KSQUARE CAREER INSTITUTE

CURRENT ELECTRICITY

Class 12 Physics • Current, Drift Velocity, Resistance • NEET / JEE Notes

Scan to get all notes

Topics Covered

1. Electric current — average & instantaneous; current due to revolving charge
2. Drift velocity, relaxation time, mobility; relation with current
3. Current density
4. Resistance, V–I graph, resistivity; R in terms of n and τ
5. Stretching & compressing wires — shortcuts
6. Effect of temperature on resistivity; temperature coefficient
7. Added: Ohm's law, combinations, cells, Kirchhoff's laws, Wheatstone bridge, power — formula sheet

ELECTRIC CURRENT

Electric current

Rate of flow of electric charge. Direction of current = direction of flow of **positive** charge (opposite to electron flow).

Current is a **scalar** (it adds algebraically even though it has a direction).

Current

Average current: $I_{avg} = \Delta q/\Delta t \ (= q/t)$

Instantaneous current: $i = dq/dt$

Charge from current: $q = \int i\,dt$ = area under the i–t graph

Due to a revolving charge: $I = q\,f = e \times$ (revolutions per second)

Q1. A flow of 10^7 electrons per second in a conducting wire constitutes a current of **[1994]**

(a) 1.6×10^{-12} A
(b) 1.6×10^{26} A
(c) 1.6×10^{-26} A
(d) 1.6×10^{12} A

Answer: (a) — $I = ne/t = 10^7 \times 1.6 \times 10^{-19}$.

Q2. If $q = t^2 + 2t$, find (i) current at t = 2 s, (ii) average current from 0 to 2 s.

Answer: (i) 6 A (ii) 4 A — $i = dq/dt = 2t + 2 = 6$ A; $I_{avg} = q(2)/2 = 8/2 = 4$ A.

Q3. In a hydrogen atom the electron makes about 0.6×10^{16} revolutions per second. The average current at any point on the orbit is

(a) 0.36 mA
(b) 0.96 mA
(c) 0.60 mA
(d) 0.24 mA

Answer: (b) — $I = ef = 1.6 \times 10^{-19} \times 0.6 \times 10^{16} = 0.96 \times 10^{-3}$ A.

DRIFT VELOCITY

1. Metals have a large number of free electrons (**~10^{28} per m^3** = free-electron density n).
2. Without an electric field, free electrons move **randomly** due to thermal energy; average thermal velocity = **zero** ⇒ no net flow.
3. On applying a field (connecting a battery), each electron experiences a force **opposite to E**; acceleration **a = eE/m**.
4. Electrons frequently **collide** with positive ions and stop momentarily; acceleration acts only between collisions.
5. This gives a small average velocity opposite to E — the **drift velocity $v_d \approx 10^{-4}$ m/s**.

Drift velocity

$$v_d = a\,\tau = (eE/m)\,\tau \quad (\tau = \text{relaxation time, mean time between collisions})$$

$$E = V/l\,; \quad \text{energy gained between collisions} = eE\lambda \quad (\lambda = \text{mean free path})$$

Q4. The velocity of charge carriers of current (about 1 A) in a metal under normal conditions is of the order of **[1991]**

(a) a fraction of mm/s
(b) velocity of light
(c) several thousand m/s
(d) a few hundred m/s

Answer: (a) — $v_d \sim 10^{-4}$ m/s.

Q5. The mean free path of electrons in a metal is 4×10^{-8} m. The field that gives on average 2 eV energy to an electron is (V/m) **[2009]**

(a) 5×10^{-11}
(b) 8×10^{-11}
(c) 5×10^{7}
(d) 8×10^{7}

Answer: (c) — $eE\lambda = 2$ eV ⇒ $E = 2/(4 \times 10^{-8}) = 5 \times 10^{7}$ V/m.

Electron Mobility

- **Mobility (μ)** — ability of a charged particle to move through a medium in response to the electric field pulling it.

Mobility

$$\mu = v_d/E = e\tau/m \quad (\text{unit } m^2\,V^{-1}\,s^{-1})$$

Q6. A charged particle with drift velocity 7.5×10^{-4} m s^{-1} in a field of 3×10^{-10} V m^{-1} has a mobility (m^2 V^{-1} s^{-1}) of **[NEET 2020]**

(a) 2.5×10^{-6}
(b) 2.25×10^{-15}
(c) 2.25×10^{15}
(d) 2.5×10^{6}

Answer: (d) — $\mu = 7.5 \times 10^{-4} / 3 \times 10^{-10}$.

▸ Relation of Drift Velocity with Current

Current in terms of drift velocity

$$n = N/V = N/(A\,l) = \text{free-electron density}$$

$$I = n\,e\,A\,v_d$$

CURRENT DENSITY (J)

Definition

Current per unit area at a point, the area being **normal** to the direction of current: **J = I/A** (A m^{-2}).

J is a **vector** (along the current); current itself is a scalar. Also **J = nev$_d$ = σE**.

Q7. Under steady state, for a conductor that is narrower at A than at B,

(a) $J_A > J_B$
(b) $J_A < J_B$
(c) $J_A = J_B$
(d) Data insufficient

Answer: (a) — Same current I throughout; J = I/A is larger where the area is smaller.

ELECTRICAL RESISTANCE

Resistance

Ratio of potential difference across the conductor to the current through it: **R = V/I**; unit **ohm (Ω) = V/A**.

R does **not** depend on V and I; it depends on the **shape and size** of the conductor and the **material** (and temperature).

- **R = slope of the V–I graph** (for an ohmic conductor the slope is constant; for non-ohmic, **R = dV/dI** varies).
- Where current **decreases** while voltage increases, the slope dI/dV is negative ⇒ **negative resistance**.

Q8. From the I–V graph (A → B rising, B → C flat, C → D falling, D → E rising), the portion corresponding to negative resistance is **[1997]**

(a) CD
(b) DE
(c) AB
(d) BC

Answer: (a) — I decreases as V increases.

Resistance in Terms of Electron Density & Relaxation Time

Derivation

$$R = V/I = V/(n\,e\,A\,v_d)\,,\ v_d = eE\tau/m = eV\tau/(ml)$$

$$\Rightarrow\ R = m\,l\,/\,(n\,e^2\,\tau\,A)$$

Resistivity (Specific Resistance)

Resistivity

$$R = \rho\,l/A\,;\quad \rho = m/(n\,e^2\,\tau)\quad (\text{unit } \Omega\,m)$$

$$\text{Conductivity } \sigma = 1/\rho$$

- Resistivity is the resistance of a conductor of **unit length and unit cross-section**.
- ρ depends only on the **material and temperature**, **not on shape and size** (e.g. ρ of copper at 20 °C = 1.68×10^{-8} Ω m for any shape).

Q9. The resistance of an iron wire is R. If its length and radius are both doubled, **[2004]**

(a) R doubles, ρ halves
(b) R halves, ρ unchanged
(c) R halves, ρ doubles
(d) both unchanged

Answer: (b) — $R \propto l/r^2 \Rightarrow 2/4 = ½$.

Q10. Copper wires have masses in the ratio 1 : 3 : 5 and lengths 5 : 3 : 1. Their resistances are in the ratio **[1988]**

(a) 1 : 3 : 5
(b) 1 : 25 : 125
(c) 5 : 3 : 1
(d) 125 : 15 : 1

Answer: (d) — Volume = m/density, so $R = \rho l/A = \rho \times \text{density} \times l^2/m \Rightarrow R \propto l^2/m = 25 : 3 : 1/5 = 125 : 15 : 1$.

STRETCHING & COMPRESSING WIRES — SHORTCUTS

Volume (and mass) remain constant: A l = constant.

Shortcuts

$$R \propto l^2\quad (\text{stretched n times in length} \Rightarrow R' = n^2R)$$

$$R \propto 1/A^2\ \propto 1/r^4$$

$$\text{For small changes } (< 5\%):\ \Delta R/R = 2\,(\Delta l/l)$$

Q11. A wire of resistance R is stretched to double its length. The new resistance is

(a) R
(b) R/2
(c) 2R

(d) 4R

Answer: (d)

Q12. A wire of resistance R is melted and stretched to n times its original length. New resistance **[2017]**

(a) R/n
(b) n^2R
(c) R/n^2
(d) nR

Answer: (b)

Q13. A 4 Ω wire is stretched to twice its length. The new resistance is **[2013]**

(a) 2 Ω
(b) 4 Ω
(c) 8 Ω
(d) 16 Ω

Answer: (d)

Q14. A wire is stretched slowly by 10%. Its new resistance and specific resistance become **[2008]**

(a) both same
(b) 1.1×, 1.1×
(c) 1.2×, 1.1×
(d) 1.21×, same

Answer: (d) — $R'/R = (1.1)^2 = 1.21$; ρ is a material property.

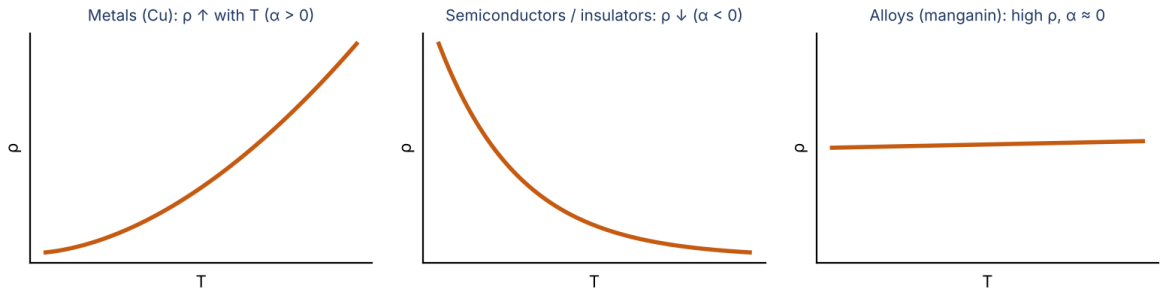
Q15. If a wire is stretched to increase its length by 1%, the change in resistance is

(a) 1%
(b) 2%
(c) 0.5%
(d) 1.5%

Answer: (b) — $\Delta R/R = 2\Delta l/l$ (valid only up to ~5%).

EFFECT OF TEMPERATURE ON RESISTIVITY

On increasing temperature — free-electron density n	On increasing temperature — relaxation time τ
More ionisation ⇒ number of free e^- increases ⇒ **n** ↑	Thermal speed ↑ ⇒ more frequent collisions ⇒ **τ** ↓



Material	What dominates	Result on heating
1. Metals / conductors	n is already very large (10^{28}–10^{29} m^{-3}), increase in n is not significant ⇒ **τ dominates**	τ ↓ ⇒ **ρ (and R) ↑**
2. Semiconductors (Si, Ge, carbon) & insulators	τ does not vary much ⇒ **n dominates**	n ↑ ⇒ **ρ (and R) ↓**
3. Alloys (nichrome, manganin, constantan)	Very small change	**High ρ, very low α** ⇒ used for standard resistors

Q16. Which graph represents the variation of resistivity ρ with temperature T for copper?

Answer: A curve rising with T (ρ increases, slightly non-linearly)

Q17. Specific resistance of a conductor increases with **[2002]**

(a) increase in temperature
(b) increase in cross-section area
(c) increase in cross-section and decrease in length
(d) decrease in cross-section area

Answer: (a)

Q18. Copper and silicon are cooled from 300 K to 60 K. The specific resistance **[2001]**

(a) decreases in Cu, increases in Si
(b) increases in Cu, decreases in Si
(c) increases in both
(d) decreases in both

Answer: (a)

▸ Temperature Coefficient of Resistance (α)

Temperature dependence

$$R_T = R_0 (1 + \alpha \Delta T) ; \quad \rho_T = \rho_0 (1 + \alpha \Delta T)$$

$$\alpha = (R_T - R_0) / (R_0 \Delta T) \quad (\text{unit } °C^{-1} \text{ or } K^{-1})$$

Q19. A copper coil has resistance 20.0 Ω at 0 °C and 26.4 Ω at 80 °C. The temperature coefficient of resistance is

(a) 2×10^{-3} °C^{-1}
(b) 4×10^{-3} °C^{-1}
(c) 6×10^{-3} °C^{-1}
(d) 8×10^{-3} °C^{-1}

Answer: (b) — $\alpha = 6.4/(20 \times 80) = 4 \times 10^{-3}$ °C^{-1}.

Material	α (°C^{-1})
Copper (conductor)	$+4 \times 10^{-3}$ (positive)
Silicon (semiconductor)	-7×10^{-2} (negative)
Carbon (graphite)	-5×10^{-4} (negative)

Material	α (°C⁻¹)
Manganin (alloy)	2×10^{-6} (very small)

BEYOND THE PDF — REST OF THE CHAPTER (ADDITIONAL TOPIC)

Topic	Key formula / fact
Ohm's law	V = IR (at constant temperature, for ohmic conductors); vector form J = σE
Series combination	$R_{eq} = R_1 + R_2 + \ldots$; same current
Parallel combination	$1/R_{eq} = 1/R_1 + 1/R_2 + \ldots$; same voltage
Cell: EMF & internal resistance	I = E/(R + r); terminal voltage V = E – Ir (discharging), V = E + Ir (charging)
Cells in series / parallel	Series: $E_{eq} = \Sigma E$, $r_{eq} = \Sigma r$; parallel (identical): $E_{eq} = E$, $r_{eq} = r/n$
Kirchhoff's junction law (KCL)	ΣI = 0 at a junction (conservation of charge)
Kirchhoff's loop law (KVL)	ΣΔV = 0 around a closed loop (conservation of energy)
Wheatstone bridge	Balanced when P/Q = R/S (no current through galvanometer)
Meter bridge	R/S = l/(100 – l)
Electrical power & energy	$P = VI = I^2R = V^2/R$; energy W = Pt; 1 kWh = 3.6×10^6 J

REVISION — FORMULA SHEET

1. $I_{avg} = \Delta q/\Delta t$; $i = dq/dt$; $q = \int i\,dt$ (area under i–t)
2. Revolving charge: I = q f
3. $v_d = a\tau = eE\tau/m$; $E = V/l$
4. Energy between collisions = eEλ
5. $\mu = v_d/E$
6. $I = n\,e\,A\,v_d$; $J = I/A = nev_d$ (direction of J = direction of I)
7. $R = V/I = dV/dI = \rho l/A = ml/(ne^2\tau A)$; $\rho = m/(ne^2\tau)$
8. Stretching: $R \propto l^2 \propto 1/A^2$; $\Delta R/R = 2\Delta l/l$ (small changes)
9. $R_T = R_o(1 + \alpha\Delta T)$

Physics = concepts + PYQs. Keep practising!

Ksquare Courses: https://ksquare.classx.co.in/new-courses/31?redirectToApp=true | Telegram: t.me/ksquareofficial