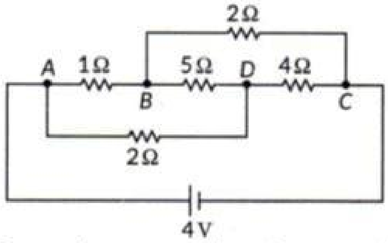
SURE SHOT QUESTIONS 2026

Chapter – 03 (Questions)

Current Electricity

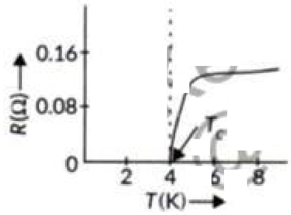
Question

1. Calculate the current drawn from the battery by the network of resistors shown in the figure.

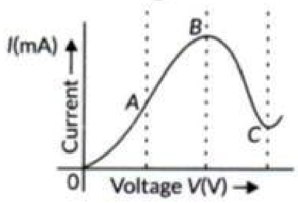


2. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor : current, current density, electricity field, drift speed?

3. (i) The graph between resistance (R) and temperature (T) for Hg is shown in the figure. Explain the behaviour of Hg near 4 K.



(ii) In which region of the graph shown in the figure is the resistance negative and why?



4. A cell of emf 'E' and internal resistance 'r' is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I. It is found that when $R = 4\,\Omega$, the current is 1 A and when R is increased to $9\,\Omega$, the current reduces to 0.5 A. Find the values of the emf E and internal resistance r.

5. (a) Two cells of emf E_1 and E_2 have their internal resistances r_1 and r_2 respectively. Deduce an expression for the equivalent emf and internal resistance of their parallel combination when connected across an external resistance R. Assume that the two cells are supporting each other.

(b) In case the two cells are identical, each of emf E = 5 V and internal resistance $r = 2\,\Omega$, calculate voltage across the external resistance $R = 10\,\Omega$.

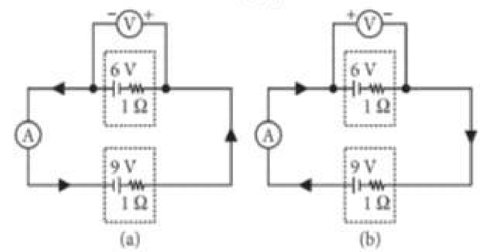
6. A variable resistor R is connected across a cell of emf E and internal resistance r.

(a) Draw the circuit diagram.

(b) Plot the graph showing variation of potential drop across R as function of R.

(c) At what value of R current in circuit will be maximum.

7. In the two electric circuits shown in the figure, determine the readings of ideal ammeter (A) and the ideal voltmeter (V).



8. A steady current flows in a metallic conductor of non- uniform cross-section. Which of these quantities is constant along the conductor : current, current density, electric field, drift speed?

9. Define resistivity of a conductor. How does the resistivity of a conductor depend upon the following:

(a) Number density of free electrons in the conductor (n)

(b) Their relaxation time (τ)

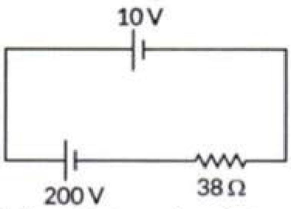
10. Find the temperature at which the resistance of a conductor increases by 25% of its value at 27°C. The temperature coefficient of resistance of the conductor is $2.0 \times 10^{-4}\,°C^{-1}$

11. Define the term 'drift velocity' of electrons in a current carrying conductor. Obtain the relationship between the current density and the drift velocity of electrons.

12. Define the term 'mobility' of charge carriers in a current carrying conductor. Obtain the relation for mobility in terms of relaxation time.

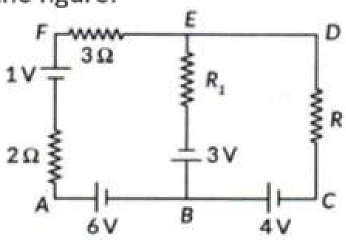
13. Using the concept of drift velocity of charge carriers in a conductor, deduce the relationship between current density and resistivity of the conductor.

14. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit.



15. A cell of emf 'E' and internal resistance 'r' is connected across a variable resistor 'R'. Plot a graph showing variation of terminal voltage 'V' of the cell versus the current 'I'. Using the plot, show how the emf of the cell and its internal resistance can be determined.

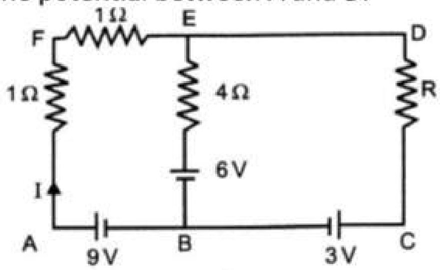
16. Use Kirchhoff's rules to determine the potential difference between the points A and D when no current flows in the BE of the electric network shown in the figure.



17. Write a relation between current and drift velocity of electrons in a conductor. Use this relation to explain how the resistance of a conductor changes with the rise in temperature.

18. (a) Define the term drift velocity.
(b) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of conductor depend?
(c) Why alloys like constantan and manganic are used for making standard resistors?

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



20. Define drift Velocity & Relaxation Time

21. Deduce Ohm's law using the concept of drift Velocity.

22. Establish a relation between electric current and drift velocity.

23. Define the term current density of a metallic conductor. Deduce the relation connecting current density (J) and the conductivity σ of the conductor, when an electric field E, is applied to it.

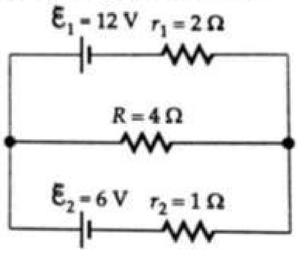
24. What is conductivity & mobility? Derive an expression for conductivity in terms of mobility.

25. Two cells of emfs 1.5 V and 2.0 V and internal resistances 0.2 Ω and 0.3 Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell.

26. State Kirchhoff's rules. Explain briefly how these rules are justified.

27. Use Kirchhoff's rules to obtain conditions for the balance condition in a Wheatstone bridge.

28. Find the potential difference across each cell and the rate of energy dissipation in R.



29. Two cells of emfs 1.5 V and 2.0 V and internal resistances 1 Ω and 2 Ω respectively are connected in parallel so as to send current in the same direction through an external resistance of 5Ω.

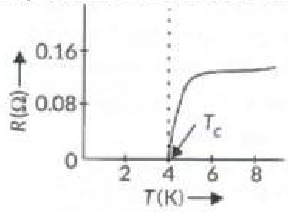
i. Draw the circuit diagram.

ii. Using Kirchhoff's laws, calculate

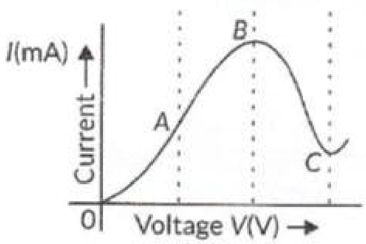
a. Current through each branch of the circuit.

b. P.d. across the 5 Ω resistance.

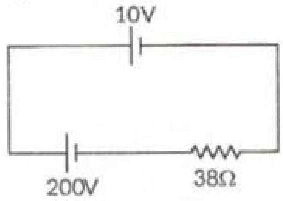
30. (i) The graph between resistance (R) and temperature (T) for Hg is shown in the figure. Explain the behaviour of Hg near 4 K.



(ii) In which region of the graph shown in the figure is the resistance negative and why?

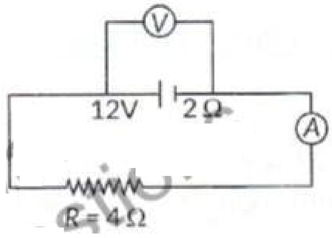


31. A 10 V cell of negligible internal resistance is connected in parallel across a battery of emf 200 V and internal resistance 38 Ω as shown in the figure. Find the value of current in the circuit.



32. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?

(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings.



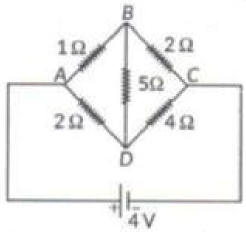
Chapter – 03 (Solutions)

Current Electricity

Solution

1. Ans. Since the condition $\frac{P}{Q} = \frac{R}{S}$ is satisfied, it is a balanced bridge.

The equivalent Wheatstone bridge for the given combination is shown in figure.



The resistance of arm ABC, $R_{S_1} = 2 + 1 = 3\Omega$

Also, the resistance of arm ADC,

$R_{S_2} = 4 + 2 = 6\Omega$

Equivalent resistance

$R_{eq} = \frac{R_{S_1} \times R_{S_2}}{R_{S_1} + R_{S_2}} = \frac{3\times6}{3+6} = \frac{18}{9} = 2\Omega$

Current drawn from the battery

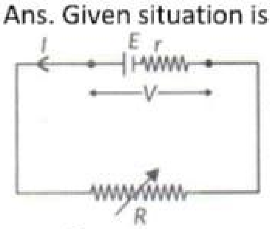
$I = \frac{V}{R_{eq}} = \frac{4}{2} \therefore I = 2A.$

2. Ans. Current is constant is non – uniform cross-section.

3. Ans. (i) Resistance of Hg below 4 K is zero so it behaves like a super conductor. Between T = 4 K to 5 K resistance rises linearly and beyond T = 5K resistance becomes constant.

(ii) In region BC, the material shows negative resistance property because current decreases with increase in voltage or slope of BC is negative.

4. Ans. Given situation is shown in figure

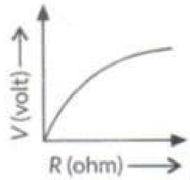


$I = \frac{E}{r+R}$

(i) V versus R, Terminal voltage,

$V = E - Ir$

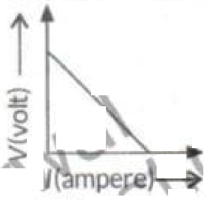
$V = E - Ir = E - \frac{E}{r+R}r = \frac{ER}{r+R}$



(ii) V versus I,

V = E – Ir

When $R = 4\Omega$,



Then $I_1 = 1A$

$\therefore 1 = \frac{E}{r+4}$

$r + 4 = E$ ....(i)

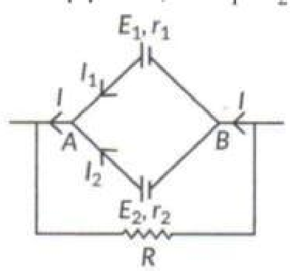
When $R = 9\Omega$, then $I = 0.5A = \frac{1}{2}A$

$\therefore \frac{1}{2} = \frac{E}{r+9} = \frac{r+4}{r+9}$ [Using eqn. (i)]

$r + 9 = 2r + 8, r = 1\Omega$

From eqn. (i), emf, E = 1 + 4 = 5V

5. Ans. (a) Here, $I = I_1 + I_2$ ....(i)



Let V = Potential difference between A and B

For cell E_1,

$V = E_1 - I_1 r_1 \Rightarrow I_1 = \frac{E_1 - V}{r_1}$

Similarly, for cell E_2, $I_2 = \frac{E_2 - V}{r_2}$

Putting these values in equation (i)

$I = \frac{E_1 - V}{r_1} + \frac{E_2 - V}{r_2}$

or $I = \left(\frac{E_1}{r_1} + \frac{E_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

$$or V = \left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right) - I\left(\frac{r_1 r_2}{r_1 + r_2}\right) \ldots\ldots\ldots (ii)$$

Comparing the above equation with the equivalent circuit of emf 'E_{eq}' and internal resistance 'r_{eq}' then,

$V = E_{eq} - Ir_{eq}$ ....(iii)

Then, $E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$ and $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$

(b) Given $E_1 = E_2 = E = 5V$

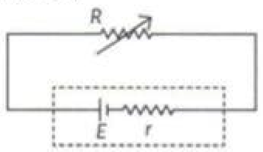
And $r_1 = r_2 = r = 2\Omega$, and $R = 10\Omega$

Then current, $I = \frac{E_{eq}}{R + r_{eq}} = \frac{5}{10 + 4/4} = \frac{5}{11} A$

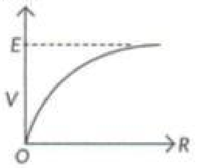
$\therefore$ Voltage across the external resistance,

$$V = IR = \frac{5}{11} \times 10 = \frac{50}{11} = 4.55V$$

6. Ans. (a)



(b) .



(c) Maximum current drawn will be at R = 0

7. Soln. In first circuit Reading of ideal voltmeter = 6 V

Net potential difference = 9 + 6 = 15 V

Total resistance = $1 + 1 = 2\Omega$

Current in ammeter = $\frac{V}{R} = \frac{15}{2} = 7.5A$

In second Circuit Reading of ideal volt meter = 6V Net potential difference = 9 – 6 = 3 V

Total resistance = $1 + 1 = 2\Omega$

Current in ammeter = $\frac{V}{R} = \frac{3}{2} = 1.5A$

8. Soln. Current is constant in non-uniform cross-section.

9. Ans. Resistivity is defined as the measure of resistance offered by a conductor of unit length across unit area of cross section.

The resistivity ρ is given by, $\rho = \frac{m}{ne^2\tau}$

where m is mass of charge, n is the number density and τ is relaxation time.

10. Ans. Resistance of the conductor for a temperature change ΔT is given as;

$R = R_0(1 + \alpha\Delta T)$

When R increases by 25% then

$R = R_0 + \frac{25}{100}R_o = \frac{5R_o}{4}$

$\frac{5R_o}{4} = R_0(1 + \alpha(T_f - T_i))$; $\frac{1}{4} = \alpha(T_f - T_i)$

$T_f = T_i + \frac{1}{4\alpha}$; $T_f = 27 + \frac{1}{2 \times 4 \times 10^{-4}}$

$T_f = 27 + 1250 = 1277\,°C$

11. Ans. When an electric field is applied across a conductor then the charge carriers inside the conductor move with an average velocity which is independent of time. This velocity is known as drift velocity (v_d).

Current flowing in a conductor is given by $I = neAv_d$

Current density $J = \frac{I}{A}$

$\therefore \quad J = nev_d$

12. Ans. Mobility of a charge carrier is defined as the drift velocity of the charge carrier per unit electric field.

It is generally denote by μ.

$$\mu = \frac{v_d}{E}$$

The SI unit of mobility is $m^2 V^{-1} s^{-1}$. Mobility in term of relaxation time: $\vec{v_d} = \frac{-e\vec{E}}{m}\tau$

In magnitude, $v_d = \frac{eE}{m}\tau$ or $\frac{v_d}{E} = \frac{e\tau}{m}$; $\mu = \frac{e\tau}{m}$

13. Ans. As we know that

$$I = neAv_d$$

Also current density J is given by $J = \frac{I}{A}$

$\therefore |\vec{J}| = \frac{ne^2}{m}\tau|\vec{E}| \left(\because v_d = \frac{e\tau E}{m}\right)$

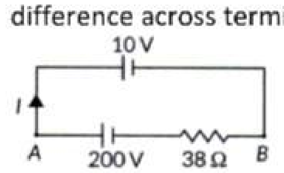
is parallel to $\vec{E}$,

$\therefore \vec{J} = \frac{ne^2}{m}\tau\vec{E}$

$\because \sigma = \frac{1}{\rho} = \frac{ne^2}{m}\tau$

$\therefore \vec{J} = \frac{\vec{E}}{\rho}$

14. Ans. As cells are connected in parallel so potential difference across terminals of each cell is same.

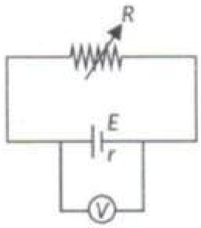


$200 - 38I = 10$

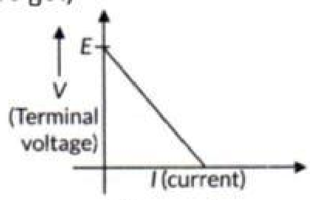
$38I = 200 - 10 = 190$

$I = \frac{190}{38} = 5A$

15. Ans. Terminal voltage 'V' of the cell is $V = E - Ir$
E is the emf of the cell, r is the internal resistance of the cell and I is the current through the circuit.



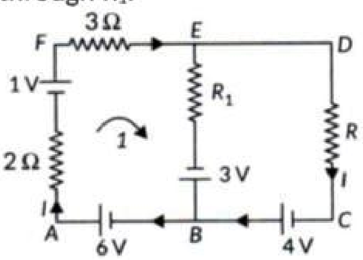
So, $V = -Ir + E$
Comparing with the equation of a straight line
y = mx + c, we get,



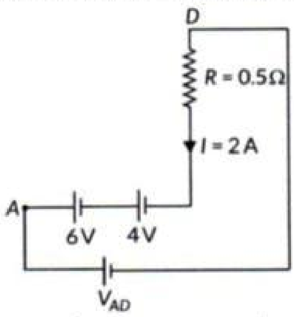
$y = V; x = I;$
$m = -r; c = E$

Graph showing variation of terminal voltage 'V' of the cell versus the current 'I'.
Emf of the cell = Intercept on V axis
Internal resistance = slope of line.

16. Ans. First we need to calculate R for no current through R_1.



By Kirchhoff's law,
$3I + RI + 2I = 1 + 4 + 6$
$5I + RI = 11........(i)$
Also, in loop (1),
$3I + 2I = 3 + 6 + 1$
$5I = 10 or I = 2amp.............(ii)$
Using in eqn.(i),
$10 + R \times 2 = 11$
$2R = 1 or R = 0.5\Omega...........(iii)$



Now the determine the potential difference between A and D, we can assume a cell of required potential V_{AD} between two points.
On applying Kirchhoff's law,
$V_{AD} - 6 - 4 = -2 \times 0.5$
$V_{Ad} - 10 = -1$
$$V_{AD} = 9 volt$$

17. Soln. Drift velocity $v_d = \frac{e\vec{E}}{m}\tau$, where E is electric field strength. And the relation between current and drift velocity is $I = neAv_d$.

$$\therefore \frac{I}{A} = \frac{ne^2\tau}{m}E \Rightarrow j = \sigma AE$$
$$\sigma = \frac{ne^2\tau}{m} = \frac{1}{\rho} or, \rho = \frac{m}{ne^2\tau}$$

With rise of temperature, the rate of collision of electrons with ions of lattice increases, so relaxation time decreases. As a result resistivity of the material increases with the rise of temperature, hence the resistance.

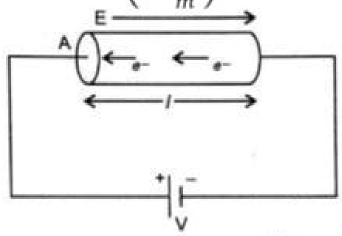
18. Soln.

(a) Drift velocity is defined as the average velocity with which the free electrons are drifted towards the positive terminal under the effect of applied electric field. Thermal velocities are randomly distributed and average thermal velocity is zero.

$$\frac{\vec{u}_1 + \vec{u}_2 + ... + \vec{u}_N}{N} = 0$$
$$i.e., v_d = -\frac{eE\tau}{m}$$

(b) We know that the current flowing through the conductor is:

$$I = nAev_d$$
$$\therefore I = neA\left(-\frac{eE\tau}{m}\right)$$



Using $$E = -\frac{V}{l}$$
$$I = neA\left(\frac{eV}{ml}\right)\tau$$
$$= \left(\frac{ne^2A\tau}{ml}\right)V = \frac{1}{R}V$$

$I \propto V \rightarrow$ by Ohm's law

Where, $R = \frac{ml}{nAe^2\tau}$ is a constant for a particular conductor at a particular temperature and is called the resistance of the conductor.

$$R = \left(\frac{m}{ne^2\tau}\right)\frac{l}{A} = \frac{\rho l}{A}$$
$$\rho = \left(\frac{m}{ne^2\tau}\right)$$

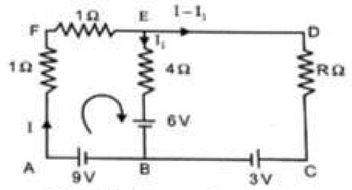
Where ρ is the specific resistance or resistivity of the material of the wire. It depends on number of free electron per unit volume and temperature.

(c) They are used to make standard resistors because:

1. They have high value of resistivity.
2. Temperature coefficient of resistance is less.

3. They are least affected by temperature.

19. Soln.



Apply Kirchhoff's law in loop AFEBA:

$$I + I + 4I_1 = 9 - 6$$

$$2I + 4I_1 = 3 \quad ....(i)$$

As there is no current flowing through the 4Ω resistance,

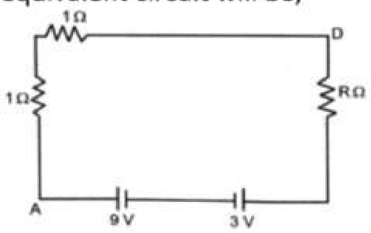
$\therefore I_1 = 0$

Or $2I = 3$

Or $I = 1.5A$

Thus, the current through resistance R is 1.5 A.

As there is no current through branch EB, thus equivalent circuit will be,



By applying Kirchhoff's loop law, we get

$$1.5 + 1.5 + R(1.5) = 9 - 3$$

$$R = 2\Omega$$

Potential difference between A and D = $2 \times 1.5 = 3V$

20. Soln. Drift velocity may be defined as the average velocity gained by the free electrons of a conductor in the opposite direction of the externally applied electric field.

The average time that elapses between two successive collisions of an electron is called relaxation time.

21. Soln. Deduction of Ohm's law. When a potential difference V is applied across a conductor of length l, the drift velocity in terms of V is given by

$$v_d = \frac{eE\tau}{m} = \frac{eV\tau}{ml}$$

If the area of cross-section of the conductor is A and the number of electrons per unit volume or the electron density of the conductor is n, then the current through the conductor will be

$$I = enAv_d = enA.\frac{eV\tau}{ml}$$

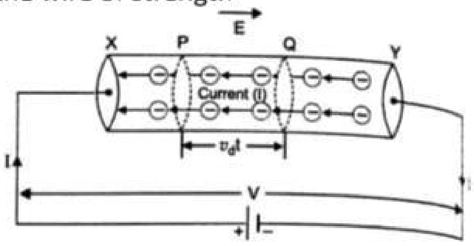
Or $\frac{V}{I} = \frac{ml}{ne^2\tau A}$.

At a fixed temperature, the quantities m, l, n, e, τ and A, all have constant values for a given conductor. Therefore,

$$\frac{V}{I} = \text{a constant, R}$$

This proves Ohm's law for a conductor and here $R = \frac{ml}{ne^2\tau A}$ is the resistance of the conductor.

22. Soln. Consider a uniform metallic wire XY of length l and cross-sectional area A. A potential difference V is applied across the ends X and Y of the wire. This causes an electric field at each point of the wire of strength



$$E = \frac{V}{l}. \quad ....(i)$$

Due to this electric field, the electrons gain a drift velocity v_d opposite to direction of electric field. If q be the charge passing through the cross-section of wire in t seconds, then

Current in wire $I = \frac{q}{t}$ ....(ii)

The distance traversed by each electron in time t = average velocity x time = $v_d t$

If we consider two planes P and Q at a distance v_d t in a conductor, then the total charge flowing in time t will be equal to the total charge on the electrons present within the cylinder PQ.

The volume of this cylinder = cross sectional area x height

$$= A\, v_d\, t$$

If n is the number of free electrons in the wire per unit volume, then the number of free electrons in the cylinder $= n(A\, v_d t)$

If charge on each electron is $-e(e = 1.6 \times 10^{-19}\text{ C})$, then the total charge flowing through a cross-section of the wire

$$q = (nA\, v_d\, t)(-e) = -neAv_d\, t \quad ....(iii)$$

$\therefore$ Current flowing in the wire,

$$I = \frac{q}{t} = \frac{-neAv_d t}{t}$$

i.e., current I = $-neAv_d$ ....(iv)

This is the relation between electric current and drift velocity. Negative sign shows that the direction of current is opposite to the drift velocity.

Numerically $I = neAv_d$ ....(v)

Current density, $\therefore \quad J = \frac{I}{A} = nev_d$

$\Rightarrow \quad J \propto v_d$.

That is, current density of a metallic conductor is directly proportional to the drift velocity.

23. Soln. In a conductor, current density at particular point is the current flowing per unit area in conductor provided the area is in direction normal to current.

$$J = \frac{I}{A}$$

Current density is a vector quantity. Its direction is the direction of motion of positive charge. The unit of current density is ampere/metre^2, or [Am^{-2}].

Relation between J and E:

$$I = nAev_d = nAe\left(\frac{eE}{m}\tau\right)$$

$$I = \frac{nAe^2\tau E}{m}$$

Or $$\frac{I}{A} = \frac{ne^2\tau E}{m}$$

Or $$J = \frac{1}{\rho}E$$

$$\left[\because J = \frac{I}{A} and \rho = \frac{m}{ne^2\tau}\right]$$

$$J = \sigma E \qquad \left[\because \sigma = \frac{1}{\rho}\right]$$

24. Soln. The conductivity of any material is due to its mobile charge carriers. These may be electrons in metals, positive and negative ions in electrolytes; and electrons and holes in semiconductors.

The mobility of a charge carrier is the drift velocity acquired by it in a unit electric field. It is given by

$$\mu = \frac{v_d}{E}$$

25. Soln. $E_1 = 1.5V, r_1 = 0.2\Omega$

$E_2 = 2.0V, r_2 = 0.3\Omega$

Emf of equivalent cell

$$E = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_1}$$

$$= \left(\frac{1.5 \times 0.3 + 2 \times 0.2}{0.2 + 0.3}\right) = \frac{0.45 + 0.40}{0.5} V = 1.7V$$

Internal resistance of equivalent cell

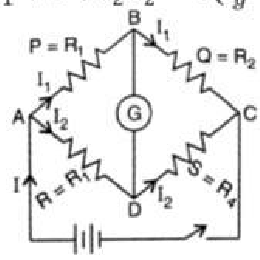
$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{r_1 r_2}{r_1 + r_2} = \left(\frac{0.2 \times 0.3}{0.2 + 0.3}\right)\Omega = \frac{0.06}{0.5}\Omega = 0.12\Omega$$

26. Soln. Kirchhoff's first law is known as junction rule which states that for a given junction or node in a circuit, sum of the currents entering will be equal to sum of current leaving.

Kirchhoff's second law is also known as loop rule which shows that around any closed loop in a circuit, sum of the potential differences across all elements will be zero Justification: The junction rule is in accordance with the conservation of charge that serves as basis of current rule while loop rule is based on law of conservation of energy.

27. Soln. Applying Kirchhoff's loop rule to closed loop ADBA

$-I_1R_1 + 0 + I_2R_2 = 0 (I_g = 0)$ ....(i)



For loop CBDC,

$-I_2R_4 + 0 + I_1R_3 = 0$

From equation (i)

$$\frac{I_1}{I_2} = \frac{R_1}{R_2}$$

From equation (ii)

$$\frac{I_1}{I_2} = \frac{R_4}{R_3}$$

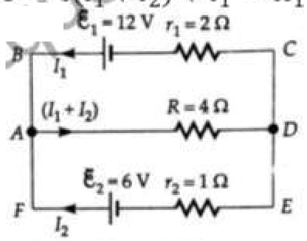
$$\therefore \frac{R_1}{R_2} = \frac{R_4}{R_3}$$

28. Soln. Applying Kirchhoff's laws, For closed loop ADCBA

$12 = 4(I_1 + I_2) + 2I_1 = 6I_1 + 4I_2$..........(i)

For closed loop ADEFA,

$6 = 4(I_1 + I_2) + I_1 = 4I_1 + 5I_2$ ....(ii)



Solving (i) and (ii), we get

$I_1 = \frac{18}{7} A and I_2 = -\frac{6}{7} A$

P.D. across R = V

$= (I_1 + I_2) R$

$= \left(\frac{18-6}{7}\right) \times 4 volt = \frac{48}{7} V$

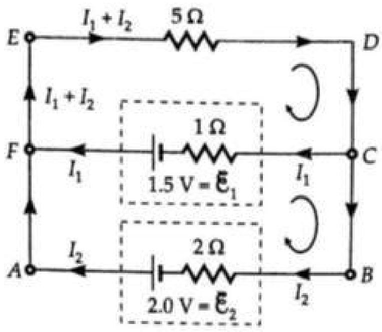
P.D. across each cell = P.D. across $R = \frac{48}{7}$V

Energy dissipated in $R = 4\Omega$ resistor

$= (I_1 + I_2)^2 R = \left(\frac{12}{7}\right)^2 \times 4J$

$= \frac{576}{49} J = 11.75J$

29. Soln. (i)



(ii) (a) Let I_1 and I_2 be the currents as shown in fig.
Using Kirchhoff's second law for the loop AFCBA, we get

$2I_2 - 1I_1 = \varepsilon_2 - \varepsilon_1 = 2 - 1.5$

Or $\quad 2I_2 - I_1 = 0.5$ ....(i)

For loop CFEDC, we have

$1I_1 + 5(I_1 + I_2) = \varepsilon_1 = 1.5$

Or $\quad 5I_2 + 6I_1 = 1.5$.............(ii)

Solving equations (i) and (ii), we get

$$I_1 = \frac{1}{34}A, I_2 = \frac{9}{34}A$$

∴ Current through branch BA,

$$I_1 = \frac{1}{34}A$$

Current through branch CF,

$$I_2 = \frac{9}{34}A$$

Current through branch DE,

$$I_1 + I_2 = \frac{10}{34}A.$$

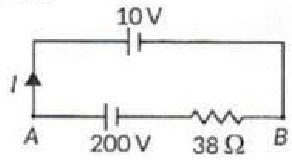
(b) P.D. across the 5Ω resistance

$= (I_1 + I_2) \times 5 = \frac{10}{34} \times 5V = 1.47V,$

30. Soln. (i) Resistance of Hg below 4 K is zero so it behaves like a superconductor. Between T = 4 K to 5 K resistance rises linearly and beyond T = 5 K resistance becomes constant.

(ii) In region BC, the material shows negative resistance property because current decreases with increase in voltage or slope of BC is negative.

31. Soln. As cells are connected in parallel so potential difference across terminals of each cell is same.



$200 - 32l = 10$

$38l = 200 - 10 = 190$

$l = \frac{190}{38} = 5A$

32. Soln. (a) $\because H = \frac{V^2}{R}t \Rightarrow \frac{H}{t} = \frac{V^2}{R}$

$\therefore \frac{H}{t} \propto V^2$

Given heat produce per second $\frac{H}{t}$, increases by a factor of 9,

Hence, applied potential difference V increased by factor of 3.

(b) $I = \frac{E}{R+r} = \frac{12}{4+2} = \frac{12}{6} = 2A$

$V = E - Ir = 12 - 2 \times 2 = 8V$