

CURRENT ELECTRICITY

1. ELECTRIC CURRENT

Electric current is the rate of flow of electric charge.

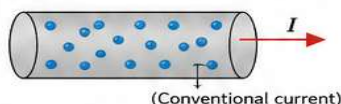
$$I = \frac{dQ}{dt} \quad (\text{Unit: ampere, A})$$

$$1 \text{ A} = 1 \text{ C s}^{-1}$$

Conventional current flows from higher potential to lower potential.

2. FLOW OF ELECTRIC CHARGES IN A METALLIC CONDUCTOR

In a metal, current is due to the flow of free electrons.



Electrons drift opposite to the conventional current.

3. DRIFT VELOCITY

Average velocity acquired by free electrons in a conductor due to the applied electric field.

$$v_d = \frac{I}{nAe}$$

where, n = number density of free electrons
 A = cross-sectional area
 e = charge of electron ($1.6 \times 10^{-19} \text{ C}$)

Direction of v_d is opposite to I .

4. MOBILITY AND ITS RELATION WITH CURRENT

Mobility (μ) is the drift velocity acquired per unit electric field.

$$\mu = \frac{v_d}{E} \quad (\text{Unit: m}^2 \text{ V}^{-1} \text{ s}^{-1})$$

Since $E = \frac{V}{\ell}$ and $I = nAev_d$

$$I = nAe\mu E = \frac{nAe\mu}{\ell} V$$

Current is directly proportional to potential difference (V) for a given conductor (Ohm's law).

Where,
 n = number density
 A = cross-sectional area
 e = charge of electron
 μ = mobility
 ℓ = length of conductor
 E = electric field
 V = potential difference

5. OHM'S LAW

At constant temperature, current through a conductor is directly proportional to the potential difference across it.

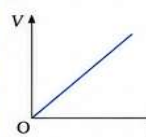
$$V = IR$$

where, R = resistance (ohm, Ω)

$$R = \frac{V}{I}$$

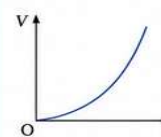
6. V-I CHARACTERISTICS

(a) Linear (Ohmic Conductor)



Straight line
 $(R = \text{constant})$

(b) Non-linear (Non-ohmic Conductor)



Curve
 $(R \neq \text{constant})$

7. ELECTRICAL ENERGY AND POWER

Electrical Energy (W)

Work done in time t :

$$W = VIt = I^2 Rt = \frac{V^2}{R} t$$

Unit: joule (J) or watt-hour (Wh)

Electrical Power (P)

Rate of doing work:

$$P = \frac{W}{t} = VI = I^2 R = \frac{V^2}{R}$$

Unit: watt (W)

8. RESISTIVITY AND CONDUCTIVITY

Resistivity (ρ)

$$R = \rho \frac{\ell}{A}$$

Unit: $\Omega \text{ m}$
 (Depends on material and temperature)

Conductivity (σ)

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

Unit: S m^{-1}
 (Siemens per meter)

Good conductors: high σ (low ρ)

9. TEMPERATURE DEPENDENCE OF RESISTANCE

For metals (approx.)

$$R_T = R_0 [1 + \alpha(T - T_0)]$$

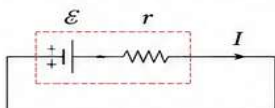
where,
 R_T = resistance at temperature T
 R_0 = resistance at reference temperature T_0
 α = temperature coefficient of resistance (K^{-1})

For semiconductors: Resistance decreases with increase in temperature.



10. INTERNAL RESISTANCE OF A CELL

A real cell has some resistance (r) inside it.



Terminal potential difference across R :

$$V = IR = \mathcal{E} - Ir$$

11. POTENTIAL DIFFERENCE AND EMF OF A CELL

Potential Difference (V)

Energy spent per unit charge between two points.

$$V = \frac{W}{q}$$

EMF ($\mathcal{E}$)

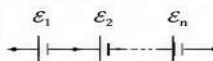
Energy supplied per unit charge by the cell (open circuit).

$$\mathcal{E} = \frac{W}{q}$$

For a cell delivering current: $\mathcal{E} = V + Ir$

12. COMBINATION OF CELLS

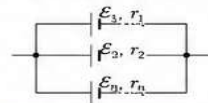
(a) Series Combination



$$\mathcal{E}_{eq} = \mathcal{E}_1 + \mathcal{E}_2 + \dots + \mathcal{E}_n$$

$$r_{eq} = r_1 + r_2 + \dots + r_n$$

(b) Parallel Combination



$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \dots + \frac{1}{r_n}$$

(If cells are identical: $\mathcal{E}_{eq} = \mathcal{E}$, $r_{eq} = \frac{r}{n}$)

13. KIRCHHOFF'S RULES

(a) Junction Rule (KCL)

Algebraic sum of currents at a junction is zero.

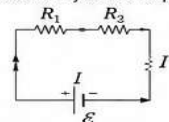


$$I_1 + I_2 = I_3 + I_4$$

$$(\text{or } \sum I = 0)$$

(b) Loop Rule (KVL)

Algebraic sum of potential differences around any closed loop is zero.

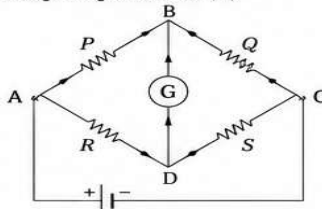


$$\sum (\pm IR) + \sum (\pm \mathcal{E}) = 0$$

$$(\text{or } \sum V = 0)$$

14. WHEATSTONE BRIDGE

A bridge is balanced when no current flows through the galvanometer (G).



Balance condition:

$$\frac{P}{Q} = \frac{R}{S} \quad \text{or} \quad PS = QR$$

Symbols Used

I : Current (A)
 V : Potential difference (V)
 R : Resistance (Ω)
 r : Internal resistance (Ω)
 $\mathcal{E}$: EMF (V)
 ρ : Resistivity ($\Omega \text{ m}$)
 σ : Conductivity (S m^{-1})
 μ : Mobility ($\text{m}^2 \text{ V}^{-1} \text{ s}^{-1}$)
 v_d : Drift velocity (m s^{-1})
 A : Area (m^2)
 n : Number density (m^{-3})
 e : Charge of electron (C)
 ℓ : Length (m)
 T : Temperature (K)

Key Units

Current : ampere (A)
 Charge : coulomb (C)
 Potential : volt (V)
 Resistance : ohm (Ω)
 Energy : joule (J)
 Power : watt (W)
 Resistivity : $\Omega \text{ m}$
 Conductivity : S m^{-1}

Note

All relations are for steady current and uniform conductors unless stated.

MULTIPLE CHOICE QUESTIONS

For Aspiring DOCTORS

1. In a metallic conductor, if the length is doubled keeping the cross-section and applied voltage constant, the drift velocity: [NEET 2025]
 (a) Doubles (b) Halves (c) Remains same (d) Becomes four times
2. A wire obeys Ohm's law. If the current through it is tripled, the resistance: [AIIMS 2024]
 (a) Triples (b) Reduces to one-third (c) Remains the same (d) Increases nine times
3. The resistivity of silver at 20°C is $1.6 \times 10^{-8} \Omega \cdot \text{m}$. A silver wire of length 2 m and radius 1 mm has resistance approximately: [NEET 2025]
 (a) 0.010Ω (b) 0.020Ω (c) 0.032Ω (d) 0.064Ω
4. When n identical resistors of resistance R are connected in series and then separately in parallel, the ratio of power consumed (series: parallel) for the same supply voltage is: [AIIMS]
 (a) $1: n^2$ (b) $n^2: 1$ (c) $1: n$ (d) $n: 1$
5. In a meter bridge, if P and Q (the ratio arms) are interchanged and the null point shifts from 40 cm to 60 cm. This confirms: [NEET 2023]
 (a) $P = Q$ (b) $P = 3Q/2$ (c) $P/Q = 2/3$ (d) The bridge is faulty

For Aspiring ENGINEERS

6. The drift velocity of electrons for a conductor connected to a battery is v . If the radius and length of the conductor are both doubled, keeping the voltage constant, the new drift velocity will be: [JEE Main 2023]
 (a) $v/2$ (b) v (c) $2v$ (d) $v/4$
7. A copper wire has a resistance of 10Ω at 0°C . If the temperature coefficient of resistance is $4 \times 10^{-3} / ^{\circ}\text{C}$, its resistance at 100°C will be: [JEE Main 2022]
 (a) 12Ω (b) 14Ω (c) 16Ω (d) 20Ω
8. Two cells of emf 2V and 4V and internal resistance 1Ω and 2Ω respectively are connected in parallel. The equivalent emf is: [JEE Main 2024]
 (a) 3V (b) 2.67V (c) 2.5V (d) 2V
9. The voltage and current between points A and B shown in the circuit are [JEE Main 2026]

- (a) 24V, 12A (b) 24V, 4A (c) 18V, 12A (d) 27V, 4A

10. Two cells of emfs 1V and 2V and internal resistance 2Ω and 1Ω , respectively connected in parallel, gave current of 1A through an external resistance. If the polarity of one cell is reversed, then value of current through the external resistance will be $\frac{\alpha}{5}$ A. The value of α is [JEE Main 2026]

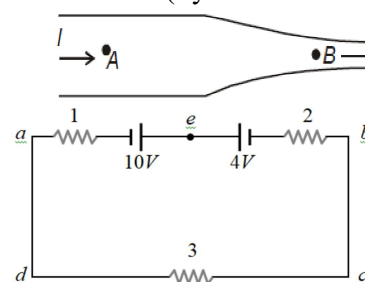
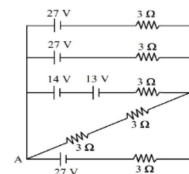
- (a) 3 (b) 2 (c) 1 (d) 4

11. Figure shows a current carrying conductor of non-uniform cross section. Current I is flowing from left to right as shown. Which of the following relation is correct? (Symbols have usual meaning)

- (a) $\sigma_A = \sigma_B$ (b) $E_A < E_B$ (c) $v_{dA} < v_{dB}$ (d) All of these

12. The magnitude and direction of the current in the circuit shown will be

- (a) $\frac{7}{3}A$ from a to b through e (b) $\frac{7}{3}A$ from b to a through e
 (c) $1A$ from b to a through e (d) $1A$ from a to b through e

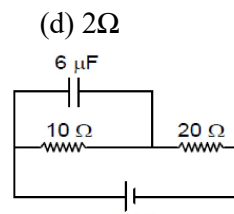


13. Two identical cells send the same current in 2 ohm resistance, whether connected in series or in parallel. The internal resistance of the cell should be

- (a) 0 (b) 0.5Ω (c) 1.5Ω (d) 2Ω

14. The charge on the shown capacitor in steady state is

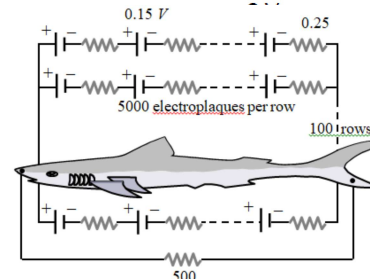
- (a) $4\mu\text{C}$ (b) $8\mu\text{C}$ (c) $12\mu\text{C}$ (d) Zero



15. Cells are able to generate current with biological cells called electro

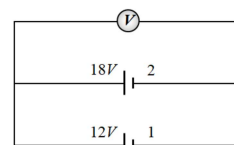
plaques. The electro plaques in an eel are arranged in 100 rows, each row stretching horizontally along the body of the fish containing 5000 electro plaques. The arrangement is suggestively shown below. Each electro plaques has an emf of 0.15 V and internal resistance of 0.25Ω . The water surrounding the eel completes a circuit between the head and its tail. If the water surrounding it has a resistance of 500Ω , the current an eel can produce in water is about

- (a) 1.5 A (b) 3.0 A (c) 15 A (d) 30 A



16. Two batteries, one of emf 18 volts and internal resistance 2Ω and the other of emf 12 volt and internal resistance 1Ω , are connected as shown. The voltmeter V will record a reading of

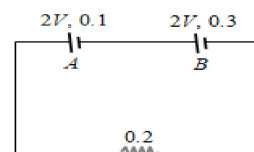
- (a) 15 volt (b) 30 volt (c) 14 volt (d) 18 volt



17. The internal resistances of two cells shown are 0.1Ω and 0.3Ω .

If $R = 0.2\Omega$, the potential difference across the cell

- (a) B will be zero (b) A will be zero
(c) A and B will be 2 V (d) A will be $> 2\text{ V}$ and B will be $< 2\text{ V}$

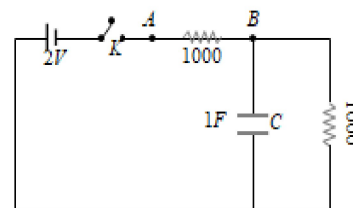


18. In Wheatstone's bridge $P = 9\Omega$, $Q = 11\Omega$, $R = 4\Omega$ and $S = 6\Omega$. How much resistance must be put in parallel to the resistance S to balance the bridge

- (a) 24Ω (b) $\frac{44}{9}\Omega$ (c) 26.4Ω (d) 18.7Ω

19. When the key K is pressed at time $t = 0$, which of the following statements about the current I in the resistor AB of the given circuit is true

- (a) $I = 2\text{ mA}$ at all t (b) I oscillates between 1 mA and 2 mA
(c) $I = 1\text{ mA}$ at all t
(d) At $t = 0$, $I = 2\text{ mA}$ and with time it goes to 1 mA



20. Masses of 3 wires of same metal are in the ratio 1 : 2 : 3 and their lengths are in the ratio 3 : 2 : 1. The electrical resistances are in ratio

- (a) 1 : 4 : 9 (b) 9 : 4 : 1 (c) 1 : 2 : 3 (d) 27 : 6 : 1

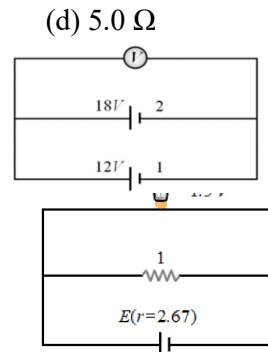
ANSWERS (MULTIPLE CHOICE QUESTIONS)

- (b) $E = V/L$. Doubling L halves E . $v_d = eE\tau/m \propto E \rightarrow v_d$ halves.
- (c) For an ohmic wire, $R = V/I$ is constant (independent of I or V). Resistance doesn't change.
- (a) $R_T = 10(1 + 4 \times 10^{-3} \times 75) = 10(1 + 0.3) = 10 \times 1.3 = 13\Omega$.
- (a) $P_{\text{series}} = V^2/(nR)$; $P_{\text{parallel}} = V^2/(R/n) = nV^2/R$. Ratio = $(V^2/nR)/(nV^2/R) = 1/n^2$.
- (c) Initially $l = 40\text{ cm}$: $P/Q = 40/60 = 2/3$. After swap $l = 60\text{ cm}$: $Q/P = 60/40 \rightarrow P/Q$ still $2/3$.

6. (a) $v/2$, $v_d = eE\tau/m = eV\tau/(mL)$. Since L is doubled ($2L$), v_d becomes $v/2$. Radius change doesn't affect v_d if V and L are considered, though it affects current.
7. (b) $14\ \Omega$, Explanation: $R = R_0(1 + \alpha\Delta T) = 10(1 + 4 \times 10^{-3} \times 100) = 10(1 + 0.4) = 14\ \Omega$.
8. (b) $2.67V$, $\epsilon_{eq} = (\epsilon_1/r_1 + \epsilon_2/r_2) / (1/r_1 + 1/r_2) = (2/1 + 4/2) / (1/1 + 1/2) = (2+2)/(1.5) = 4/1.5 = 8/3 = 2.67V$.
9. (b) $24V$, $E_{eq} = 27V$ and $R_{eq} = 3/4\Omega$, $I_{AB} = \frac{27}{6+3/4} A$, $V_{AB} = 4 \times 6 = 24V$
10. (a) 3
11. (d) All of these
12. (d) Applying Kirchhoff's voltage law
- $-1 \times i + 10 - 4 - 2 \times i - 3i = 0 \Rightarrow i = 1A$ (a to b via e). $\therefore$ Current $= \frac{V}{R} = \frac{10-4}{6} = 1.0A$
13. (d) In series, $i_1 = \frac{2E}{2+2r}$
In parallel, $I_2 = \frac{E}{2+\frac{r}{2}} = \frac{2E}{4+r}$, Since $i_1 = i_2 \Rightarrow \frac{2E}{4+r} = \frac{2E}{2+2r} \Rightarrow r = 2\Omega$
14. (a) Potential Difference across capacitor $= 2/3 V$, $Q = CV$ so $Q = 4\ \mu C$
- 15 (a) given problem is the case of mixed grouping of cells $I = \frac{nE}{R + \frac{nr}{m}}$, so total current produced.
Here $m=100$, $n=5000$, $R=500\Omega$. $E=0.15 V$ and $r=0.25\ \Omega$, $i = \frac{5000 \times 0.15}{500 + \frac{5000 \times 0.25}{100}} = 1.5A$
- 16 (c) Reading of voltmeter, $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = (18 \times 1 + 12 \times 2) / (1 + 2) = 14 V$
- 17 (a) Applying Kirchhoff law, $(2 + 2) = (0.1 + 0.3 + 0.2)i \Rightarrow i = \frac{20}{3} A$, Hence potential difference across $A = 2 - 0.1 \times \frac{20}{3} = \frac{4}{3} V$ (less than $2V$), Potential difference across $B = 0$
- 18 (c) $\frac{P}{Q} = \frac{R}{S'}$ (For balancing bridge $\Rightarrow S' = \frac{4 \times 11}{9} = \frac{44}{9} \Rightarrow \frac{1}{S'} = \frac{1}{r} + \frac{1}{6} \Rightarrow \frac{9}{44} - \frac{1}{6} = \frac{1}{r} \Rightarrow r = 26.4\Omega$
- 19 (d) At time $t = 0$ i.e. when capacitor is charging, current $i = \frac{2}{1000} = 2mA$
When capacitor is full charged, no current will pass through it, hence the current through the circuit $i = \frac{2}{2000} = 1mA$
- 20 (d) $27:6:1$ as $R \propto \frac{l^2}{m}$

EXERCISE QUESTIONS

1. A $50V$ battery is connected across a $10\ \Omega$ resistor. The current is $4.5 A$. The internal resistance of the battery is
(a) Zero (b) $0.5\ \Omega$ (c) $1.1\ \Omega$ (d) $5.0\ \Omega$
2. Two batteries, one of emf $18\ volts$ and internal resistance $2\ \Omega$ and the other of emf $12\ volt$ and internal resistance $1\ \Omega$ are connected as shown. The voltmeter V will record a reading of
(a) $15\ volt$ (b) $30\ volt$ (c) $14\ volt$ (d) $18\ volt$
3. The magnitude and direction of the current in the circuit shown will be
(a) $\frac{7}{3}A$ from a to b through e (b) $\frac{7}{3}A$ from b to a through e



- (c) 1 A from b to a through e (d) 1 A from a to b through e

4. A torch bulb rated as 4.5 W , 1.5 V is connected as shown in the figure.

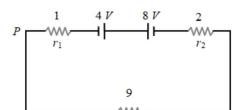
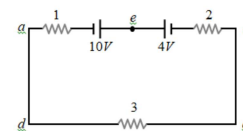
The *e.m.f.* of the cell needed to make the bulb glow at full intensity is

- (a) 4.5 V (b) 1.5 V (c) 2.67 V (d) 13.5 V

5. Two batteries of e.m.f. 4 V and 8 V with internal resistances $1\ \Omega$ and $2\ \Omega$ are connected in a circuit with a resistance of $9\ \Omega$ as shown in figure.

The current and potential difference between the points P and Q are

- (a) $\frac{1}{3}\text{ A}$, 3 V (b) $\frac{1}{6}\text{ A}$, 4 V (c) $\frac{1}{9}\text{ A}$, 9 V (d) $\frac{1}{2}\text{ A}$, 12 V



ANSWERS (EXERCISE QUESTIONS)

1. (c) 2. (c) 3. (d) 4. (d) 5. (d)

ASSERTION & REASON QUESTIONS

Read the assertion and reason carefully to mark the correct option given below

- (a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
 (b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
 (c) If assertion is true but reason is false.
 (d) If the assertion and reason both are false.

1. Assertion (A): Drift velocity of electrons in a conductor increases when the temperature of the conductor is increased, keeping the potential difference constant.

Reason (R): At higher temperatures, the relaxation time of electrons decreases due to increased lattice vibrations. [NEET 2017]

2. Assertion (A): The current density J in a conductor depends on both the magnitude and direction of the electric field E .

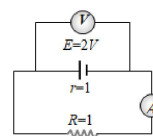
Reason (R): Current density is a vector quantity defined as $J = \sigma E$, where σ is the electrical conductivity. [AIIMS 2020]

3. Assertion: The temperature coefficient of resistance is positive for metals and negative for semiconductor.

Reason: The effective charge carriers in metals are negatively charged whereas in semiconductor they are positively charged.

4. Assertion: In the following circuit emf is 2 V and internal resistance of the cell is $1\ \Omega$ and $R = 1\ \Omega$, then reading of the voltmeter is 1 V .

Reason: $V = E - ir$ where $E = 2\text{ V}$, $i = \frac{2}{2} = 1\text{ A}$ and $R = 1\ \Omega$



5. Assertion (A): The resistivity of all materials is temperature-independent. [AIIMS 2020]

Reason (R): Resistivity depends only on the type of material, not on its dimensions.

6. Assertion: Electric appliances with metallic body have three connections, whereas an electric bulb has a two pin connection.

Reason: Three pin connections reduce heating of connecting wires.

7. Assertion: The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.

Reason: On increasing temperature, conductivity of metallic wire decreases.

8. Assertion (A): When a wire of resistance R is cut into n equal pieces and all are connected in parallel, the new resistance is R/n^2 .

Reason (R): Each piece has resistance R/n . When n such pieces are in parallel, equivalent resistance $= (R/n)/n = R/n^2$. [NEET 2023]

Assertion: The electric bulbs glow immediately when switch is on.

Reason: The drift velocity of electrons in a metallic wire is very high.

9. Assertion: Bending a wire does not affect electrical resistance.

Reason: Resistance of wire is proportional to resistivity of material.

10. Assertion: In meter bridge experiment, a high resistance is always connected in series with a galvanometer. **Reason:** As resistance increases current through the circuit increases.

ANSWERS (ASSERTION & REASON QUESTIONS)

1. (d) Explanation: Assertion is WRONG: drift velocity decreases at higher T because $v_d = \frac{eE\tau}{m}$ and τ decreases.
2. (a) Explanation: Both statements are correct. $J = \sigma E$ is a vector relation — J is in the direction of E (for isotropic conductors), and σ is the proportionality constant.
3. (b) The temperature co-efficient of resistance for metal is positive and that for semiconductor is negative. In metals free electrons (negative charge) are charge carriers while in P -type semiconductors, holes (positive charge) are majority charge carriers.
4. (a) Here, $E = 2V$, $1 = \frac{2}{2} = 1A$ and $r = 1\Omega$. Therefore, $V = E - ir = 2 - 1 \times 1 = 1V$
5. (d) (6) (c) (7) (b) (8) (a) (9) (a) (10) (c)

EXERCISE-- ASSERTION & REASON

1. **Assertion:** Voltmeter measures current more accurately than ammeter.
Reason: Relative error will be small if measured from voltmeter.
2. **Assertion :** Electric field outside the conducting wire which carries a constant current is zero.
Reason: Net charge on conducting wire is zero.
3. **Assertion:** The resistance of super-conductor is zero.
Reason: The super-conductors are used for the transmission of electric power.
4. **Assertion:** Each bulb in a frill of 20 bulbs in series when connected to supply voltage will emit more light than each bulb in frill of 19 bulbs in series when connected to same supply voltage.
Reason: Each bulb in a frill of 20 bulbs in series will get less voltage than that in frill of 19 bulbs.
5. **Assertion :** Kirchhoff's voltage law indicates that electro static field is conservative.
Reason: Potential difference between two points in a circuit does not depend on path.

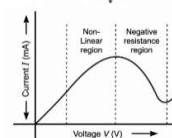
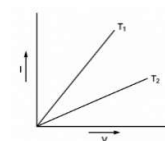
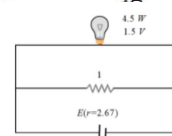
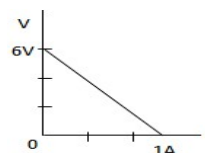
ANSWERS (EXERCISE-- ASSERTION & REASON)

1. (a) 2. (a) 3. (b) 4. (d) 5. (a)

VERY SHORT ANSWER TYPE QUESTIONS

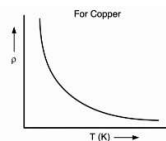
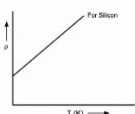
1. Plot a graph showing variation of current versus voltage for the material GaAs.
2. Two materials Si and Cu, are cooled from 300 K to 60 K. What will be the effect on their resistivity?
3. A cell of emf (E) and internal resistance (r) is connected across a variable external resistance (R). Plot graphs to show variation of (i) E with R , (ii) Terminal p.d. of the cell (V) with R .
4. A p.d. of V volts is applied to a conductor of length L and diameter D . How will the drift velocity of e 's and the resistance of the conductor change when (i) V is doubled (ii) L is halved and (iii) D is halved, where in each case, the other two factors remain same. Give reason.
5. Two wires, one of copper and the other of manganin, have same resistance and equal thickness. Which wire is longer? Justify your answer.

6. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is as shown below. What is the emf of each cell?
7. Why are alloys used for making standard resistance coils?
8. A torch bulb rated as 4.5 W , 1.5 V is connected as shown in the figure. The *e.m.f.* of the cell needed to make the bulb glow at full intensity?
9. The amount of electric charge passing through a cross-section of wire in time t is $Q(t) = At^2 + Bt + C$. Where A , B and C are constants having values 5 , 4 and 1 respectively. Calculate the electric current at $t = 4\text{ s}$.
10. $I - V$ graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in the figure. Which of the two temperatures is lower and why?

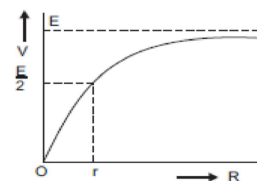


ANSWERS (VERY SHORT ANSWER TYPE QUESTIONS)

1. The variation of electric current with applied voltage for GaAs is as
2. In silicon, the resistivity increases In copper, the resistivity decreases



3. (i) The emf E of a cell is independent of external resistance (R). (ii) The terminal p.d. $V = IR = \frac{E}{r+R} R = \frac{E}{1+\frac{r}{R}}$. On increasing R , V increases. When $R = 0$, $V \rightarrow 0$. When $R = r$, $V = \frac{E}{2}$. When $R \rightarrow \infty$, $V = E$.



$$4. V_d = \frac{eE}{m}\tau = \frac{eV}{ml}\tau \quad \text{and} \quad R = \rho \frac{l}{A} = \rho \frac{l}{\pi D^2}$$

(i) When V is doubled, V_d becomes double and R remains unchanged.

(ii) When l is halved, V_d becomes double and R becomes halved

(iii) When D is halved, V_d remains unchanged and R becomes $4R$.

5. Copper, $R = \frac{\rho l}{A}$, $\rho l = \text{Const.}$

6. Let E be emf of each cell and r be the total internal resistance of circuit. The equation of terminal potential difference $V = 3E - Ir$(1)

At $V = 6V$, $I = 0$. Therefore from eq (1), $6 = 3E - 0 \Rightarrow E = 2V$

7. Alloys like Manganin and Constantan are used to make standard resistance coils because of their high resistivity and low temperature coefficient of resistance. This makes their resistance relatively stable and predictable over a range of temperatures, which is crucial for accurate measurements. Additionally, alloys are generally less susceptible to corrosion than pure metals, ensuring the longevity of the resistance coils.

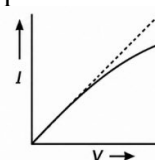
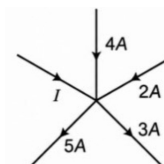
8. Current in the bulb $= \frac{P}{V} = \frac{4.5}{1.5} = 3A$, Current in $1\ \Omega$ resistance $= \frac{1.5}{1} = 1.5A$, Hence total current from the cell $i = 3 + 1.5 = 4.5A$, By using $E = V + ir \Rightarrow E = 1.5 + 4.5 \times (2.67) = 13.5V$

9. $I = \frac{dQ}{dt}$, $I = 2At + B$, $I = 44\text{ A}$

10. If a constant current I flows through the conductor, resistance at temperature T_1 and T_2 is $R_2 > R_1$

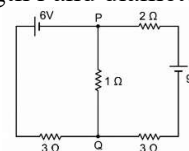
EXERCISE QUESTIONS

- Current of 4.8 amperes is flowing through a conductor. Find the number of electrons per second.
- When the current i is flowing through a conductor, the drift velocity is v . If $2i$ current is flowed through the same metal but having double the area of cross-section, then find the drift velocity.
- What is the value of I in the given current distribution?
- Current is allowed to flow in a metallic wire at a constant potential difference. When the wire becomes hot, cold water is poured on half of its portion. By doing so, its other half portion becomes still more hot. Explain its reason.
- The I-V characteristics of a resistor are observed to deviate from a straight line for higher values of current as shown in the adjoining figure why?

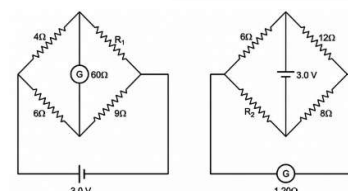


SHORT ANSWER TYPE QUESTIONS

- A potential difference V is applied across the ends of copper wire of length l and diameter D . What is the effect on drift velocity of electrons if (i) V is halved (ii) l is doubled (iii) D is halved

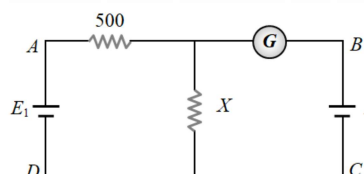


- Find the magnitude and direction of current in 1Ω resistor in the given circuit.



- Figure shows two circuits each having a galvanometer and a battery of 3V. When the galvanometers in each arrangement do not show any deflection, obtain the ratio R_1/R_2 ?

- In the adjoining circuit, the battery E_1 has an *e.m.f.* of 12volt and zero internal resistance while the battery E has an *e.m.f.* of 2volt. If the galvanometer G reads zero, then find the value of the resistance X in ohm?



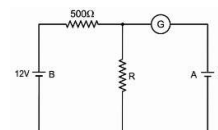
- Plot a graph showing temperature dependence of resistivity for a typical semiconductor. How is this behavior explained?

- Answer the following:

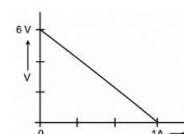
- Why are the connections between the resistors in a meter bridge made of thick copper strips?
- Why is it generally preferred to obtain the balance point in the middle of the meter bridge wire?

- Which material is used for the meter bridge wire and why?

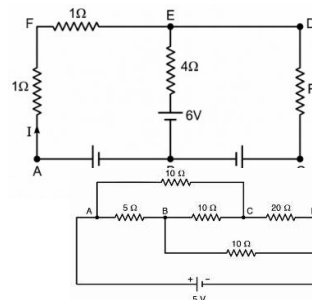
- In the circuit shown in the figure, the galvanometer 'G' gives zero deflection. If the batteries A and B have negligible internal resistance, find the value of the resistor R ?



- The plot of the variation of potential difference across a combination of three identical cells in series, versus current is shown alongside. What is the emf and internal resistance of each cell?



9. Using Kirchoff's rules determine the value of unknown resistance R in the circuit so that no current flows through 4Ω resistance. Also find the potential difference between A and D?



10. Calculate the value of the current drawn from a 5 V battery in the circuit as shown.

ANSWERS (SHORT ANSWER TYPE QUESTIONS)

$$1. \quad v_d = \frac{I}{ne} = \frac{V/R}{ne} = \frac{V}{ne \left(\frac{\rho L}{A} \right)}$$

(i) V is halved then drift velocity is halved (ii) l is doubled then drift velocity is halved

(iii) Drift velocity is independent of D

2. Use Kirchhoff's laws to make equations, After solving the equations

$$I_1 = -1.2A$$

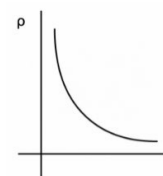
3. Sol. For balanced Wheatstone bridge, if no current flows through the galvanometer

$$\frac{4}{6} = \frac{R_1}{9} \text{ So, } R_1 = 6\Omega \text{ and } \frac{6}{R_2} = \frac{12}{8} \text{ so } R_2 = 4\Omega, \text{ Hence } R_1/R_2 = 6/4 = 3/2$$

4. For no current through galvanometer, we have, $\left(\frac{E_1}{500+X} \right) X = E \Rightarrow \left(\frac{12}{500+X} \right) X = 2 \Rightarrow X = 100 \Omega$

5. The resistivity of a typical semiconductor (carbon) decreases with increase of temperature. The graph is shown in figure.

Explanation: In semiconductor the number density of free electrons (n) increases with increase in temperature (T) and consequently the relaxation period decreases. But the effect of increase in n has higher impact than decrease of τ . So, resistivity decreases with increase in temperature.



6. (i) A thick copper strip offers a negligible resistance, so does not alter the value of resistances used in the meter bridge.

(ii) If the balance point is taken in the middle, it is done to minimise the percentage error in calculating the value of unknown resistance.

(iii) Generally alloys magnin/constantan/nichrome are used in Meter Bridge, because these materials have low temperature coefficient of resistivity.

7. If galvanometer G gives zero deflection, then current of source of 12 V flows through R, and voltage across R becomes 2 V. Current in the circuit is

$$I = \frac{12}{500 + R}$$

$$\text{And } V = IR, \left(\frac{12}{500+R} \right) R = 2 \text{ Solving } R = 100\Omega$$

8. We know that for a circuit

$$V = E_{eq} - I R_{eq}$$

From graph, when $I=0$ A, then $V=6$ V and $I=1$ A, then $V=0$ V. Putting in equation and solving $E_{eq} = 6$ V and $R_{eq} = 2 \Omega$, Hence emf of each cell = 2V. Resistance of each cell = 2Ω

9. Applying Kirchhoff's loop rule for loop ABEFA, $-9 + 6 + 4 \times 0 + 2I = 0$, $I = 1.5$ A ...(i)

For loop BCDEB, $3 + IR + 4 \times 0 - 6 = 0$, $\therefore IR = 3$

Putting the value of I from (i) we have

$$1.5 \times R = 3 \text{ so } R = 2 \Omega$$

Potential diff. between A and D through path ABCD

$$9 - 3 - IR = V_{AD} \quad 9 - 3 - 1.5 \times 2 = V_{AD} \text{ so } V_{AD} = 3V$$

10. it is a balanced wheatstone bridge

Find equivalent resistance and hence find current $I = 0.5 \text{ A}$

LONG ANSWER TYPE QUESTIONS

1. (i) Answer the following giving reason:

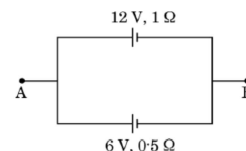
(I) The electron drift speed is estimated to be only a few mm/s for currents in the range of a few amperes. How, then, is the current established almost the instant a circuit is closed?

(II) A large voltage supply from which one needs high currents must have very low internal resistance. Why?

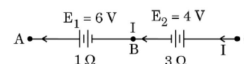
(III) The assertion that $V = IR$ is a statement of Ohm's Law is not true. Why?

(ii) Two cells of emf 12 V and 6 V are connected in parallel as shown in figure. Their internal resistance are 1Ω and 0.5Ω respectively. Calculate the emf and internal resistance of the equivalent cell between points A and B

[CBSE 2026]



2. (a) In the given figure, a steady current I flows through the circuit when points A and C are connected by a wire of negligible resistance. Find the potential difference between B and C. [CBSE 2026]



(b) A battery of emf 21 V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 3 A, find:

(i) Resistance of the resistor. (ii) The terminal voltage of the battery.

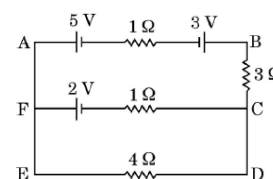
3. (a) An electric field E is established across the ends of a cylindrical conductor of length L and area of cross section A . Discuss how electrons attain the average velocity, independent of time. Hence, obtain a relation between current in the conductor and this 'average velocity' of electrons.

(b) (i) The electron drift speed is estimated to be only a few mm/s for currents in the range of a few amperes. How, then, is the current established almost the instant a circuit is closed?

(ii) Two copper wires having their radii in the ratio of 3:2 are connected in series across a battery. Find the ratio of the drift velocities of the electrons in the wire.

4. (a) State Kirchhoff's rules. Using these rules, find the current flowing through branch FC in the given circuit

[CBSE 2026]

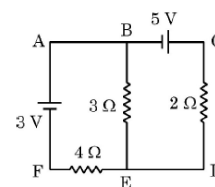


(b) Establish the relation between drift velocity of the electrons (v_d) and electric current (I) in the conductor.

5. (i) (a) Explain the statement: "Current is a scalar although we represent current with an arrow".

(b) Use Kirchhoff's rules to find the current flowing through 3Ω resistor in the circuit shown in the figure.

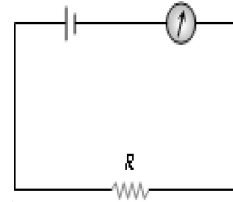
(ii) How is v_d affected when the length of the conductor is doubled, keeping the voltage applied across the conductor constant?



CASE STUDY BASED QUESTIONS

1. Read the following paragraphs and answer the questions that follow.

Whenever an electric current is passed through a conductor, it becomes hot after some time. The Phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit the energy expended by the source entirely appears as heat. But if the



circuit has an active element like a motor, then a part of the energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating form the basis of various electrical appliances such as electric bulb, electric furnace, electric press etc

- I. Alloys used for making standard resistance coils as alloys
 - (a) have more conductivity
 - (b) less conductivity
 - (c) less temperature coefficient of resistivity
 - (d) more temperature coefficient of resistivity
 - II. Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Wire which gets heated up more is
 - (a) Nichrome
 - (b) copper
 - (c) both gets heated up to same values
 - (d) can't say
 - III. A 25 W and 100 W are joined in series and connected to the mains. The bulb which will glow brighter is
 - (a) 25W as it has high resistance
 - (b) 100 W as it has high resistance
 - (c) 25W as it has low resistance
 - (d) 100 W as it has low resistance
 - IV. The heat emitted by an iron of 100 W in 1 minute is
 - (a) 600J
 - (b) 6000J
 - (c) 60J
 - (d) 60000J
2. When electric field is applied across a conductor then the electrons move in the direction opposite to the electric field due to electric force on them. The average velocity with which free electrons get drifted in the direction opposite to the applied electric field inside a conductor is called drift velocity. This motion of the electrons in the direction opposite to the electric field is superimposed on their random motion. Drift velocity depends on electric field applied, the nature of material and temperature. On increasing the temperature, relaxation time decreases. Hence decrease in relaxation time, due to increase in temperature, will reduce the drift speed.
- I. When a potential difference V be applied across a cylindrical conductor of length L and radius R , is doubled then the drift velocity of electrons gets:
 - (a) doubled
 - (b) four times
 - (c) remain same
 - (d) halved
 - II. Two wires made of same material but of different diameters are connected in series in a circuit. The current flows in the combination of wires. When the current flows from the wire with larger diameter to the one with smaller diameter then drift velocity of electrons:
 - (a) will decrease
 - (b) will increase
 - (c) remains same
 - (d) first will increase and after some time decrease
 - III. Two wires each of radius of cross section r but of different materials are connected together end to end (in series). If the densities of charge carriers in the two wires are in the ratio 1:4, the drift velocity of electrons in the two wires will be in the ratio:
 - (a) 1 : 2
 - (b) 2 : 1
 - (c) 4 : 1
 - (d) 1 : 4

- IV. A current I flows through a uniform wire of diameter d when the electron drift velocity is v . The same current will flow through a wire of diameter $d/2$ made of the same material if the drift velocity of the electrons is
 (a) $v/4$ (b) $v/2$ (c) $2v$ (d) $4v$
3. When the electric cell (source of EMF) is in a closed circuit, the current flows through the circuit. There is a fall of potential across the internal resistance of the cell. The terminal potential difference between the two electrodes of the cell becomes less than the EMF of the cell by an amount equal to the potential drop across the internal resistance of the cell. Thus, in a closed circuit the terminal potential difference of a cell is always less than the EMF of the cell.
- I. EMF of a cell is independent of:
 (a) size of the electrodes (b) quantity of electrolyte present in the cell
 (c) distance between the electrodes (d) all of these
- II. Three cells of EMF, 2.0 V, 2.5 V and 3.0 V are connected in series. Their internal resistances are $0.20\ \Omega$, $0.20\ \Omega$ and $0.15\ \Omega$ respectively. The battery is connected to an external resistor of $6.5\ \Omega$ wire a very low resistance ammeter, what would be the reading of ammeter?
 (a) $1.1\ \Omega$ (b) $1\ \Omega$ (c) $2\ \Omega$ (d) $2.1\ \Omega$
- III. A cell of emf E and internal resistance r is connected in series with an external resistance ' nr '. Then ratio of terminal potential difference to emf is:
 (a) $1/n$ (b) $1/(n+1)$ (c) $n/(n+1)$ (d) $(n+1)/n$
- IV. In an experiment a student measures terminal potential difference (TPD) of a cell. When the same cell is connected to an external resistance of $5\ \Omega$ then the TPD is 2 V and when the same is repeated for an external resistance of $10\ \Omega$ then the TPD is 2.4 V. What is the EMF and internal resistance of cell?
 (a) 2.5 V, $3\ \Omega$ (b) 3 V, $3.5\ \Omega$ (c) 3 V, $2.5\ \Omega$ (d) 2.5 V, $3\ \Omega$

ANSWERS (CASE STUDY BASED QUESTIONS)

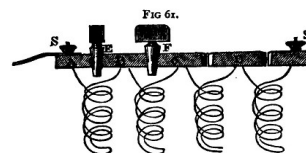
- | | | | | |
|---|------|--------|---------|--------|
| 1 | (i)c | (ii) a | (iii) a | (iv) b |
| 2 | (i)a | (ii) b | (iii) c | (iv) d |
| 3 | (i)d | (ii) a | (iii) c | (iv) c |

EXERCISE QUESTIONS

1. In a metallic conductor, an electron, moving due to thermal motion, suffers collisions with the heavy fixed ions but after collision, it will emerge out with the same speed but in random directions. If we consider all the electrons, their average velocity will be zero. When an electric field is applied, electrons move with an average velocity, known as drift velocity (V_d). The average time between successive collisions is known as relaxation time (τ). The magnitude of drift velocity per unit electric field is called mobility (μ). An expression for current through the conductor can be obtained in terms of drift velocity, number of electrons per unit volume (n), electronic charge ($-e$), and the cross-sectional area (A) of the conductor. This expression leads to an expression between current density (J) and the electric field (E). Hence, an expression for resistivity (ρ) of a metal is obtained. This expression helps us to understand increase in resistivity of a metal with increase in its temperature, in terms of change in the relaxation time (τ) and change in the number density of electrons (n).
- (i) Consider the contribution of the following two factors I and II in resistivity of a metal
- I. Relaxation time of electrons

- II. Number of electrons per unit volume The resistivity of a metal increases with increase in its temperature because :
- (A) I decreases and II increases. (B) I increases and II is almost constant.
 (C) Both I and II increase. (D) I decreases and II is almost constant.
- (ii) A steady current flows in a copper wire of non-uniform cross-section. Consider the following three physical quantities :
- I. Electric field II. Current density III. Drift speed Then at the different points along the wire:
- (A) II and III change, but I is constant. (B) I and II change, but III is constant.
 (C) I and III change, but II is constant. (D) All I, II and III change.
- (iii) The resistivity of iron is $1 \times 10^{-7} \text{ ohm} - m$. The resistance of a iron wire of particular length and thickness is 1 ohm . If the length and the diameter of wire both are doubled, then the resistivity in $\text{ohm} - m$ will be
- (a) 1×10^{-7} (b) 2×10^{-7} (c) 4×10^{-7} (d) 8×10^{-7}
- (iv) The temperature coefficient of resistance for a wire is $0.00125/^{\circ}C$. At $300K$ its resistance is 1 ohm . The temperature at which the resistance becomes 2 ohm is
- (a) $1154 K$ (b) $1100 K$ (c) $1400 K$ (d) $1127 K$

2. The box which contains the resistors of different values for estimating and comparing the resistance is known as the resistance box. The accuracy of the resistance box is very high. The main advantage of the resistance box is that the variable resistances are available at one point. Resistance values are adjusted by removing the brass pegs. The box is constructed with the pegs in parallel with precision wound resistance coils-with the peg in place the current flows through the peg (approx. 0 ohms), when removed the current flows through the resistor.
- If the length of material is small then surely, resistance will be low and current flows through that material will be high. and if the cross- section area of material is small then; resistance will be low and current flows through material will be high.



- (i) The resistances in a resistance box are arranged in-
- (a) Series Combination (b) Parallel combination
 (c) Mixed grouped (d) None of the above.
- (ii) How can the values of resistors apply to a circuit be changed in a resistance box?
- (a) By inserting the keys (b) By removing the keys
 (c) By changing the connections. (d) By changing the coils inside the resistance box.
- (iii) Which statement is correct-
- (a) Resistance box is used to apply variable resistance and Rheostat is used to apply constant resistance
 (b) Rheostat is used to apply variable resistance and the Resistance box is used to apply constant resistance.
 (c) In resistance box, the value of applied resistance is known.
 (d) In rheostat, the value of applied resistance is known.
- (iv) Why wire is double folded in resistance box?
- (a) to nullify the inductance effect. (b) to increase the resistance
 (b) for space arrangement (d) to increase the inductance effect.

ANSWERS (EXERCISE QUESTIONS)

- 1 (i) d (ii) a (iii) a (iv) d
2 (i) a (ii) b (iii) b (iv) a



ELECTRICITY FORMULA SHEET

Quick Revision • Key Concepts • Important Formulas



1 ELECTRIC CURRENT

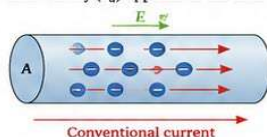
Electric current is the rate of flow of electric charge.

$$I = \frac{dQ}{dt}$$

I = Current (A)
 Q = Charge (C)
 t = Time (s)

2 FLOW OF ELECTRIC CHARGES IN A METALLIC CONDUCTOR

- Current in metals is due to the flow of free electrons.
- Electrons move randomly in the absence of electric field. When an electric field (E) is applied, they acquire a small average drift velocity (v_d) opposite to the field.



3 DRIFT VELOCITY, MOBILITY AND RELATION WITH CURRENT

Drift velocity (v_d):

$$v_d = \frac{e E \tau}{m}$$

e = charge of electron
 E = electric field
 τ = relaxation time
 m = mass of electron

Mobility (μ):

$$\mu = \frac{v_d}{E} = \frac{e \tau}{m}$$

Unit: $\text{m}^2 \text{V}^{-1} \text{s}^{-1}$

Relation with current (I):

$$I = n e A v_d = n e \mu A E$$

n = number density of free electrons
 A = cross-sectional area of conductor

4 OHM'S LAW

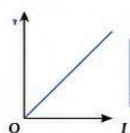
$$V = I R$$

V = Potential difference (V)
 I = Current (A)
 R = Resistance (Ω)

At constant physical conditions (especially temperature), current is directly proportional to the potential difference.

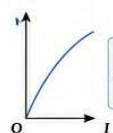
5 V-I CHARACTERISTICS

(a) Ohmic Conductor (Linear)



$V \propto I$
Slope = R
(Resistance constant)

(b) Non-Ohmic Conductor (Non-linear)



$V \not\propto I$
Slope changes with I

Examples: Diode, Filament lamp, Thermistor, etc.

6 ELECTRICAL ENERGY AND POWER

Electrical Energy (Work done):

$$W = V I t = I^2 R t = \frac{V^2}{R} t$$

W = Energy (J), t = time (s)

Electrical Power:

$$P = V I = I^2 R = \frac{V^2}{R}$$

P = Power (Watt)

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

7 RESISTIVITY AND CONDUCTIVITY

Resistivity (ρ):

$$\rho = \frac{R A}{l}$$

ρ = Resistivity ($\Omega \text{ m}$)

R = Resistance (Ω)

A = Area (m^2)

l = Length (m)

Conductivity (σ):

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

Unit of σ : S m^{-1}

Also,

$$R = \rho \frac{l}{A} = \frac{l}{\sigma A}$$

8 TEMPERATURE DEPENDENCE OF RESISTANCE

(For metals)

$$R_T = R_0 [1 + \alpha (T - T_0)]$$

R_T = Resistance at temperature T

R_0 = Resistance at reference temperature T_0

α = Temperature coefficient of resistance (K^{-1})

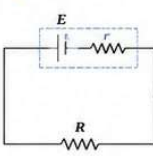
(For small temperature range)

$$R_T \approx R_0 (1 + \alpha \Delta T)$$

$$\Delta T = T - T_0$$

For semiconductors (NTC):
 R decreases as T increases

9 INTERNAL RESISTANCE OF A CELL



Terminal voltage,
 $V = E - I r$

E = EMF of cell (V)

r = Internal resistance (Ω)

I = Current (A)

R = External resistance (Ω)

As current increases, terminal voltage decreases.

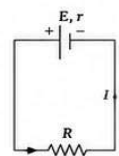
10 POTENTIAL DIFFERENCE AND EMF OF A CELL

EMF (E): Potential difference between the terminals of a cell when no current flows. (It is the open-circuit voltage)

Potential Difference (V): Potential difference between the terminals when current I flows through an external circuit.

$$V = E - I r$$

$E > V$ (when cell is supplying current)



11 COMBINATION OF CELLS

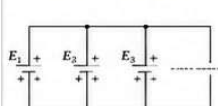
(a) In Series (Add)



$$E_{eq} = E_1 + E_2 + E_3 + \dots$$

$$r_{eq} = r_1 + r_2 + r_3 + \dots$$

(b) In Parallel (Add)



$$E_{eq} = E_1 = E_2 = E_3 = \dots$$

(If cells are identical)

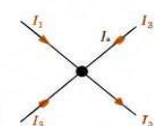
$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \dots$$

12 KIRCHHOFF'S RULES

(i) Kirchhoff's Current Law (KCL)

At any junction (node),
Algebraic sum of currents is zero.

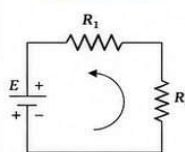
$$\sum I_{in} = \sum I_{out}$$



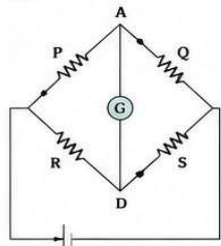
(ii) Kirchhoff's Voltage Law (KVL)

In any closed loop,
Algebraic sum of potential differences is zero.

$$\sum \Delta V = 0$$



13 WHEATSTONE BRIDGE



Balance condition
(no current through G):

$$\frac{P}{Q} = \frac{R}{S}$$

Unknown resistance,

$$S = \frac{Q R}{P}$$

Used to find unknown resistance accurately.



Tip: Understand concepts + Practice numericals = Mastery

Memorize • Understand • Apply



Keep Revising, Keep Excelling!