = (1/2\pi) \sqrt{(mB \div I)}$
Stable equilibrium	$\theta = 0°$ (m parallel to B, U minimum)
Unstable equilibrium	$\theta = 180°$ (m anti-parallel to B, U maximum)

5.3 Magnetisation & Magnetic Intensity

Quantity	Formula / Definition
Magnetisation (M)	$M = m_{net} \div V$ (net magnetic moment per unit volume) ; unit A/m
Magnetic intensity (H)	$H = B \div \mu_0 - M$; unit A/m
Relation B, H, M	$B = \mu_0(H + M)$
Magnetic susceptibility	$\chi = M \div H$ (dimensionless)
Relative permeability	$\mu_r = 1 + \chi$
Permeability	$\mu = \mu_0 \mu_r$; $B = \mu H$

5.4 Classification of Magnetic Materials

Property	Diamagnetic	Paramagnetic	Ferromagnetic
Susceptibility χ	Small, negative	Small, positive	Large, positive
Relative perm. μ_r	Slightly < 1	Slightly > 1	Much > 1
In external field	Weakly repelled	Weakly attracted	Strongly attracted

Property	Diamagnetic	Paramagnetic	Ferromagnetic
Examples	Bi, Cu, water	Al, Na, O_2	Fe, Co, Ni
Effect of temperature	No effect	$\chi \propto 1/T$ (Curie)	Loses above Curie T

5.5 Curie's Law & Hysteresis

Concept	Formula / Detail
Curie's law (paramagnetic)	$\chi = C \div T$ (C = Curie constant)
Curie temperature (T_c)	Above it, ferromagnetic → paramagnetic
Curie–Weiss law	$\chi = C \div (T - T_c)$ for $T > T_c$
Hysteresis	Lag of B behind H when H is varied cyclically
Retentivity	Residual magnetism when H = 0
Coercivity	Reverse H needed to make B = 0
Hysteresis loss	Energy lost per cycle = area of B–H loop
Soft vs hard material	Soft (small loop, electromagnet) ; Hard (large loop, permanent magnet)

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Bar magnet fields	Axial = $2km/r^3$; Equatorial = km/r^3. Axial is TWICE — same as electric dipole.
Torque & PE	$\tau = mB \sin\theta$; $U = -mB \cos\theta$. Stable at 0°, unstable at 180°.
Oscillation period	$T = 2\pi\sqrt{(I/mB)}$. Stronger field → faster oscillation.
B, H, M link	$B = \mu_0(H + M)$; $\chi = M/H$; $\mu_r = 1 + \chi$.
Three materials	Dia: χ small −ve ; Para: χ small +ve ; Ferro: χ large +ve.
Curie's law	Paramagnetic $\chi \propto 1/T$. Heating reduces magnetisation.
Soft vs hard	Soft iron → electromagnets ; Steel/Alnico → permanent magnets.
Hysteresis loss	= area of the B–H loop. Soft material → thin loop → low loss.

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Chapter 6 : Electromagnetic Induction (NCERT)

6.1 Magnetic Flux

Concept	Formula
Magnetic flux	$\Phi = B \cdot A = BA \cos\theta$; unit weber (Wb)
1 weber	$1\ Wb = 1\ T \cdot m^2$
Maximum flux	When B perpendicular to plane ($\theta = 0°$): $\Phi = BA$
Zero flux	When B parallel to plane ($\theta = 90°$)
Flux through N turns	$\Phi_{total} = N \times BA \cos\theta$

6.2 Faraday's & Lenz's Laws

Concept	Formula / Statement
Faraday's first law	EMF is induced when magnetic flux linked with a circuit changes
Faraday's second law	$\varepsilon = -d\Phi/dt$ (EMF = rate of change of flux)
For N turns	$\varepsilon = -N\ d\Phi/dt$
Lenz's law	Induced current opposes the change causing it (the minus sign)
Basis of Lenz's law	Conservation of energy
Induced charge	$q = \Delta\Phi/R = N\ \Delta\Phi/R$ (independent of time taken)
Average induced EMF	$\varepsilon_{avg} = -N\ (\Phi_2 - \Phi_1)/\Delta t$

6.3 Motional EMF

Concept	Formula
Motional EMF (rod)	$\varepsilon = B\ l\ v$ (rod of length l moving with speed v)
Induced current	$I = Blv \div R$
Force on rod	$F = BIl = B^2l^2v \div R$ (opposes motion)
Power dissipated	$P = F\ v = B^2l^2v^2 \div R$
Rotating rod EMF	$\varepsilon = \frac{1}{2} B\ l^2\ \omega$ (rod rotating about one end)
Rotating disc EMF	$\varepsilon = \frac{1}{2} B\ R^2\ \omega$

6.4 Self-Inductance

Concept	Formula
Self-inductance	$\Phi = L\ I$; $\varepsilon = -L\ (dI/dt)$; unit henry (H)
Solenoid inductance	$L = \mu_0\ n^2\ A\ l = \mu_0\ N^2\ A \div l$
Energy stored in inductor	$U = \frac{1}{2} L\ I^2$
Energy density (magnetic)	$u = B^2 \div (2\mu_0)$

Concept	Formula
EMF from changing current	$\varepsilon = -L\,(dI/dt)$

6.5 Mutual Inductance

Concept	Formula
Mutual inductance	$\Phi_2 = M I_1$; $\varepsilon_2 = -M\,(dI_1/dt)$; unit henry (H)
Two coupled solenoids	$M = \mu_0 n_1 n_2 A l$ (sharing area A)
Reciprocity	$M_{12} = M_{21} = M$
Coupling coefficient	$k = M \div \sqrt{(L_1 L_2)}$; $0 \le k \le 1$
Maximum coupling	$k = 1 \rightarrow M = \sqrt{(L_1 L_2)}$

6.6 AC Generator & Eddy Currents

Concept	Formula / Detail
AC generator EMF	$\varepsilon = NBA\omega \sin(\omega t) = \varepsilon_0 \sin(\omega t)$
Peak EMF	$\varepsilon_0 = NBA\omega$
Principle	Electromagnetic induction (rotating coil in magnetic field)
Eddy currents	Induced circulating currents in bulk conductors
Eddy current uses	Electric brakes, induction furnace, dead-beat galvanometer
Reducing eddy losses	Use laminated (slotted) cores

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Faraday's law	$\varepsilon = -N\,d\Phi/dt$. Faster flux change → larger EMF.
Lenz's law	The minus sign = opposition. Induced effects fight the change (energy conservation).
Motional EMF	$\varepsilon = Blv$. Rotating rod: $\frac{1}{2}Bl^2\omega$ (note the ½ and the square).
Induced charge	$q = N\Delta\Phi/R$ — depends only on flux change & resistance, NOT on time.
Self-inductance	$\Phi = LI$; energy $U = \frac{1}{2}LI^2$ (analogous to $\frac{1}{2}mv^2$).
Mutual inductance	$M = k\sqrt{(L_1L_2)}$; $M_{12} = M_{21}$ always.
AC generator	$\varepsilon = NBA\omega \sin\omega t$; peak $\varepsilon_0 = NBA\omega$.
Eddy currents	Reduced by laminating the core ; used in braking & induction heating.

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Chapter 7 : Alternating Current (NCERT)

7.1 AC Quantities — RMS & Average

Concept	Formula
Alternating EMF / current	$V = V_0 \sin \omega t$; $I = I_0 \sin \omega t$
Angular frequency	$\omega = 2\pi f$; f = frequency, $T = 1/f$
RMS current	$I_{rms} = I_0 \div \sqrt{2} = 0.707\ I_0$
RMS voltage	$V_{rms} = V_0 \div \sqrt{2} = 0.707\ V_0$
Average over half cycle	$I_{avg} = 2I_0 \div \pi = 0.637\ I_0$
Average over full cycle	Zero (for symmetric AC)
Form factor	$= I_{rms} \div I_{avg} = 1.11$

7.2 AC Through Single Elements

Element	Opposition & Phase
Pure resistor (R)	I and V in phase ; opposition = R
Pure inductor (L)	I lags V by 90° ; inductive reactance $X_L = \omega L = 2\pi fL$
Pure capacitor (C)	I leads V by 90° ; capacitive reactance $X_C = 1/(\omega C) = 1/(2\pi fC)$
X_L with frequency	Increases with f (inductor blocks high f)
X_C with frequency	Decreases with f (capacitor passes high f)
Reactance unit	Ohm (Ω)

7.3 Series LCR Circuit

Concept	Formula
Impedance	$Z = \sqrt{[R^2 + (X_L - X_C)^2]}$
Current amplitude	$I_0 = V_0 \div Z$
Phase angle	$\tan \varphi = (X_L - X_C) \div R$
If $X_L > X_C$	Circuit is inductive (V leads I)
If $X_C > X_L$	Circuit is capacitive (V lags I)
Admittance	$Y = 1 \div Z$

7.4 Resonance in Series LCR

Concept	Formula
Resonance condition	$X_L = X_C \rightarrow \omega_0 = 1/\sqrt{(LC)}$
Resonant frequency	$f_0 = 1 \div (2\pi\sqrt{(LC)})$
At resonance	Z = R (minimum) ; current maximum ; $\varphi = 0$ (in phase)

Concept	Formula
Quality factor (Q)	$Q = \omega_0 L \div R = 1 \div (R) \times \sqrt{(L/C)}$
Q in terms of bandwidth	$Q = f_0 \div \Delta f$ (sharpness of resonance)
Bandwidth	$\Delta f = R \div (2\pi L)$
Application	Tuning circuits (radio, TV)

7.5 Power in AC Circuits

Concept	Formula
Instantaneous power	$P = VI$
Average power	$P_{avg} = V_{rms} I_{rms} \cos \varphi$
Power factor	$\cos \varphi = R \div Z$
Pure R	$\cos \varphi = 1$ (maximum power)
Pure L or C	$\cos \varphi = 0$ (no power consumed — wattless current)
Wattless current	Current component with $\varphi = 90°$ ($I_{rms} \sin \varphi$)
Apparent power	$= V_{rms} I_{rms}$ (volt-ampere)

7.6 Transformer & LC Oscillations

Concept	Formula
Transformer ratio	$V_s/V_p = N_s/N_p = I_p/I_s$
Step-up transformer	$N_s > N_p$ → voltage increases, current decreases
Step-down transformer	$N_s < N_p$ → voltage decreases, current increases
Ideal efficiency	Power in = power out: $V_p I_p = V_s I_s$
Transformer losses	Copper, iron (eddy + hysteresis), flux leakage
LC oscillation frequency	$f = 1 \div (2\pi\sqrt{(LC)})$

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RMS values	$I_{rms} = I_0/\sqrt{2} \approx 0.707\ I_0$. Household 220 V is the RMS value.
Reactance	$X_L = \omega L$ (rises with f) ; $X_C = 1/\omega C$ (falls with f).
Phase in L and C	Inductor: I LAGS V (ELI). Capacitor: I LEADS V (ICE). → 'ELI the ICE man'.
Impedance	$Z = \sqrt{[R^2 + (X_L - X_C)^2]}$. At resonance $X_L = X_C$, so $Z = R$.
Resonance	$f_0 = 1/(2\pi\sqrt{LC})$; current is maximum, impedance minimum.
Power factor	$\cos\varphi = R/Z$. Pure L or C → $\cos\varphi = 0$ (wattless).
Quality factor	$Q = (1/R)\sqrt{(L/C)} = f_0/\Delta f$ — higher Q means sharper tuning.
Transformer	V ratio = turns ratio ; current ratio is INVERSE. Power stays the same.

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Chapter 8 : Electromagnetic Waves (NCERT)

8.1 Displacement Current & Maxwell's Equations

Concept	Formula / Statement
Displacement current	$I_d = \varepsilon_0 (d\Phi_E/dt)$ (due to changing electric flux)
Why introduced	Makes Ampere's law consistent for capacitor charging
Modified Ampere's law	$\oint B \cdot dl = \mu_0(I_c + I_d)$
Maxwell's key idea	A changing E-field produces a B-field, and vice versa
Source of EM waves	Accelerating (oscillating) charges

8.2 Properties of Electromagnetic Waves

Property	Detail / Formula
Speed in vacuum	$c = 1 \div \sqrt{(\mu_0\varepsilon_0)} = 3 \times 10^8$ m/s
Speed in medium	$v = 1 \div \sqrt{(\mu\varepsilon)} = c \div n$ (n = refractive index)
E and B relation	$c = E_0 \div B_0$ (ratio of amplitudes)
Nature	Transverse ; $E \perp B \perp$ direction of propagation
E, B, c directions	$E \times B$ points along the direction of wave propagation
Carry energy & momentum	Can exert radiation pressure
No medium needed	Travel through vacuum

8.3 Energy & Intensity of EM Waves

Concept	Formula
Energy density (electric)	$u_E = \frac{1}{2} \varepsilon_0 E^2$
Energy density (magnetic)	$u_B = B^2 \div (2\mu_0)$
Average energy density	$u_{avg} = \frac{1}{2} \varepsilon_0 E_0^2 = B_0^2 \div (2\mu_0)$
u_E = u_B	Electric & magnetic energy densities are equal
Intensity	$I = u_{avg} \times c = \frac{1}{2} \varepsilon_0 E_0^2 c$
Radiation pressure (absorbed)	$P = I \div c$
Radiation pressure (reflected)	$P = 2I \div c$

8.4 Electromagnetic Spectrum (Increasing Frequency)

Wave	Wavelength / Use
Radio waves	> 0.1 m ; radio, TV, mobile communication
Microwaves	0.1 m – 1 mm ; radar, microwave oven, satellite
Infrared (IR)	1 mm – 700 nm ; heat, remote controls, night vision

Wave	Wavelength / Use
Visible light	700 nm – 400 nm ; human vision (VIBGYOR)
Ultraviolet (UV)	400 nm – 1 nm ; sterilisation, vitamin D
X-rays	1 nm – 10^{-3} nm ; medical imaging, crystallography
Gamma rays	< 10^{-3} nm ; nuclear reactions, cancer therapy

8.5 Production & Detection

Wave	Production / Detection
Radio waves	Oscillating circuits (LC) ; detected by antennas
Microwaves	Klystron / magnetron ; detected by point-contact diodes
Infrared	Hot bodies & molecules ; thermopiles, bolometers
Visible	Atoms & molecules in excitation ; eye, photocells
Ultraviolet	Special lamps, very hot bodies ; photocells, photographic film
X-rays	X-ray tubes (high-energy electrons hitting metal) ; photographic plates
Gamma rays	Radioactive nuclei ; Geiger tubes, scintillators

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Speed of light	$c = 1/\sqrt{\mu_0\varepsilon_0} = 3 \times 10^8$ m/s. Also $c = E_0/B_0$.
Transverse & perpendicular	$E \perp B \perp$ propagation. $E \times B$ gives the travel direction.
Energy densities equal	$u_E = u_B$ in an EM wave — energy is split evenly.
Radiation pressure	Absorbed: $P = I/c$; Reflected: $P = 2I/c$ (twice).
Spectrum order	'Radio Micro Infra Visible Ultra X Gamma' — frequency increases left to right.
VIBGYOR	Visible spectrum: Violet (high f) to Red (low f).
Displacement current	$I_d = \varepsilon_0\, d\Phi_E/dt$ — completes Ampere's law for capacitors.
Source	Only ACCELERATING charges radiate EM waves.

CLASS 12 PHYSICS — FORMULA SHEET

Chapter 9 : Ray Optics and Optical Instruments (NCERT)

9.1 Reflection & Spherical Mirrors

Concept	Formula
Laws of reflection	Angle of incidence = angle of reflection ; rays & normal coplanar
Focal length relation	$f = R \div 2$ (R = radius of curvature)
Mirror formula	$1/v + 1/u = 1/f$
Magnification	$m = -v \div u = h_i \div h_o$
Sign convention	Distances measured from pole ; +ve along incident light direction
Concave mirror	f negative (converging)
Convex mirror	f positive (diverging) ; always virtual, erect, diminished image

9.2 Refraction & Snell's Law

Concept	Formula
Snell's law	$n_1 \sin i = n_2 \sin r$; or ${}_1n_2 = \sin i \div \sin r$
Refractive index	$n = c \div v$ (speed in vacuum ÷ speed in medium)
Relative refractive index	${}_1n_2 = n_2 \div n_1 = v_1 \div v_2$
Real & apparent depth	n = Real depth ÷ Apparent depth
Apparent shift	Shift = $t(1 - 1/n)$
Lateral shift (slab)	$d = t \sin(i - r) \div \cos r$

9.3 Total Internal Reflection (TIR)

Concept	Formula / Condition
Conditions for TIR	Light goes from denser to rarer + angle > critical angle
Critical angle	$\sin C = n_{rarer} \div n_{denser} = 1 \div n$ (for medium-air)
Relation	$n = 1 \div \sin C$
Applications	Optical fibres, sparkling diamonds, mirage, prisms in binoculars

9.4 Refraction at Spherical Surfaces & Lens Maker

Concept	Formula
Refraction at single surface	$n_2/v - n_1/u = (n_2 - n_1) \div R$
Lens maker's formula	$1/f = (n - 1)(1/R_1 - 1/R_2)$
Thin lens formula	$1/v - 1/u = 1/f$
Magnification (lens)	$m = v \div u = h_i \div h_o$
Power of lens	$P = 1 \div f$ (in metres) ; unit dioptre (D)

Concept	Formula
Convex lens	f positive (converging) ; Concave lens: f negative (diverging)

9.5 Combination of Lenses & Prism

Concept	Formula
Lenses in contact	$1/f = 1/f_1 + 1/f_2 + \ldots$; $P = P_1 + P_2 + \ldots$
Lenses separated by d	$1/f = 1/f_1 + 1/f_2 - d/(f_1 f_2)$
Magnification (combination)	$m = m_1 \times m_2 \times \ldots$
Prism: angle relation	$A + \delta = i + e$ (A = prism angle, δ = deviation)
Prism: refraction	$A = r_1 + r_2$
Minimum deviation	$n = \sin[(A + \delta_m)/2] \div \sin(A/2)$
Thin prism deviation	$\delta = (n - 1)A$

9.6 Optical Instruments

Instrument	Magnification Formula
Simple microscope (near point)	$m = 1 + D/f$
Simple microscope (far point)	$m = D/f$
Compound microscope	$m = (L/f_o)(D/f_e)$ (approx, near point)
Compound microscope (general)	$m = m_o \times m_e = (v_o/u_o)(D/f_e)$
Telescope (normal adjustment)	$m = f_o \div f_e$
Telescope tube length	$L = f_o + f_e$ (normal adjustment)
Telescope (near point)	$m = (f_o/f_e)(1 + f_e/D)$

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Mirror & lens formula	Mirror: $1/v + 1/u = 1/f$. Lens: $1/v - 1/u = 1/f$. Note the sign difference!
Magnification	Mirror: $m = -v/u$; Lens: $m = v/u$. $+m \rightarrow$ erect, $-m \rightarrow$ inverted.
Sign convention	Measure from pole/optical centre ; against incident light is negative.
Critical angle	$\sin C = 1/n$. Denser medium → smaller critical angle.
Lens maker	$1/f = (n-1)(1/R_1 - 1/R_2)$. Power $P = 1/f$ (in metres), unit dioptre.
Lenses in contact	Add the powers: $P = P_1 + P_2$. Focal lengths add as reciprocals.
Prism deviation	Thin prism: $\delta = (n-1)A$. At min deviation, $r_1 = r_2 = A/2$.
Telescope vs microscope	Telescope: $m = f_0/fe$ (big objective f). Microscope: small f_0.

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Chapter 10 : Wave Optics (NCERT)

10.1 Wavefront & Huygens' Principle

Concept	Detail
Wavefront	Locus of points vibrating in the same phase
Spherical wavefront	From a point source
Plane wavefront	From a source at infinity
Huygens' principle	Each point on a wavefront acts as a secondary source ; new wavefront is the tangent envelope
Ray	Always perpendicular to the wavefront

10.2 Interference — Young's Double Slit

Concept	Formula
Path difference	$\Delta = d \sin\theta \approx d\,x / D$ (x = distance on screen)
Constructive (bright)	$\Delta = n\lambda$ ($n = 0, 1, 2, \ldots$)
Destructive (dark)	$\Delta = (2n - 1)\lambda/2$
Position of bright fringe	$x_n = n\lambda D \div d$
Position of dark fringe	$x_n = (2n - 1)\lambda D \div (2d)$
Fringe width	$\beta = \lambda D \div d$
Angular fringe width	$\theta = \lambda \div d$
Fringe width in medium	$\beta' = \beta \div n$

10.3 Intensity in Interference

Concept	Formula
Resultant intensity	$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\varphi$
Phase ↔ path difference	$\varphi = (2\pi/\lambda) \times \Delta$
Max intensity	$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$; for equal: $4I_0$
Min intensity	$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$; for equal: 0
Ratio	$I_{max}/I_{min} = [(\sqrt{I_1}+\sqrt{I_2})/(\sqrt{I_1}-\sqrt{I_2})]^2$
Equal sources	$I = 4I_0 \cos^2(\varphi/2)$
Condition for interference	Coherent sources (constant phase difference)

10.4 Diffraction — Single Slit

Concept	Formula
Central maximum width	Angular = $2\lambda/a$; Linear = $2\lambda D/a$

Concept	Formula
Minima (dark)	a sin θ = nλ (n = 1, 2, 3, …)
Secondary maxima	a sin θ = (2n + 1)λ/2
Half angular width of central max	θ = λ ÷ a
Width of secondary maxima	Half the central maximum
Fresnel distance	$Z_F = a^2 \div \lambda$

10.5 Resolving Power & Polarisation

Concept	Formula
Resolving power of microscope	RP = 2n sin θ ÷ λ ; limit of resolution = λ/(2n sinθ)
Resolving power of telescope	RP = D ÷ (1.22λ) ; limit = 1.22λ/D
Polarisation	Restricting light vibrations to one plane (only transverse waves)
Malus's law	$I = I_0 \cos^2 \theta$ (θ = angle between polariser axes)
Brewster's law	tan i_p = n (i_p = polarising angle)
At Brewster angle	Reflected & refracted rays are perpendicular (i_p + r = 90°)

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Fringe width	β = λD/d. Wider fringes with longer λ, bigger D, or smaller slit gap d.
Bright vs dark	Bright: Δ = nλ. Dark: Δ = (2n−1)λ/2. (Interference)
Single slit minima	a sinθ = nλ — note this is OPPOSITE to interference bright condition.
Intensity (equal)	$I = 4I_0\cos^2(\varphi/2)$. Max = $4I_0$, Min = 0.
Central max width	Single slit central maximum is TWICE as wide as the others (2λD/a).
Malus's law	$I = I_0\cos^2\theta$. Crossed polarisers (θ=90°) → zero light.
Brewster's law	tan i_p = n. Reflected & refracted rays are 90° apart at this angle.
Resolving power	Telescope: D/1.22λ (bigger aperture → better). Microscope: 2n sinθ/λ.

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Chapter 11 : Dual Nature of Radiation and Matter (NCERT)

11.1 Electron Emission & Work Function

Concept	Detail
Work function (φ_0)	Minimum energy to free an electron from a metal surface
Threshold frequency (ν_0)	Minimum frequency for emission ; $\varphi_0 = h\nu_0$
Threshold wavelength (λ_0)	$\lambda_0 = hc \div \varphi_0 = c \div \nu_0$
Types of emission	Thermionic, photoelectric, field, secondary
1 electron volt (eV)	$= 1.6 \times 10^{-19}$ J

11.2 Photoelectric Effect

Concept	Formula / Law
Einstein's photoelectric equation	$h\nu = \varphi_0 + KE_{max} = h\nu_0 + \frac{1}{2}mv_{max}^2$
Max kinetic energy	$KE_{max} = h\nu - \varphi_0 = h(\nu - \nu_0)$
Stopping potential	$eV_0 = KE_{max} = h\nu - \varphi_0$
In terms of wavelength	$KE_{max} = hc(1/\lambda - 1/\lambda_0)$
Photon energy	$E = h\nu = hc/\lambda$
Effect of intensity	Intensity ↑ → number of photoelectrons ↑ (NOT their energy)
Effect of frequency	Frequency ↑ → KE_{max} ↑ (linear), if $\nu > \nu_0$
No emission if	$\nu < \nu_0$ (regardless of intensity)

11.3 Laws of Photoelectric Effect

Law	Statement
First law	Photoelectric current ∝ intensity of incident light
Second law	KE_{max} depends only on frequency, not on intensity
Third law	Below threshold frequency, no emission occurs
Fourth law	Emission is instantaneous (no time lag)
Stopping potential vs ν	Graph is a straight line ; slope = h/e

11.4 Photon — Particle Nature of Light

Property	Formula
Photon energy	$E = h\nu = hc/\lambda$
Photon momentum	$p = E/c = h/\lambda = h\nu/c$
Photon mass (rest)	Zero (rest mass) ; effective mass = E/c^2
Number of photons (power P)	$N = P \div (h\nu)$ per second

Property	Formula
Photon nature	Travels at speed c ; no charge ; not deflected by E or B fields

11.5 de Broglie Hypothesis (Matter Waves)

Concept	Formula
de Broglie wavelength	$\lambda = h \div p = h \div (mv)$
In terms of KE	$\lambda = h \div \sqrt{(2m \cdot KE)}$
For accelerated charge (V volts)	$\lambda = h \div \sqrt{(2mqV)}$
For electron	$\lambda = 12.27 \div \sqrt{V}$ Å (V in volts)
For gas at temperature T	$\lambda = h \div \sqrt{(3mkT)}$
Significance	Matter has wave nature ; significant only for microscopic particles

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Einstein equation	$h\nu = \varphi_0 + KE\_max$. Energy in = work function + leftover KE.
Stopping potential	$eV_0 = KE\_max$. Graph V_0 vs ν is a straight line with slope h/e.
Intensity vs frequency	Intensity → MORE electrons. Frequency → MORE energy per electron.
Threshold	No emission below ν_0, no matter how bright the light.
Photon momentum	$p = h/\lambda = E/c$. Photons carry momentum despite zero rest mass.
de Broglie	$\lambda = h/p = h/\sqrt{(2m \cdot KE)}$. For electron: $\lambda = 12.27/\sqrt{V}$ Å.
Heavier → smaller λ	Big or fast particles have tiny λ (why we don't see matter waves).
12400 / 12.27	Photon: E(eV)·λ(Å) = 12400. Electron de Broglie: $\lambda = 12.27/\sqrt{V}$ Å.

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Chapter 12 : Atoms (NCERT)

12.1 Atomic Models

Model	Key Idea
Thomson's model	Positive charge spread uniformly with electrons embedded (plum pudding)
Rutherford's model	Tiny dense positive nucleus ; electrons orbit around it
Alpha-scattering result	Most pass straight ; few deflected ; very few rebound → nucleus is tiny
Distance of closest approach	$r_0 = (1/4\pi\varepsilon_0)(2Ze^2 \div KE)$
Impact parameter	$b = (Ze^2 \cot(\theta/2)) \div (4\pi\varepsilon_0 \times KE)$
Drawback of Rutherford	Orbiting electron should radiate & spiral in (unstable atom)

12.2 Bohr's Model (Postulates)

Postulate	Statement / Formula
Stable orbits	Electrons revolve in fixed orbits without radiating energy
Quantisation of angular momentum	$mvr = nh \div (2\pi)$; $n = 1, 2, 3 \ldots$
Energy emission/absorption	$h\nu = E_2 - E_1$ (transition between orbits)
Applies to	Hydrogen and hydrogen-like ions (He^+, Li^{2+})

12.3 Bohr Model — Derived Formulas

Quantity	Formula	Quick Value
Radius of nth orbit	$r_n = (0.529 \times n^2/Z)$ Å	$r_1(H) = 0.529$ Å
Velocity of electron	$v_n = (2.18 \times 10^6 \times Z/n)$ m/s	$v_1(H) \approx c/137$
Energy of nth orbit	$E_n = -13.6 \times Z^2/n^2$ eV	$E_1(H) = -13.6$ eV
Kinetic energy	$KE = +13.6\ Z^2/n^2$ eV $= -E_n$	Positive
Potential energy	$PE = -27.2\ Z^2/n^2$ eV $= 2E_n$	Negative
Total : KE : PE	$E : KE : PE = 1 : -1 : 2$ ($TE = -KE = PE/2$)	—
Frequency of revolution	$f = v \div (2\pi r)$	—

12.4 Hydrogen Spectrum

Concept	Formula / Detail
Rydberg formula	$1/\lambda = R Z^2 (1/n_1^2 - 1/n_2^2)$; $R = 1.097 \times 10^7\ m^{-1}$
Lyman series	$n_1 = 1$ → ultraviolet
Balmer series	$n_1 = 2$ → visible
Paschen series	$n_1 = 3$ → infrared
Brackett series	$n_1 = 4$ → infrared

Concept	Formula / Detail
Pfund series	$n_1 = 5 \rightarrow$ infrared
Ionisation energy (H)	13.6 eV ($n = 1$ to ∞)
Max spectral lines	From level n: $n(n-1)/2$

12.5 Energy Levels & Transitions

Concept	Detail
Energy of hydrogen levels	n=1: −13.6 ; n=2: −3.4 ; n=3: −1.51 ; n=4: −0.85 eV
Excitation energy	Energy to raise an electron from ground state to higher level
Ionisation energy	Energy to remove electron completely ($n \rightarrow \infty$)
Energy of emitted photon	$\Delta E = 13.6\ Z^2\ (1/n_1^2 - 1/n_2^2)$ eV
Wavelength emitted	$\lambda = hc \div \Delta E = 1240 \div \Delta E(\text{eV})$ nm

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Angular momentum	$mvr = nh/2\pi$ — the quantisation condition ($n = 1, 2, 3...$).
Energy levels	$E_n = -13.6\ Z^2/n^2$ eV. n=1 → −13.6, n=2 → −3.4, n=3 → −1.51 eV.
E : KE : PE	Total = −KE = PE/2. Ratio 1 : −1 : 2 (handy check).
Radius & velocity	$r_n \propto n^2/Z$ (grows) ; $v_n \propto Z/n$ (shrinks) with higher n.
Spectrum series	'Lyman UV, Balmer Visible, Paschen+ Infrared.'
Rydberg	$1/\lambda = RZ^2(1/n_1^2 - 1/n_2^2)$. $R = 1.097 \times 10^7\ m^{-1}$.
Spectral lines	From level n down to ground: $n(n-1)/2$ possible lines.
Ionisation energy	Hydrogen ground state needs 13.6 eV to fully ionise.

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Chapter 13 : Nuclei (NCERT)

13.1 Nucleus — Composition & Size

Concept	Formula / Detail
Notation	${}^{A}_{Z}X$: A = mass number, Z = atomic number, N = A − Z neutrons
Nuclear radius	$R = R_0 A^{1/3}$; $R_0 = 1.2 \times 10^{-15}$ m (fermi)
Nuclear volume	$V \propto A$ (proportional to mass number)
Nuclear density	Nearly constant (2.3×10^{17} kg/m^3), independent of A
Atomic mass unit (u)	1 u = 1.66×10^{-27} kg = 931.5 MeV/c^2
Isotopes / isobars / isotones	Same Z / same A / same N

13.2 Mass–Energy & Binding Energy

Concept	Formula
Einstein mass–energy	$E = mc^2$; 1 u = 931.5 MeV
Mass defect	$\Delta m = [Z m_p + (A-Z) m_n] - M_{nucleus}$
Binding energy	$BE = \Delta m \times c^2 = \Delta m$ (in u) × 931.5 MeV
Binding energy per nucleon	BE/A = BE ÷ A (measure of stability)
Most stable nuclei	Around A ≈ 56 (iron) ; BE/A ≈ 8.8 MeV (maximum)
Heavy & light nuclei	Lower BE/A → less stable → undergo fission/fusion

13.3 Radioactivity & Decay Law

Concept	Formula
Radioactive decay law	$N = N_0 e^{(-\lambda t)}$ (λ = decay constant)
Activity	$A = \lambda N = A_0 e^{(-\lambda t)}$; unit becquerel (Bq) or curie (Ci)
Half-life	$T_{1/2} = 0.693 \div \lambda = (\ln 2) \div \lambda$
Mean (average) life	$\tau = 1 \div \lambda = T_{1/2} \div 0.693 = 1.44\, T_{1/2}$
After n half-lives	$N = N_0 \div 2^n$; $n = t \div T_{1/2}$
1 curie	1 Ci = 3.7×10^{10} Bq (decays/sec)

13.4 Types of Radioactive Decay

Decay	Equation & Detail
Alpha (α) decay	${}^{A}_{Z}X \rightarrow {}^{(A-4)}_{(Z-2)}Y + {}^{4}_{2}He$; A↓4, Z↓2
Beta-minus (β⁻) decay	${}^{A}_{Z}X \rightarrow {}^{A}_{(Z+1)}Y + e^- + \bar{\nu}$; neutron → proton
Beta-plus (β⁺) decay	${}^{A}_{Z}X \rightarrow {}^{A}_{(Z-1)}Y + e^+ + \nu$; proton → neutron
Gamma (γ) decay	Excited nucleus → ground state + γ photon ; A & Z unchanged

Decay	Equation & Detail
Penetrating power	$\gamma > \beta > \alpha$
Ionising power	$\alpha > \beta > \gamma$

13.5 Nuclear Fission & Fusion

Concept	Detail
Nuclear fission	Heavy nucleus splits into lighter nuclei + energy (e.g. U-235)
Fission example	${}^{235}_{92}U + n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3n$ + energy
Energy per fission	200 MeV
Chain reaction	Released neutrons trigger further fissions
Nuclear fusion	Light nuclei combine into a heavier one + energy
Fusion example	Hydrogen → helium (powers the Sun)
Why energy is released	Products have higher BE/A → mass converted to energy
Conditions for fusion	Very high temperature & pressure (thermonuclear)

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Nuclear radius	$R = R_0 \times A$ raised to 1/3. Density is the SAME for all nuclei (independent of A).
1 u = 931.5 MeV	Convert mass defect (in u) to energy by multiplying by 931.5 MeV.
Binding energy	$BE = \Delta m \times 931.5$ MeV. Higher BE/A → more stable nucleus.
Most stable	Iron (A about 56) has the highest BE/A, about 8.8 MeV.
Half-life	$T_{1/2} = 0.693/\lambda$; mean life $\tau = 1/\lambda = 1.44\ T_{1/2}$.
n half-lives	$N = N_0/2^n$. After 3 half-lives, 1/8 remains.
Penetration vs ionisation	Penetration: $\gamma>\beta>\alpha$. Ionisation: $\alpha>\beta>\gamma$ (exactly reversed).
Fission vs fusion	Both release energy by moving toward higher BE/A (iron peak).

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Chapter 14 : Semiconductor Electronics (NCERT)

14.1 Classification of Solids (Energy Bands)

Type	Band Gap & Property
Conductor (metal)	No gap (overlapping bands) ; conducts freely
Insulator	Large band gap (> 3 eV) ; e.g. diamond (6 eV)
Semiconductor	Small band gap (1 eV) ; Si ≈ 1.1 eV, Ge ≈ 0.7 eV
Conduction band	Higher energy band where electrons conduct
Valence band	Lower band normally filled with electrons
Forbidden gap (E_g)	Energy gap between valence & conduction bands

14.2 Intrinsic & Extrinsic Semiconductors

Type	Detail
Intrinsic	Pure semiconductor ; $n_e = n_h = n_i$
Mass-action law	$n_e \times n_h = n_i^2$
Extrinsic	Doped semiconductor (more carriers)
n-type	Doped with pentavalent (P, As, Sb) ; electrons are majority
p-type	Doped with trivalent (B, Al, In) ; holes are majority
n-type carriers	$n_e >> n_h$; donor impurity
p-type carriers	$n_h >> n_e$; acceptor impurity
Conductivity	$\sigma = e(n_e\mu_e + n_h\mu_h)$

14.3 p-n Junction Diode

Concept	Detail
Depletion region	Charge-free zone at junction (immobile ions)
Potential barrier	Built-in voltage (0.3 V Ge, 0.7 V Si)
Forward bias	p to +, n to − ; barrier ↓, current flows (low resistance)
Reverse bias	p to −, n to + ; barrier ↑, tiny leakage current (high resistance)
Diode equation	$I = I_0 [e^{(eV/kT)} - 1]$
Knee/threshold voltage	Voltage where forward current rises sharply
Breakdown (reverse)	Avalanche or Zener breakdown at high reverse voltage

14.4 Diode Applications — Rectifiers

Concept	Detail / Formula
Rectifier	Converts AC to DC using diodes

Concept	Detail / Formula
Half-wave rectifier	Uses 1 diode ; conducts in one half-cycle only
Full-wave rectifier	Uses 2 diodes (centre-tap) ; both half-cycles
Ripple frequency (half-wave)	Same as input (f)
Ripple frequency (full-wave)	Twice the input (2f)
Efficiency (half-wave)	40.6%
Efficiency (full-wave)	81.2%
Filter	Capacitor smooths the pulsating DC output

14.5 Special Diodes

Diode	Use / Property
Zener diode	Operated in reverse breakdown ; voltage regulator
LED (light-emitting diode)	Forward biased ; emits light ($E_g \approx h\nu$ of emitted light)
Photodiode	Reverse biased ; current depends on light intensity
Solar cell	Generates EMF from light (no external bias)
LED wavelength	$\lambda = hc \div E_g$

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Band gaps	Conductor: 0 ; Semiconductor: 1 eV ; Insulator: >3 eV.
Si vs Ge	Si band gap 1.1 eV, barrier 0.7 V ; Ge 0.7 eV, barrier 0.3 V.
n-type vs p-type	n: pentavalent donor, electrons majority ; p: trivalent acceptor, holes majority.
Mass-action law	$n_e \times n_h = n_i^2$ (always holds for a given temperature).
Forward vs reverse	Forward: low resistance, current flows. Reverse: high resistance, tiny leakage.
Rectifier ripple	Half-wave: ripple f. Full-wave: ripple 2f (smoother).
Efficiency	Half-wave 40.6% ; full-wave 81.2% (about double).
Special diodes	Zener → regulator ; LED → emits light ; Photodiode/Solar → detect/generate from light.