FREE EDITION · NOTES + 3 SAMPLE MCQS

CUET · PHYSICS · CLASS XII · CODE 322

Current Electricity

CUET unit: Current Electricity

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- Defines steady electric current as net charge per unit time across an area, $I = q/t$ (and instantaneously $I = \lim \Delta Q/\Delta t$).
- Builds the microscopic picture of conduction: free electrons drift through a lattice of fixed positive ions, giving rise to drift velocity $v_d = -eE\tau/m$, mobility $\mu = v_d/E = e\tau/m$, and Ohm's law $V = IR$ with $R = \rho l/A$.
- Classifies materials as conductors, semiconductors, and insulators by resistivity range, and gives the linear temperature law $\rho_T = \rho_0[1 + \alpha(T - T_0)]$ for metals ($\alpha > 0$), contrasting with semiconductors/ insulators (ρ decreases with T).
- Develops circuit tools used by CUET: electrical power $P = VI = I^2R = V^2/R$, series/parallel resistors, EMF and internal resistance $V = \epsilon - Ir$, combinations of cells, Kirchhoff's junction and loop rules, and the Wheatstone bridge balance $R_1/R_2 = R_3/R_4$.
- High-weightage CUET unit because almost every concept yields a direct one-line MCQ (definitions, units, sign of α) and a 2-step numerical MCQ (drift velocity, terminal voltage, bridge balance).

📖 Detailed Notes

2.1 Core concepts

- Charges in motion constitute an electric current; in solid conductors the carriers are free electrons against a background of fixed positive ions (NCERT §3.1–3.3, p. 81–83).
- For steady current across an area in time t with net forward charge q, $I = q/t$; more generally $I(t) = \lim \Delta Q/\Delta t$ as $\Delta t \to 0$. SI unit is the ampere; nerve currents are in μA while lightning carries tens of thousands of A (NCERT §3.2, p. 82).
- Without an electric field, electrons move thermally with random directions, so the average velocity is zero and no net current flows (NCERT §3.3, p. 82–83).
- Ohm's law (1828, G.S. Ohm): for many conductors, V ∝ I, written $V = IR$; R is the resistance of the conductor, SI unit ohm (Ω) (NCERT §3.4, p. 83).
- Geometry of R: doubling length doubles R; halving cross-section doubles R; hence $R = \rho l/A$, where ρ (resistivity) depends only on material (NCERT §3.4, p. 83–84).

- Current density $j = I/A$ (A m^{-2}); in vector form $E = \rho j$ or equivalently $j = \sigma E$, where $\sigma = 1/\rho$ is conductivity (NCERT §3.4, p. 84–85).
- Drift velocity: averaging electron motion under field E with average collision time τ (relaxation time) gives $v_d = -(eE/m)\tau$, independent of time (NCERT §3.5, Eq. 3.17, p. 85–86).
- This yields the microscopic form of Ohm's law: $j = (ne^2\tau/m)\, E$ and hence $\sigma = ne^2\tau/m$, $\rho = m/(ne^2\tau)$ (NCERT §3.5, Eqs. 3.21–3.23, p. 86).
- Worked estimate (Example 3.1): in a Cu wire (A = 1.0 × 10^{-7} m^2, I = 1.5 A, n = 8.5 × 10^{28} m^{-3}), drift speed $v_d \approx 1.1$ mm s^{-1} — about 10^{-5} times the thermal speed and 10^{-11} times the speed of EM signal propagation (NCERT §3.5, Example 3.1, p. 86–87).
- Mobility $\mu = |v_d|/E = e\tau/m$, SI unit m^2 V^{-1} s^{-1} (NCERT §3.5.1, Eqs. 3.24–3.25, p. 88–89).
- Limitations of Ohm's law: (a) V not proportional to I, (b) V–I relation depends on sign of V (diode), (c) V–I relation not single-valued (GaAs) (NCERT §3.6, p. 89).
- Materials by resistivity: metals 10^{-8}–10^{-6} Ω m; insulators ~10^{18} times that of metals; semiconductors in between, with ρ that decreases with rising temperature (NCERT §3.7, p. 89–90).
- Temperature dependence for metals over a limited range: $\rho_T = \rho_0\, [1 + \alpha(T - T_0)]$; α (temperature coefficient of resistivity, dimension K^{-1}) is positive for metals; alloys like nichrome, manganin, constantan have very weak α and are used in standard resistors (NCERT §3.8, Eq. 3.26, p. 90).
- Microscopic explanation via $\rho = m/(ne^2\tau)$: in metals n ≈ const, τ falls with T so ρ rises; in semiconductors/insulators n rises strongly with T and dominates, so ρ falls (NCERT §3.8, p. 91).
- Electrical energy and power: in time Δt charge $I\Delta t$ drops through V, dissipating $\Delta W = IV\Delta t$, so $P = IV = I^2R = V^2/R$ (ohmic loss) (NCERT §3.9, Eqs. 3.31–3.33, p. 92–93).
- High-voltage transmission: with cable resistance R_c, wasted power $P_c = P^2R_c/V^2$, so raising V reduces transmission loss (NCERT §3.9, Eq. 3.35, p. 93).
- A cell has emf $\varepsilon = V_+ + V_-$ — the open-circuit potential difference between terminals — and internal resistance r; when current I flows, terminal voltage $V = \epsilon - Ir$, and $I = \epsilon/(R + r)$; maximum current $I_{max} = \epsilon/r$ (NCERT §3.10, Eqs. 3.36–3.40, p. 93–95).
- Cells in series (same orientation): $\epsilon_{eq} = \epsilon_1 + \epsilon_2$, $r_{eq} = r_1 + r_2$; if a cell is reversed its emf enters with a negative sign (NCERT §3.11, Eqs. 3.45–3.47, p. 95–96).
- Cells in parallel: $1/r_{eq} = 1/r_1 + 1/r_2$ and $\epsilon_{eq}/r_{eq} = \epsilon_1/r_1 + \epsilon_2/r_2$; extends to n cells (NCERT §3.11, Eqs. 3.56–3.59, p. 96–97).

- Kirchhoff's rules: (a) Junction rule — at any junction $\Sigma I_{in} = \Sigma I_{out}$ (conservation of charge); (b) Loop rule — algebraic sum of changes of potential around any closed loop is zero (conservation of energy) (NCERT §3.12, p. 97–98).
- Wheatstone bridge: four resistors R1, R2, R3, R4 with battery across one diagonal and galvanometer across the other; balance ($I_g = 0$) gives `R2/R1 = R4/R3`, equivalently `R1/R2 = R3/R4`; a practical realisation is the metre bridge, which uses this balance to find an unknown resistance (NCERT §3.13, Eqs. 3.62–3.64, p. 100–101).

2.2 Definitions to memorise

Term	Definition	Page
Electric current I	Net charge crossing a cross-section per unit time; `I = lim ΔQ/Δt`. SI unit ampere (A).	p. 82
Current density j	Current per unit area normal to the flow; vector along E; SI unit A m^{-2}.	p. 84
Drift velocity vd	Average velocity acquired by electrons under field E; `vd = -eEτ/m`.	p. 86
Relaxation time τ	Average time between successive collisions of an electron with ions.	p. 85
Mobility μ	Magnitude of drift velocity per unit electric field; `μ = vd/E = eτ/m`; SI unit $m^2 V^{-1} s^{-1}$.	p. 88
Resistance R	Ratio V/I for an ohmic conductor; SI unit ohm ($\Omega = 1 V A^{-1}$).	p. 83
Resistivity ρ	Material property in `R = ρl/A`; SI unit Ω m.	p. 84
Conductivity σ	Reciprocal of resistivity, $\sigma = 1/\rho$; SI unit S m^{-1} (or $\Omega^{-1} m^{-1}$).	p. 85
Temperature coefficient of resistivity α	Fractional change in ρ per unit rise in T; `ρT = ρ0[1+α(T−T0)]`; positive for metals.	p. 90
Electromotive force (emf) ε	Potential difference between the terminals of a source in open circuit; $\varepsilon = V_+ + V_-$.	p. 94
Internal resistance r	Resistance of the electrolyte/source itself; gives `V = ϵ - Ir` when I flows.	p. 94
Junction rule (Kirchhoff I)	Σ currents entering a junction = Σ currents leaving (conservation of charge).	p. 97
Loop rule (Kirchhoff II)	Algebraic sum of potential changes around any closed loop is zero.	p. 98
Wheatstone bridge balance	Galvanometer null when `R1/R2 = R3/R4` (equivalently `R2/R1 = R4/R3`).	p. 101

2.3 Diagrams / processes to remember

- Fig. 3.1 (p. 83): metallic cylinder with +Q and –Q on end discs — electrons drift to neutralise charges, motivating the need for a cell to maintain steady current.
- Fig. 3.2 (p. 83–84): rectangular slab of length l and area A illustrating `R = ρl/A`.
- Fig. 3.3 (p. 85): zig-zag electron path A → B between collisions, with a slight drift B → B′ opposite to E.
- Fig. 3.4 (p. 86): cylinder of unit area and length vd containing charge carriers — used to derive `I = neAvd`.
- Fig. 3.5 (p. 89): V vs I for a good conductor — solid curve deviates from dashed Ohm's-law line at large V.
- Fig. 3.6 (p. 89): characteristic curve of a diode (asymmetric forward/reverse) — Ohm's-law failure type (b).
- Fig. 3.7 (p. 89): V vs I for GaAs showing non-unique V for the same I — Ohm's-law failure type (c).
- Fig. 3.8 (p. 90): ρ of copper vs T — linear in the usual range, deviates at very low T.
- Fig. 3.9 (p. 90): ρ of nichrome — very weak dependence on T.
- Fig. 3.10 (p. 90): ρ of a typical semiconductor — decreases with T.
- Fig. 3.11 (p. 93): cell driving a resistor R; heat dissipated in R comes from chemical energy of the electrolyte.
- Fig. 3.12 (p. 94): electrolytic cell with positive (P) and negative (N) terminals; emf is $V_+ + V_-$.
- Fig. 3.13 (p. 95): two cells in series — yields `ϵeq = ϵ1 + ϵ2`, `req = r1 + r2`.
- Fig. 3.14 (p. 96): two cells in parallel — yields `1/req = 1/r1 + 1/r2`.
- Fig. 3.15 (p. 98): junction a where I3 = I1 + I2; loop rules for closed loops `ahdcba` and `ahdefga`.
- Fig. 3.16 (p. 98) and Fig. 3.17 (p. 99): cubical network of 12 equal resistors (Example 3.5, Req = 5R/6) and a non-symmetric mesh (Example 3.6) — classic Kirchhoff applications.
- Fig. 3.18 (p. 101): Wheatstone bridge — battery on AC, galvanometer on BD, balance `R2/R1 = R4/R3`.

2.4 Common confusions / NTA trap points

- Current is a scalar, not a vector — even though we draw arrows; currents do not add by the parallelogram law. The arrow only indicates direction along the wire (Points to Ponder 1, p. 104).
- "V = IR is Ohm's law" is wrong as stated: V = IR is the definition of R and applies to any conducting device. Ohm's law is the stronger claim that R is independent of V (i.e., the V–I plot is a straight line through the origin) (Points to Ponder 2, p. 105).

- Drift speed vs signal speed vs thermal speed: drift speed in a metal is ~mm s^{-1}, thermal speed of ions ~10^2 m s^{-1}, while the electric field itself propagates near the speed of light. Distractors swap these in MCQs (NCERT Example 3.1 & 3.2, p. 87–88).
- Sign of α: positive for metals (ρ increases with T) but negative for semiconductors and insulators (ρ decreases with T). NTA likes to flip this.
- Terminal voltage: when the cell is discharging through R, $V = \varepsilon - Ir$ ($V < \varepsilon$); when it is being charged from outside, the formula reverses sign ($V = \varepsilon + Ir$ for the terminal voltage of the battery being charged). Many students always write $\varepsilon - Ir$.
- Wheatstone bridge balance condition is sometimes mis-written. The NCERT writes it as `R1/R2 = R3/R4` (Summary, p. 104) and equivalently `R2/R1 = R4/R3` from the loop derivation (Eq. 3.64a, p. 101) — both forms are correct provided the arms are paired consistently (adjacent arms on the same side of the galvanometer).

🎯 Practice MCQs

📊 PYQ Alignment

Current Electricity is one of the most heavily tested CUET (UG) units in 322 Physics, typically contributing 4–6 MCQs every shift (2023–2025 papers): expect at least one direct definition (current/resistivity/mobility), one numerical on drift velocity or `R = ρl/A`, one series/parallel combination, one terminal-voltage or "internal resistance" sum, one Kirchhoff/Wheatstone-balance problem, and one V–I graph or temperature-dependence conceptual MCQ.

CUET 2025 — Actual PYQs from this chapter

Q.9 (CUET 2025) Conductors develop electric currents in them:

- A) Only applying electric field B) Placing the conductor in magnetic field C) Applying gravitational field only D) Applying magnetic and gravitational field Tests: Source of conduction current — applied electric field Answer: Not in extracted key

Q.10 (CUET 2025) Resistivity of a conductor depends on:

- A) Material and dimensions B) Material and temperature C) Dimensions only D) Temperature only Tests: Resistivity — material and temperature dependence Answer: Not in extracted key

Q.11 (CUET 2025) In absence of electric field and presence of electric field, paths of electrons between collisions are:

- A) Straight line, straight line B) Curved, straight line C) Curved, curved D) Straight line, curved Tests: Electron paths between collisions — with and without E-field Answer: Not in extracted key

Q.12 (CUET 2025) A resistor develops 800 J thermal energy in 20 s when 20 V is applied. The resistance is:

- A) 20 Ω B) 10 Ω C) 40 Ω D) 0.5 Ω Tests: Joule heating — $H = V^2t/R$ Answer: Not in extracted key

Q.13 (CUET 2025) A wire of resistance 4 Ω is used to make a coil of radius 7 cm. Wire diameter = 1.4 mm Resistivity = 2×10^{-7} Ω m Number of turns in coil:

- A) 70 B) 40 C) 140 D) 20 Tests: Coil from a wire — number of turns from R, ρ, geometry Answer: Not in extracted key

Q.14 (CUET 2025) A battery of emf 12 V and internal resistance 3 Ω is connected to external resistor. If current = 0.6 A, voltage across external resistor is:

- A) 10.2 V B) 17.0 V C) 12.0 V D) 13.8 V Tests: Terminal voltage $V = \varepsilon - Ir$ Answer: Not in extracted key

Q.15 (CUET 2025) A 12 Ω wire is cut into three pieces in ratio 1 : 2 : 3. These pieces form a triangle. A cell of 8 V with internal resistance 5 Ω is connected across largest side. Current in circuit is:

- A) 2 A B) 0.5 A C) 0.4 A D) 1 A Tests: Triangle of resistors — current in cell circuit Answer: Not in extracted key

CUET 2024 — Actual PYQs from this chapter

Q.5 (CUET 2024) Two resistors 100 Ω and 200 Ω are in series with 20 V battery. A 200 Ω voltmeter is across the 200 Ω resistor. Voltmeter reading:

- A) 4 V B) 20/3 V C) 10 V D) 16 V Tests: Voltmeter loading effect in a series resistor circuit Answer: Not in extracted key

Q.6 (CUET 2024) Current through 4/3 Ω external resistance connected to two cells (2V,1Ω) and (1V,2Ω) in parallel is:

- A) 1 A B) 2/3 A C) 3/4 A D) 5/6 A Tests: Cells in parallel — equivalent EMF and current Answer: Not in extracted key

Q.7 (CUET 2024) A wire stretched so its radius becomes half. New resistance R′, resistivity ρ′, power rating P′:

- A) $\rho'=2\rho$, $R'=2R$, $P'=2P$ B) $\rho'=\rho/2$, $R'=R/2$, $P'=P/2$ C) $\rho'=\rho$, $R'=16R$, $P'=P/16$ D) $\rho'=\rho$, $R'=R/16$, $P'=16P$ Tests: Stretching a wire — R, ρ, P dependence (resistivity unchanged) Answer: Not in extracted key

Q.36 (CUET 2024) A metal wire is under constant potential difference. When temperature increases:

- A) Drift velocity increases, thermal velocity decreases B) Drift velocity decreases, thermal velocity decreases C) Drift velocity increases, thermal velocity increases D) Drift velocity decreases, thermal velocity increases Tests: Drift velocity vs thermal velocity with rising temperature Answer: Not in extracted key

Q.37 (CUET 2024) (From circuit diagram in the paper) The equivalent resistance between A and B is:

- A) 9 Ω B) 18 Ω C) 4 Ω D) 14 Ω Tests: Equivalent resistance of resistor network Answer: Not in extracted key

Q.38 (CUET 2024) A cell of emf 1.1 V and internal resistance 0.5 Ω is connected to 0.5 Ω wire. Another identical emf cell is added in series but current remains same. Internal resistance of second cell:

- A) 1 Ω B) 2.5 Ω C) 1.5 Ω D) 2 Ω Tests: Cells in series with same current — internal resistance Answer: Not in extracted key

Q.39 (CUET 2024) In Wheatstone bridge: P = 3 Ω Q = 3 Ω R = 3 Ω S = 4 Ω Resistance needed to shunt S for balance:

- A) 14 Ω B) 12 Ω C) 15 Ω D) 7 Ω Tests: Wheatstone bridge — shunt for balance Answer: Not in extracted key

Q.44 (CUET 2024) (From circuit diagram in the paper) Determine current in the circuit. Options provided in paper.

- (options not in extracted source — see official paper) Tests: Current in a DC circuit from given circuit diagram Answer: Not in extracted key

CUET 2023 — Actual PYQs from this chapter

Q.7 (CUET 2023) Kirchhoff's Second Law is based on the law of conservation of:

- A) Charge B) Energy C) Momentum D) Mass and energy Tests: Kirchhoff's laws — loop rule based on energy conservation Answer: Not in extracted key

Q.8 (CUET 2023) Identify the graph showing the temperature dependence of resistivity for a typical semiconductor.

- A) Linearly increasing graph B) Linearly decreasing graph C) Exponential decrease D) Exponential increase Tests: Temperature dependence of resistivity — semiconductors Answer: Not in extracted key

Q.9 (CUET 2023) In a potentiometer arrangement a cell of 1.5 V gives balance point at 45 cm. If the balance point shifts to 75 cm, the emf of second cell is:

- A) 2.5 V B) 1.0 V C) 1.1 V D) 1.5 V Tests: Potentiometer — comparison of EMFs from balancing lengths Answer: Not in extracted key

Q.10 (CUET 2023) A room heater rated 750 W, 220 V and a bulb rated 200 W, 220 V are connected in series with a 220 V supply. Power consumed by the bulb and heater respectively:

- A) 124.8 W, 124.8 W B) 33.25 W, 124.8 W C) 124.8 W, 33.25 W D) 33.25 W, 33.25 W Tests: Power dissipation in series combination of appliances Answer: Not in extracted key

Q.11 (CUET 2023) A cell of emf E and internal resistance r is connected to resistances R_1 and R_2. If power consumed is same in both cases, the internal resistance is:

- A) R1R2\sqrt{R_1R_2}R1 R2 B) R1R2R1+R2\frac{R_1R_2}{R_1+R_2}R1 +R2 R1 R2 C) R1+R2R_1+R_2R1 +R2 D) R1−R22\frac{R_1-R_2}{2}2R1 −R2 Tests: Maximum power transfer / internal resistance condition Answer: Not in extracted key

Q.47 (CUET 2023) For electrons mobility: A. decreases with increase in potential difference B. increases with increase in potential difference C. does not depend on potential difference D. decreases with temperature E. increases with temperature Options:

- A) A and E only B) B and E only C) C and D only D) C and E only Tests: Electron mobility — dependence on E-field/potential and temperature Answer: Not in extracted key