

Class XII

Physics

One-page chapter summaries
Large print • CBSE 2026-27 syllabus

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Chapter 1: Electric Charges and Fields

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Big idea: Charges exert forces through electric fields; Gauss's law gives the field quickly when there is symmetry.

Key points

- Charge is **quantised** ($q = ne$), **additive** and **conserved**; like charges repel, unlike attract.
- **Coulomb's law**: force $\propto q_1q_2$ and $\propto 1/r^2$; acts along the line joining the charges.
- **Superposition**: net force on a charge = vector sum of forces due to each other charge.
- **Electric field** $E = F/q_0$ (force per unit positive test charge); unit N/C or V/m.
- Field lines start on + and end on – charges, never cross, never form closed loops; crowded lines = strong field.
- **Electric dipole**: charges $\pm q$ separated by $2a$; dipole moment $p = q \times 2a$, directed from $-q$ to $+q$.
- **Gauss's law**: total flux through a closed surface = $q_{\text{enclosed}}/\epsilon_0$, independent of the surface's size or shape.

Formulas & key derivations

- $F = (1/4\pi\epsilon_0) q_1q_2/r^2$, with $1/4\pi\epsilon_0 = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$
- Point charge: $E = (1/4\pi\epsilon_0) q/r^2$
- Dipole, axial ($r \gg a$): $E = (1/4\pi\epsilon_0) 2p/r^3$; equatorial: $E = (1/4\pi\epsilon_0) p/r^3$, opposite to p
- Torque on dipole in uniform E : $\tau = p \times E = pE \sin\theta$; net force = 0
- **Gauss's law**: $\phi = \oint \mathbf{E} \cdot d\mathbf{S} = q/\epsilon_0$
- Long straight wire: $E = \lambda/(2\pi\epsilon_0 r)$; infinite plane sheet: $E = \sigma/(2\epsilon_0)$
- Thin spherical shell: $E = (1/4\pi\epsilon_0) q/r^2$ outside ($r \geq R$); $E = 0$ inside

Exam focus: how to score

- **Derivations: dipole field on axis and on equatorial line; torque on a dipole** (3 marks each).
- Gauss's law applications (wire, sheet, shell): draw the Gaussian surface, state symmetry, then apply $\phi = q/\epsilon_0$.
- Flux depends only on enclosed charge, not on the size of the Gaussian surface: a favourite MCQ.
- Draw field lines for $+q$, $-q$, a dipole and two like charges.

★ Important questions from CBSE sample papers

- Point charge $+Q$ at the centre of a Gaussian sphere; radius doubled. What happens to the flux? (SQP 2026-27, 1 mark)
- State Gauss's theorem; use it to derive E due to an infinitely long straight wire of linear charge density λ . (SQP 2024-25, 3 marks)

Remember: Flux counts only the charge INSIDE: $\phi = q/\epsilon_0$.

Chapter 2: Electrostatic Potential and Capacitance

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Big idea: Potential is work per unit charge; capacitors store charge and energy, and dielectrics increase capacitance.

Key points

- Electrostatic force is **conservative**: work done depends only on the end points, not the path.
- **Potential** V at a point = work done per unit charge in bringing a test charge from infinity; a scalar.
- **Equipotential surfaces**: no work is done moving a charge on them; E is always perpendicular to them.
- Inside a conductor $E = 0$; charge resides on the surface; V is constant throughout and on the surface.
- **Dielectric** gets polarised in a field, reducing the net field, so capacitance rises: $C = KC_0$.
- **Capacitor**: two conductors separated by an insulator; $C = Q/V$, unit farad; depends only on geometry and medium.

Formulas & key derivations

- Point charge: $V = (1/4\pi\epsilon_0) q/r$; dipole: $V = (1/4\pi\epsilon_0) p \cos\theta/r^2$
- **$E = -dV/dr$** (field = negative potential gradient)
- PE of two charges: $U = (1/4\pi\epsilon_0) q_1q_2/r$; dipole in field: $U = -p \cdot E$
- Parallel plate: $C = \epsilon_0 A/d$; with dielectric slab of thickness t : $C = \epsilon_0 A/(d - t + t/K)$
- Series: $1/C = 1/C_1 + 1/C_2 + \dots$; parallel: $C = C_1 + C_2 + \dots$
- Energy stored: $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = Q^2/2C$ (formula only); energy density = $\frac{1}{2}\epsilon_0 E^2$

Exam focus: how to score

- Derive potential due to a dipole and **$E = -dV/dr$** .
- **Capacitance with a dielectric or metal slab** (metal slab: $C = \epsilon_0 A/(d - t)$) is a repeat 3-marker.
- Combination problems: series gives minimum C , parallel gives maximum C .
- Energy of capacitor: no derivation in 2026-27, use the formulae.

★ Important questions from CBSE sample papers

- Find C of a parallel plate capacitor with (I) a dielectric slab and (II) a metallic slab of thickness $t < d$. Which is more and why? (SQP 2024-25, 3 marks)
- Show that $E =$ negative potential gradient. A sphere reaches max potential 5×10^5 V before air breaks down at 2.5×10^6 V/m: find its minimum radius. (SQP 2026-27, 5 marks)
- Why can't an isolated conductor have a large capacitance? Connect 6, 9, 18 μF for minimum and maximum C . (SQP 2026-27, 5 marks)

Remember: Series = smaller than the smallest; parallel = just add.

Chapter 3: Current Electricity

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Big idea: A steady current needs an emf; drift of electrons, resistance and Kirchhoff's rules explain every circuit.

Key points

- **Current** = charge per unit time through an area; needs a closed circuit and a source of **emf**.
- Free electrons move randomly; in a field they gain a small average **drift velocity** opposite to E .
- **Mobility** $\mu = v_d/E$; **relaxation time** τ = average time between collisions.
- **Ohm's law** $V = IR$ is not universal: fails for non-linear, direction-dependent or non-unique V - I (diode, GaAs).
- Resistivity of metals rises with temperature (τ falls); semiconductors' resistivity falls.
- **Internal resistance** r : terminal voltage $V = \varepsilon - Ir$ while the cell delivers current.
- **Kirchhoff's junction rule** = conservation of charge; **loop rule** = conservation of energy.
- **Wheatstone bridge** balanced when no current flows through the galvanometer.

Formulas & key derivations

- $I = neAv_d$; **$v_d = eE\tau/m$**
- $R = \rho l/A$; $\rho = m/(ne^2\tau)$; conductivity $\sigma = 1/\rho$
- $\rho_T = \rho_0[1 + \alpha(T - T_0)]$
- Power $P = VI = I^2R = V^2/R$
- Cells in series: $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$, $r_{eq} = r_1 + r_2$; parallel: $\varepsilon_{eq} = (\varepsilon_1 r_2 + \varepsilon_2 r_1)/(r_1 + r_2)$, $1/r_{eq} = 1/r_1 + 1/r_2$
- **Balanced Wheatstone bridge: $P/Q = R/S$**
- Current from a cell: $I = \varepsilon/(R + r)$

Exam focus: how to score

- Derive **$I = neAv_d$ and $\rho = m/(ne^2\tau)$** ; show how ρ depends on temperature.
- Derive the balance condition of a Wheatstone bridge using Kirchhoff's rules (5-mark choice).
- Read V - I graphs of a cell: intercept = emf, slope = $-r$.
- Cells: write ε_{eq} and r_{eq} before substituting.

★ Important questions from CBSE sample papers

- From the V vs I graph of a cell, find (I) its emf and (II) its internal resistance. (SQP 2025-26, 2 marks)
- Explain: a car starts more easily on a warm day; a heater's temperature becomes constant though heat is generated. (SQP 2026-27, 3 marks)
- Using Kirchhoff's laws obtain the balance condition of a Wheatstone bridge. (SQP 2024-25, 5 marks)

Remember: Junction rule saves charge; loop rule saves energy.

Chapter 4: Moving Charges and Magnetism

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Big idea: Moving charges and currents produce magnetic fields and feel magnetic forces.

Key points

- **Lorentz force** $F = q(E + v \times B)$; the magnetic part is perpendicular to v , so it does no work.
- Charge moving $\perp B$ goes in a circle; at an angle it follows a **helix**; frequency independent of speed.
- **Biot-Savart law** gives the field of a current element; **Ampere's law** is easier when there is symmetry.
- **Parallel currents attract**, antiparallel repel; this defines the ampere.
- A current loop is a **magnetic dipole**: $m = NIA$; in uniform B net force is zero, torque $\tau = m \times B$.
- **Moving coil galvanometer**: radial field from a cylindrical soft-iron core makes deflection $\propto$ current.
- Galvanometer $\rightarrow$ **ammeter**: small shunt in parallel; $\rightarrow$ **voltmeter**: high resistance in series.

Formulas & key derivations

- $r = mv/(qB)$; frequency $\nu = qB/(2\pi m)$
- Biot-Savart: $dB = (\mu_0/4\pi) I dl \times r / r^3$
- **Circular loop on axis: $B = \mu_0 I R^2 / [2(x^2 + R^2)^{3/2}]$; at centre $B = \mu_0 I / 2R$**
- Long straight wire (Ampere): $B = \mu_0 I / (2\pi r)$; solenoid: $B = \mu_0 n I$
- Force between parallel wires per length: $F/l = \mu_0 I_1 I_2 / (2\pi d)$
- Galvanometer: $NIA B = k\phi$; current sensitivity $\phi/I = NAB/k$
- **Shunt $S = I_g G / (I - I_g)$; series $R = V/I_g - G$**

Exam focus: how to score

- **Derive B on the axis of a circular loop (Biot-Savart)** and B near a long wire (Ampere).
- Galvanometer: principle, role of radial field, and conversion to ammeter/voltmeter with numerical.
- Define one ampere from force between parallel wires.
- Path of a charge in B : circle, helix (pitch = $v \cos\theta \times T$).

★ Important questions from CBSE sample papers

- Write the force per unit length between two parallel current-carrying wires. Hence define one ampere. (SQP 2025-26, 2 marks)
- Ammeter of resistance 13Ω reading up to 100 A is extended to 750 A : find the shunt. Why is the coil wound on a metal frame? (SQP 2026-27, 3 marks)
- State the principle of a moving coil galvanometer. What makes its scale linear? Convert 49.5Ω , 0.05 A galvanometer to a 5 A ammeter. (SQP 2025-26, 5 marks)

Remember: Shunt = small and parallel (ammeter); big and series (voltmeter).

Chapter 5: Magnetism and Matter

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Big idea: A bar magnet behaves like a solenoid; materials are dia-, para- or ferromagnetic depending on how they respond to a field.

Key points

- Magnetic poles always exist in pairs; cutting a magnet gives two smaller magnets: **no monopoles**.
- A bar magnet is equivalent to a current-carrying **solenoid** (qualitative).
- Field lines form **closed loops**: outside $N \rightarrow S$, inside $S \rightarrow N$; they never cross.
- In a uniform field a bar magnet feels **no net force** but a torque $\tau = m \times B$ (qualitative).
- **Gauss's law for magnetism**: net magnetic flux through any closed surface is zero.
- **Diamagnetic** (Bi, Cu, water, superconductors): weakly repelled, field lines pushed out, χ small negative.
- **Paramagnetic** (Al, Na, O_2): weakly attracted, χ small positive; magnetisation grows as temperature falls.
- **Ferromagnetic** (Fe, Co, Ni): strongly attracted, χ very large; become paramagnetic above the **Curie temperature**.

Formulas & key derivations

- Axial field ($r \gg l$): $B = \mu_0 \cdot 2m / (4\pi r^3)$; equatorial: $B = \mu_0 m / (4\pi r^3)$
- **Gauss's law: $\oint \mathbf{B} \cdot d\mathbf{S} = 0$**
- $H = B_0 / \mu_0$; magnetisation $M = m_{\text{net}} / V$
- $B = \mu_0(H + M)$; $M = \chi H$
- $\mu = \mu_0 \mu_r$; **$\mu_r = 1 + \chi$**

Diagrams, maps & graphs to practise

- Field lines through a diamagnetic vs paramagnetic sample
- Field lines of a bar magnet and of a solenoid

Exam focus: how to score

- **Compare dia, para, ferro**: χ sign/size, μ_r , behaviour in non-uniform field, examples, temperature effect.
- Draw field lines inside dia and para samples (2 marks).
- Numericals on H , B and M for a cored solenoid.
- Superconductor = perfect diamagnet (Meissner effect): repelled by a magnet.

★ Important questions from CBSE sample papers

- A substance has relative permeability 800. What type is it? Write two characteristics. (SQP 2026-27, 2 marks)
- State Gauss's law of magnetism and its significance. (SQP 2026-27, 2 marks)
- Solenoid core $\mu_r = 200$, 2000 turns/m, 1 A: find H , B and magnetisation. (SQP 2025-26, 3 marks)

Remember: Dia dodges, para pulls a little, ferro grabs.

Chapter 6: Electromagnetic Induction

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Big idea: A changing magnetic flux induces an emf; Lenz's law says the induced current always opposes the change.

Key points

- **Magnetic flux** $\Phi = B \cdot A = BA \cos\theta$; unit weber (Wb).
- **Faraday's law**: induced emf equals the rate of change of flux linkage.
- **Lenz's law**: induced current opposes the change producing it: a consequence of energy conservation.
- A rod moving in a field gives **motional emf**.
- **Self-induction**: a changing current in a coil induces a back emf in the same coil; L is electrical inertia.
- **Mutual induction**: changing current in one coil induces emf in a nearby coil; $M_{12} = M_{21}$.
- A magnet falling through a ring or copper tube is slowed ($a < g$) because induced currents oppose its motion.
- L and M depend on geometry (turns, area, length) and the core's permeability.

Formulas & key derivations

- $\varepsilon = -N \frac{d\Phi}{dt}$
- Motional emf: $\varepsilon = Blv$
- Self-induced emf: $\varepsilon = -L \frac{dI}{dt}$; $N\Phi = LI$
- **Long solenoid**: $L = \mu_r \mu_0 n^2 A l$
- Mutual inductance (coaxial solenoids): $M = \mu_0 n_1 n_2 \pi r_1^2 l$
- Energy stored in inductor: $U = \frac{1}{2} LI^2$

Exam focus: how to score

- Apply **Lenz's law to find direction** of induced current (magnet approaching/receding a coil).
- Derive motional emf $\varepsilon = Blv$ and self-inductance of a long solenoid.
- Explain why a falling magnet's acceleration is less than g .
- Ratio problems: how L changes when length, area or turns change.

★ Important questions from CBSE sample papers

- Two identical magnets fall 20 m, one through a copper solenoid and one in air. Compare times taken. (SQP 2025-26, 1 mark)
- A bar magnet falls through a metal ring: why is $a < g$? Side of a triangular coil frame increased 5 times (same turns per length): how does L change? (SQP 2026-27, 3 marks)
- A 50-turn coil of area $5/\pi \text{ cm}^2$ rotates along the axis of a 50 cm, 2000-turn solenoid carrying 5 A. Find the maximum emf. (SQP 2025-26, 3 marks)

Remember: Nature resists change: Lenz is the 'minus' in Faraday.

Chapter 7: Alternating Current

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Big idea: AC voltages and currents vary sinusoidally; L and C oppose AC through reactance, and resonance occurs when $X_L = X_C$.

Key points

- AC: $v = v_m \sin \omega t$; household meters read **rms** values.
- Resistor: current **in phase** with voltage.
- Inductor: current **lags** voltage by $\pi/2$; capacitor: current **leads** by $\pi/2$; average power in each is zero.
- **Phasors** are rotating vectors whose length is the peak value; used to analyse LCR circuits.
- **Resonance** in series LCR: $X_L = X_C$, $Z = R$ (minimum), current maximum; used to tune radios.
- Power factor $\cos \phi$: 1 for pure R, 0 for pure L or C (**wattless current**).
- **AC generator**: coil rotating in B; mechanical $\rightarrow$ electrical energy by EMI.
- **Transformer**: mutual induction on a laminated soft-iron core; works only with AC.

Formulas & key derivations

- $I_{rms} = I_0/\sqrt{2}$, $V_{rms} = V_0/\sqrt{2}$
- $X_L = \omega L$; $X_C = 1/(\omega C)$
- **$Z = \sqrt{R^2 + (X_L - X_C)^2}$; $\tan \phi = (X_L - X_C)/R$**
- **Resonance: $\omega_0 = 1/\sqrt{LC}$** ; $Q = \omega_0 L/R$
- Average power $P = V_{rms} I_{rms} \cos \phi$; $\cos \phi = R/Z$
- Generator: $\varepsilon = NBA\omega \sin \omega t$; $\varepsilon_0 = NBA\omega$
- Transformer: $V_s/V_p = N_s/N_p = I_p/I_s$ (ideal)

Diagrams, maps & graphs to practise

- Phasor diagram of series LCR
- Labelled AC generator and transformer

Exam focus: how to score

- Derive impedance and phase angle of series LCR with a **phasor diagram**.
- **AC generator: diagram + derive $\varepsilon = NBA\omega \sin \omega t$** (5 marks).
- Transformer: principle, diagram, turns ratio, and losses (copper, eddy current, hysteresis, flux leakage).
- A step-up transformer does not violate energy conservation: current steps down.

★ Important questions from CBSE sample papers

- Explain the AC generator with a labelled diagram; derive the instantaneous emf of a coil of N turns, area A, speed ω . (SQP 2024-25, 5 marks)
- Describe, with a labelled diagram, the device that steps up AC voltage; why isn't it 100% efficient? (SQP 2026-27, 5 marks)
- What is resonance in series LCR? Write the resonant frequency and explain its use in radio tuning. (SQP 2026-27, 5 marks)

Remember: ELI the ICE man: Voltage leads in L, Current leads in C.

Chapter 8: Electromagnetic Waves

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Big idea: Changing electric and magnetic fields sustain each other and travel as transverse waves at the speed of light.

Key points

- Maxwell added **displacement current** (from a changing electric field) to Ampere's law, removing its inconsistency.
- Displacement current produces a magnetic field just like conduction current, e.g. between capacitor plates.
- **Accelerated charges** produce EM waves; an oscillating charge radiates at its own frequency.
- Hertz (1887) first produced and detected EM waves in the laboratory.
- E and B oscillate in phase, perpendicular to each other and to the direction of travel: **transverse**.
- EM waves need no medium; all travel at c in vacuum and carry energy and momentum.
- **Spectrum** (increasing wavelength): γ -rays, X-rays, UV, visible, IR, microwaves, radio waves.

Formulas & key derivations

- **Displacement current $i_d = \epsilon_0 d\Phi_E/dt$**
- $E = E_0 \sin(kx - \omega t)$, $B = B_0 \sin(kx - \omega t)$; $k = 2\pi/\lambda$, $\omega = 2\pi\nu$
- **$E_0/B_0 = c$** ; $c = 1/\sqrt{\mu_0\epsilon_0} = 3 \times 10^8 \text{ m/s}$
- In a medium: $v = 1/\sqrt{\mu\epsilon}$; refractive index $n = c/v$
- Uses: radio (communication), microwaves (radar, ovens), IR (remote controls, heating), UV (sterilising, LASIK), X-rays (medical), γ (cancer treatment)

Exam focus: how to score

- Write E or B equation from given data; identify direction from sign of kx and ωt .
- **Order of the spectrum with one source and one use each** (1-2 marks).
- Find n of a medium from $E_0/B_0 = v$ and $n = c/v$.
- Displacement current numerical: $i_d = C dV/dt$.

★ Important questions from CBSE sample papers

- A capacitor ($A = 0.001 \text{ m}^2$, $d = 0.0001 \text{ m}$) has voltage changing at 10^8 V/s . Find the displacement current. (SQP 2024-25, 1 mark)
- B amplitude 510 nT along $\hat{k}$, wave along $+x$ in vacuum, $\omega = 60 \times 10^6 \text{ rad/s}$: write the expression for E. (SQP 2025-26, 2 marks)
- Given E and B equations of a wave in a medium, find the refractive index, frequency and identify the wave. (SQP 2026-27, 2 marks)

Remember: Gamma X-rays Use Visible Infrared Micro Radio: high to low frequency.

Chapter 9: Ray Optics and Optical Instruments

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Big idea: Light travels in straight lines, reflecting and refracting by simple rules that let us design lenses, microscopes and telescopes.

Key points

- **Cartesian sign convention:** distances along incident light positive; measured from the pole/optical centre.
- **Snell's law:** $\sin i / \sin r = n_{21}$. Denser medium bends light towards the normal.
- **Total internal reflection** (denser $\rightarrow$ rarer, $i >$ critical angle): optical fibres, diamond sparkle, mirage, prisms.
- **Power** of lens $P = 1/f$ (diopetre); lenses in contact: powers add.
- At **minimum deviation** the ray passes symmetrically through the prism ($i = e$).
- **Compound microscope:** short-focus objective and eyepiece; **telescope:** long-focus large-aperture objective.
- **Reflecting telescopes** (Cassegrain): no chromatic aberration, easier to support large mirrors.

Formulas & key derivations

- Mirror: $1/v + 1/u = 1/f$; lens: **$1/v - 1/u = 1/f$** ; $m = v/u$ (lens)
- Spherical surface: $n_2/v - n_1/u = (n_2 - n_1)/R$
- **Lens maker's: $1/f = (n_{21} - 1)(1/R_1 - 1/R_2)$**
- $\sin i_c = 1/n$
- Prism: $A + \delta = i + e$; $n = \sin[(A + \delta_m)/2] / \sin(A/2)$
- Microscope: $m = m_o \times m_e \approx (L/f_o)(D/f_e)$; simple microscope $m = 1 + D/f$
- Telescope (normal adjustment): $m = f_o/f_e$; length = $f_o + f_e$

Diagrams, maps & graphs to practise

- Ray diagrams: compound microscope, refracting telescope, Cassegrain telescope
- Refraction through a prism

Exam focus: how to score

- **Derive lens maker's formula** and the prism relation $A + \delta = i + e$ (5-mark choice).
- Microscope/telescope numericals: always find the objective image first.
- TIR questions: compare i with i_c ; say whether ray refracts or reflects.
- Neat ray diagrams with arrows earn marks.

★ Important questions from CBSE sample papers

- Diamond $n = 2.42$: a ray inside strikes the surface at 30° ; refraction or TIR? Why do cut diamonds sparkle? (SQP 2026-27, 3 marks)
- Derive lens maker's formula. Equi-convex lens, $n = 1.55$, $f = 10$ cm: find R . (SQP 2025-26, 5 marks)
- Compound microscope $f_o = 2$ cm, $f_e = 5$ cm, object at 2.2 cm: find image position and magnifying power (final image at infinity). (SQP 2026-27, 5 marks)

Remember: Lens maker: $(n - 1) \times$ curvature difference.

Chapter 10: Wave Optics

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Big idea: Light is a wave: Huygens' wavefronts explain reflection and refraction, and superposition gives interference and diffraction.

Key points

- **Wavefront:** surface of constant phase. Point source → spherical; distant source → plane.
- **Huygens' principle:** every point on a wavefront is a source of secondary wavelets; the new wavefront is their forward envelope.
- Wave theory predicts light is **slower in a denser medium** ($v_1/v_2 = n_2/n_1$): verified later (Foucault).
- **Coherent sources:** same frequency with constant phase difference; needed for sustained interference.
- Two independent bulbs are not coherent; YDSE makes coherent sources by splitting one wavefront.
- Constructive: path difference $n\lambda$; destructive: $(n + \frac{1}{2})\lambda$. Fringes are equally spaced.
- **Diffraction** at a single slit: central bright maximum twice as wide as the others (qualitative).
- Wider slit → narrower central maximum.

Formulas & key derivations

- **Huygens: $\sin i/\sin r = v_1/v_2 = n_2/n_1$ (Snell's law)**
- Reflection: angle of incidence = angle of reflection (from equal triangles)
- **YDSE fringe width $\beta = \lambda D/d$** (final expression only)
- Intensity: $I = 4I_0 \cos^2(\phi/2)$
- Single slit minima: $a \sin \theta = n\lambda$; central maximum width = $2\lambda D/a$

Diagrams, maps & graphs to practise

- Plane wavefront refracted at a surface (rarer → denser)
- Plane wavefront reflected from a plane mirror

Exam focus: how to score

- **Prove Snell's law and law of reflection using Huygens' construction** (3 marks; diagram carries a mark).
- Fringe-width numericals and effect of changing λ , D , d or medium.
- Conditions for sustained interference; coherent vs incoherent sources.
- Compare interference and diffraction patterns.

★ Important questions from CBSE sample papers

- In YDSE, $d = 0.25$ mm, $D = 1.0$ m, $\lambda = 500$ nm. Assertion: fringe width is 2.0 mm. (SQP 2026-27, 1 mark)
- Light of 4000 Å and 6000 Å in YDSE: least distance from the central maximum where a dark fringe is obtained? (SQP 2024-25, 2 marks)
- Derive Snell's law using Huygens' wave theory. What prediction was later verified? (SQP 2026-27, 3 marks)
- Draw the reflected wavefront for a plane wave on a plane surface and verify the laws of reflection. (SQP 2025-26, 3 marks)

Remember: Fringe width $\beta = \lambda D/d$: longer light, wider fringes.

Chapter 11: Dual Nature of Radiation and Matter

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Big idea: Light shows particle behaviour (photons) in the photoelectric effect, and moving particles show wave behaviour.

Key points

- **Work function** ϕ_0 : minimum energy needed to free an electron from a metal surface.
- Hertz and Lenard observed emission of electrons when UV light fell on metal surfaces.
- Photocurrent $\propto$ **intensity**; stopping potential depends on **frequency** and metal, not intensity.
- Below the **threshold frequency** ν_0 no emission, however intense the light; emission is **instantaneous**.
- Wave theory cannot explain these; Einstein: light consists of **photons** of energy $h\nu$.
- Millikan's experiments confirmed Einstein's equation and gave h .
- **de Broglie**: moving particles have wavelength $\lambda = h/p$; noticeable only for tiny masses like electrons.

Formulas & key derivations

- Photon: $E = h\nu = hc/\lambda$; $p = h/\lambda$
- **Einstein: $K_{\text{max}} = h\nu - \phi_0 = eV_0$** ; $\phi_0 = h\nu_0$
- **de Broglie: $\lambda = h/p = h/\sqrt{2mK} = h/\sqrt{2mqV}$**
- Electron: $\lambda = 1.227/\sqrt{V}$ nm
- $hc \approx 1240$ eV nm (quick conversion)

Diagrams, maps & graphs to practise

- Photocurrent vs anode potential (different intensities, different frequencies)
- Stopping potential V_0 vs frequency ν (slope h/e)
- λ vs $1/\sqrt{V}$ (straight line, slope $h/\sqrt{2mq}$)

Exam focus: how to score

- **Graphs: I vs V and V_0 vs ν** : say what changes the saturation current and what changes V_0 .
- Explain three features of photoelectric effect that wave theory fails to explain.
- Case-study questions (4 marks) appear regularly on this chapter.
- de Broglie numericals: compare λ for particles with the same K or the same V .

★ Important questions from CBSE sample papers

- Assertion: de Broglie wavelength of a freely falling body keeps decreasing. Reason: its momentum increases. (SQP 2024-25, 1 mark)
- Platinum ($\phi_0 = 5.63$ eV) lit by 1.6×10^{15} Hz: find minimum wavelength associated with the ejected electron. (SQP 2024-25, 2 marks)
- Plot λ vs $1/\sqrt{V}$ for a particle of mass m , charge q ; obtain the slope. (SQP 2025-26, 2 marks)
- Case study: define work function; why doesn't higher intensity raise K_{max} ? (SQP 2026-27, 4 marks)

Remember: Intensity decides HOW MANY electrons; frequency decides HOW FAST.

Chapter 12: Atoms

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Big idea: Rutherford found the tiny nucleus; Bohr's quantised orbits explain the stability of hydrogen and its line spectrum.

Key points

- **Thomson model:** positive sphere with embedded electrons (plum pudding); failed.
- **Rutherford α -scattering** (gold foil): most α pass undeflected, only $\sim 0.14\%$ deflected by more than 1° , very few bounce back.
- Conclusion: positive charge and almost all mass in a **tiny nucleus** ($\sim 10^{-4}$ of atomic size).
- **Impact parameter** b : small $b \rightarrow$ large scattering; $b = 0 \rightarrow$ head-on, α bounces back.
- Rutherford model fails: accelerating electron should spiral in; cannot explain line spectra.
- **Bohr's postulates:** stationary orbits, $L = nh/2\pi$, photon emitted on jump: $h\nu = E_i - E_f$.
- de Broglie: allowed orbit holds a whole number of wavelengths, $2\pi r_n = n\lambda$.
- Line spectra are a **fingerprint** of each element. Bohr model works only for single-electron atoms.

Formulas & key derivations

- Closest approach: $r_0 = 2Ze^2/(4\pi\epsilon_0 K)$
- **$r_n = n^2 h^2 \epsilon_0 / (\pi m e^2)$; $r_1 = 0.53 \text{ \AA}$ ($r \propto n^2$)**
- $v_n = e^2 / (2\epsilon_0 n h) \propto 1/n$
- **$E_n = -me^4 / (8\epsilon_0^2 n^2 h^2) = -13.6/n^2 \text{ eV}$**
- $KE = -E$, $PE = 2E$ (total energy negative: electron is bound)
- Ionisation energy of H = 13.6 eV

Exam focus: how to score

- **Derive r_n , v_n and E_n for the hydrogen atom** (Bohr model).
- α -scattering: observations $\rightarrow$ conclusions; distance of closest approach numericals.
- Which transition gives longest/shortest wavelength: compare energy gaps.
- Bohr's quantisation explained by de Broglie standing waves.

★ Important questions from CBSE sample papers

- Distance of closest approach of an α -particle is d at speed V ; for $d/2$, what speed? (SQP 2024-25, 1 mark)
- How does impact parameter affect the α -particle trajectory? Value for head-on collision? (SQP 2025-26, 2 marks)
- Why are hydrogen spectral lines an element's fingerprint? Minimum photon energy to ionise ground-state H? (SQP 2026-27, 2 marks)
- State Bohr's quantisation condition; how does de Broglie's hypothesis explain stationary orbits? (SQP 2026-27, 2 marks)

Remember: Radius grows as n^2 , energy shrinks as $1/n^2$.

Chapter 13: Nuclei

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Big idea: The nucleus is held by a strong short-range force; its mass defect is the binding energy that fission and fusion release.

Key points

- Nucleus contains **protons** (Z) and **neutrons** (N); mass number $A = Z + N$.
- **Isotopes**: same Z; **isobars**: same A; **isotones**: same N.
- $1 \text{ u} = 1/12 \text{ mass of a } ^{12}\text{C} \text{ atom} = 1.66 \times 10^{-27} \text{ kg} = 931.5 \text{ MeV}/c^2$.
- Nuclear density ($\sim 10^{17} \text{ kg/m}^3$) is the **same for all nuclei**.
- **Nuclear force**: strongest, short-range (few fm), charge-independent, attractive (repulsive below $\sim 0.8 \text{ fm}$).
- Nucleus mass < sum of nucleon masses: **mass defect** $\rightarrow$ **binding energy**.
- BE/nucleon $\sim 8 \text{ MeV}$ for $A = 30-170$; **peak $\approx 8.75 \text{ MeV}$ at $A = 56$ (iron): most stable.**
- **Fission** (heavy $\rightarrow$ middle) and **fusion** (light $\rightarrow$ heavier) both increase BE/nucleon, so release energy. Fusion powers stars.

Formulas & key derivations

- $R = R_0 A^{1/3}$, $R_0 = 1.2 \text{ fm}$
- **Mass defect $\Delta M = [Zm_p + (A - Z)m_n] - M$**
- $BE = \Delta M c^2$; BE per nucleon = BE/A
- $E = mc^2$; $1 \text{ u} \leftrightarrow 931.5 \text{ MeV}$
- Q-value = (initial mass – final mass) c^2
- Example: $^{235}\text{U} + n \rightarrow ^{133}\text{Sb} + ^{99}\text{Nb} + 4n$

Diagrams, maps & graphs to practise

- BE per nucleon vs mass number curve (mark Fe-56, fission and fusion regions)

Exam focus: how to score

- **Draw the BE/nucleon curve** and use it to explain fission and fusion.
- Binding energy and Q-value numericals: show mass defect first, then multiply by 931.5.
- Density independent of A: prove from $R \propto A^{1/3}$.
- Properties of nuclear force (2 marks).

★ Important questions from CBSE sample papers

- Ratio of nuclear densities of nuclei with $A = 8$ and $A = 27$? (SQP 2025-26, 1 mark)
- From the BE/nucleon curve, identify nuclei likely to undergo fission and fusion; justify. (SQP 2024-25, 2 marks)
- Atomic mass of ^{16}O is 15.99493 u: calculate the binding energy per nucleon. (SQP 2026-27, 3 marks)
- Write the fission reaction of Pu-239 into Xe and Zr; find the energy released. (SQP 2025-26, 3 marks)

Remember: Iron sits at the top: both splitting and joining climb towards it.

Chapter 14: Semiconductor Electronics: Materials, Devices and Simple Circuits

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Big idea: Band gaps decide conductors, insulators and semiconductors; a p-n junction diode lets current flow one way and rectifies AC.

Key points

- **Energy bands:** valence band (filled) and conduction band separated by a gap E_g .
- Metals: bands overlap ($E_g \approx 0$); semiconductors: $E_g < 3$ eV (Si 1.1 eV, Ge 0.72 eV); insulators: $E_g > 3$ eV.
- **Intrinsic** (pure) semiconductor: $n_e = n_h$; conductivity rises with temperature.
- **n-type:** pentavalent donors (P, As, Sb); electrons majority. **p-type:** trivalent acceptors (B, Al, In); holes majority.
- Doped crystal stays **electrically neutral**.
- **p-n junction:** diffusion and drift create a **depletion layer** of immobile ions and a barrier potential.
- **Forward bias** (p to +): barrier and depletion width fall, large current (mA). **Reverse bias:** barrier rises, tiny current (μ A).
- **Rectifier:** half-wave uses one diode; full-wave uses two diodes with a centre-tapped transformer.

Formulas & key derivations

- $n_e \times n_h = n_i^2$
- Insulator $E_g > 3$ eV; semiconductor 0.2-3 eV; metal ≈ 0
- Cut-in (knee) voltage: Si ≈ 0.7 V, Ge ≈ 0.2 -0.3 V
- **Full-wave output frequency = $2 \times$ input (50 Hz $\rightarrow$ 100 Hz);** half-wave = same as input

Diagrams, maps & graphs to practise

- Energy band diagrams of metal, semiconductor, insulator; p- and n-type
- I-V characteristics in forward and reverse bias
- Half-wave and full-wave rectifier circuits with input/output waveforms

Exam focus: how to score

- **Full-wave rectifier: circuit, working and waveforms** (3 marks).
- Band diagrams: draw and label E_c , E_v , donor/acceptor levels.
- Explain formation of depletion region and effect of bias on its width.
- Diode-circuit MCQs: decide which diodes are forward biased first.

★ Important questions from CBSE sample papers

- Draw energy band diagram of a p-type semiconductor at $T = 0$ K and at room temperature. (SQP 2024-25, 3 marks)
- With a circuit diagram, explain the working of a full-wave rectifier. (SQP 2025-26, 3 marks)
- Compare band diagrams of metals, insulators and semiconductors; why is diamond an insulator but tin a conductor? (SQP 2026-27, 3 marks)

Remember: Forward = flow; reverse = block. Two diodes = double frequency.