6. Current Electricity

Very Short Answer Type **Questions**

Question 1. Define mean free path of electron in a conductor.
Answer: Mean free path :
It is defined as the average distance that an electron can travel between two successive collisions.

Question 2. State Ohm's law and write its mathematical form.
Answer: Ohm's law :
At constant temperature current (I) flowing through a conductor is proportional to the potential difference between the ends of that conductor.
$V \propto I \Rightarrow V = RI$ where R = constant called resistance. Unit: Ohm (Ω).

Question 3. Define resistivity (or) specific resistance.
Answer: Resistivity :
Resistivity of a substance $\rho = \frac{RA}{l}$
It is defined as the resistance of a unit cube between its opposite parallel surfaces.

It depends on the nature of substance but not on its dimensions.
Unit: Ohm – metre (Ωm).

Question 4. Define temperature coefficient of resistance.
Answer: Temperature coefficient of resistivity :
The resistivity of a substance changes with temperature. $\rho_\tau = \rho_0 [1 + \propto (T - T_0)]$. Where a is temperature coefficient of resistivity.

Question 5. Under what conditions is the current through the mixed grouping of cells maximum? (Note: Mixed grouping of cells not given in New Syllabus.)
Answer: Let m cells are in series and there are n such rows this arrangement is called mixed grouping.
In mixed grouping current (i) = $\frac{mnE}{mr+nR}$
Current will be maximum when mr = nR
$\therefore i_{max} = \frac{nE}{2r}$

Question 6. If a wire is stretched to double its original length without loss of mass, how will the resistivity of the wire be influenced?
Answer: Resistivity (ρ) is independent of dimensions of the material. It depends only on nature of material.
So even though the wire is stretched its resistivity does not change.

Question 7. Why is manganin used for making standard resistors?
Answer: Temperature coefficient of resistance of manganin is very less. So its resistance is almost constant over a wide range of temperature.

Due to this reason manganin is used to prepare standard resistances.

Question 8. The sequence of bands marked on a carbon resistor are : Red, Red, Red, Silver. What is its resistance and tolerance?
Answer: Given sequence of colour band Red Red Red Silver
Colour code for Red = 2
1st band red = 2 ; '
2nd band Red = 2
3rd band = No. of zeros = 2 (∵ Red) :
∴ Resistance R = 2200 Ω
tolerance band (4th band) Silver = 10%
∴ For silver resistor R = 2200 Ω with 10% tolerance.

Question 9. Write the colour code of a carbon resistor of resistance 23 kilo ohms.
Answer: Reistance 23 kilo ohms = 23000
∴ 1st band = 2 ⇒ Red ;
2nd band = 3 ⇒ orange
3rd band = No. of zeroes = 3 ⇒ orange
∴ Colour code for 23 kΩ = Red Orange, Orange.

Question 10. If the voltage V applied across a conductor is increased to 2V, how will the drift velocity of the electrons change?
Answer: Drift velocity will also double.
Drift velocity vd = −pmEτ
Where E = intensity of electric field. It depends on applied potential. When applied potential is doubled (V to 2V). Intensity of electric field E is also doubled.
(∵ E = Vd , where d is not charged). So drift d velocity is doubled.

Question 11. Two wires of equal length, of copper and manganin, have the same resistance. Which wire is thicker?
Answer: Manganin wire is thicker.
Resistance R = ρlA given l is same.
For copper specific resistance ρ is less than manganin.
∵ R is constant material with high 'ρ' must have larger area A.
Hence manganin wire is thicker.

Question 12. What is the magnetic moment associated with a solenoid of 'N' turns having radius of cross-section 'r' carrying a current I?
Answer: Magnetic moment of solenoid (N) = πr^2 In × 2l where '2l' = length of solenoid, r = radius, I = current
n = number of turns.

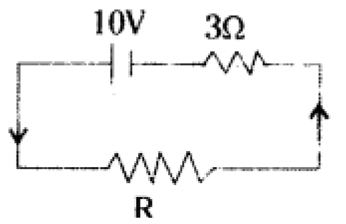
Question 13. Why are household appliances connected in parallel?
Answer: In parallel combination potential drop is constant. Different amounts of current is allowed through each component separately. i.e., we may switch off unwanted connections without disturbing other.

Hence parallel connection of appliances is prefered in household connections.

Question 14. The electron drift speed in metals is small (~ m^{-1}) and the charge of the electron is also very small (~ 10^{-19}) Q, but we can still obtain a large amount of current in a metal. Why?
Answer: Eventhough charge of electron 'e', drift velocity v_d are less number of electrons n is very high, current i = ne v_d. (i.e., charges flowing per second)
∵ n is extremely high we are getting large current.

Short Answer Questions

Question 1. A battery of emf 10 V and internal resistance 3Ω is connected to a resistor R.
(i) If the current in the circuit is 0.5 A. Calculate the value of R.
(ii) What is the terminal voltage of the battery when the circuit is closed? [TS Mar. '15]
Answer: emf E = 10V, Internal resistance r = 3Ω

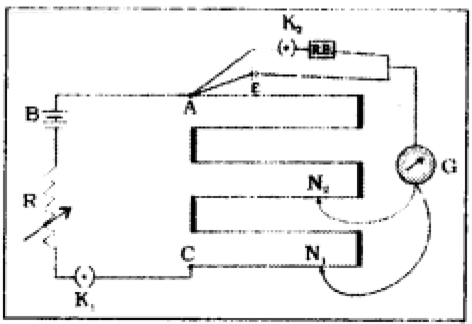


i) Current i = 0.5 A But $i = \frac{E}{R+r}$

$$\therefore\ R = \frac{E}{i} - r = \frac{10}{0.5} - 3 \Rightarrow R = 20 - 3 = 17\Omega$$

ii) Terminal voltage V = E – ir
∴ V = 10 – 0.5 × 3 = 10 – 1.5 = 8.5V

Question 2. Draw a circuit diagram showing how a, potentiometer may be used to find internal resistance of a cell and establish a formula for it.
Answer: Circuit diagram to find internal resistance; of a cell is



Circuit for determining internal resistance of a cell

Theory :
i) In circuit key 'k_2' is open and potentiometer jockey is adjusted to zero deflection.
Balancing length l_1 is measured.
Now $\varepsilon = \Phi l_1 \rightarrow (1)$

ii) Key 'k_2' is closed. Balancing length l_1 is measured.
Now $V = \Phi l_1 \rightarrow (2)$
But ε = I (R + r) and V = IR so from eq (1) & (2)

$$\frac{\varepsilon}{V} = \frac{I(R+r)}{IR} = \frac{\phi l_1}{\phi l_2} \Rightarrow \frac{l_1}{l_2} = \frac{(R+r)}{R}$$

$$\Rightarrow l_1 R = l_2 R + l_2 r \Rightarrow (l_1 - l_2)R = l_2 r$$

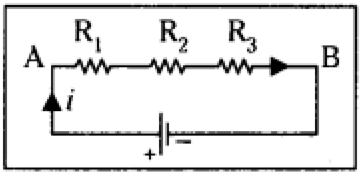
Internal resistance of battery

$$r = \frac{R(l_1 - l_2)}{l_2} = R\left(\frac{l_1}{l_2} - 1\right).$$

Question 3. Derive an expression for the effective resistance when three resistors are connected i) series ii) parallel.

Answer: (i) Series combination :

Let three resistors R_1, R2 and R_3 be connected in series as shown in figure.



Same current i flows through all resistors.

Potential drop across $R_1 \Rightarrow (V_1) = iR_1$

Similarly $V_2 = iR_2$ and $V_3 = iR_3$ are P.D across $R_2 + R_3$

Total potential across AB $(V) = V_1 + V_2 + V_3$

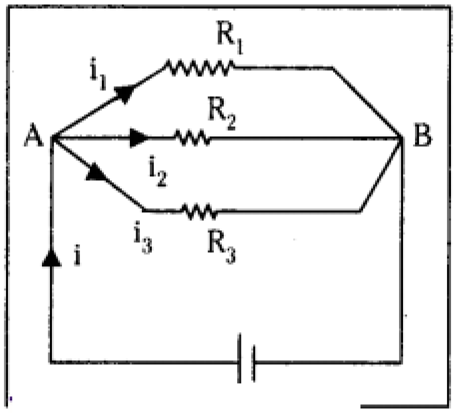
$\therefore V = iR_1 + iR_2 + iR_3 = i(R_1 + R_2 + R_3)$, But $V = i R$

$\therefore V = i R_{eq} = i(R_1 + R_2 + R_3)$

In series combination $R_{eq} = R_1 + R_2 + R_3$

$\therefore$ Equivalent resistance is the sum of individual resistors.

ii) Parallel combination of resistors :
Let three resistors R_1, R_2 and R_3 be connected in parallel as shown in figure.



Parallel combination of resistors

In this combination potential drop across AB is constant. But different values of current flows though each resistor. Total current $i = i_1 + i_2 + i_3$

Current through $R_1 \Rightarrow (i_1) = VR_1$ Similarly,
$\Rightarrow i_2 = VR_2$ and $i_3 = VR_3$.

$$\therefore i = i_1 + i_2 + i_3 \Rightarrow \frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\therefore \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \text{(OR)}$$

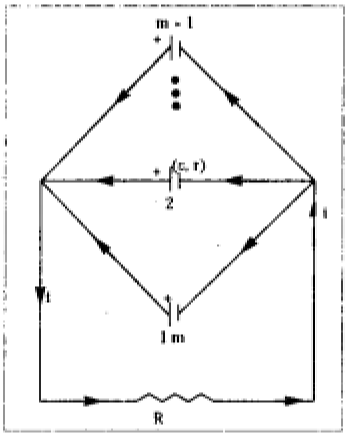
$$\boxed{R_{eq} = \frac{R_1R_2R_3}{R_1R_2 + R_2R_3 + R_3R_1}}$$

Question 4. 'm' cells each of emf E and internal resistance 'r' are connected in parallel. What is the total emf and internal resistance? Under what conditions is the current drawn from the mixed grouping of cells a maximum?
Answer: (i) Let m' identical cells each of emf E' and internal resistance V be connected in parallel as shown in the figure.
(ii) Applying Kirchoffs voltage law to the circuit, we have for the first cell,

$$-iR - \left(\frac{i}{m}\right)r + E = 0 \quad .... \quad 1$$

For the second cell, $-iR - \left(\frac{i}{m}\right)r + E = 0$

For the n^{th} cell $-iR - \left(\frac{i}{m}\right)r + E = 0$



Parallel combination of cells

(iii) Adding the above m' equations, we get, – m(iR) – m(im)r + mE = 0
(mR + r)i = mE
∴ I = mEmR+r
iv) The above expression can be written as

$$i = \frac{E}{R + \frac{r}{m}}$$

$\therefore E_{effective} = E$ and $r_{effective} = \frac{r}{m}$

Mixed grouping of cells :
Note : Mixed grouping of cells not given in New Syllabus.
Answer:
Let m cells are in series and there are n such rows this arrangement is called mixed grouping.
In mixed grouping current i = mnEmr+nR
Current will be maximum when mr = nR
$\therefore i_{max}$ = nE2r

Question 5. Define electric resistance and write it’s SI unit. How does the resistance of a conductor vary if
a) Conductor is stretched to 4 times of it’s length.
b) Temperature of conductor is increased?
Answer: Resistance :
The obstruction created by a conductor for the mobility of charges through it is known as resistance.
i) The resistance of a conductor (R) is proportional to length $R \propto l \rightarrow (1)$
ii) and inversely proportional to area of cross-section of the conductor.

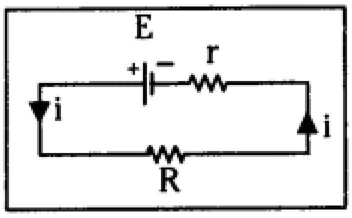
$$R \propto \frac{1}{A} - (2)$$

From eq. (1) & (2) $R \propto \frac{l}{A} \Rightarrow R = \frac{\rho l}{A}$

where “ρ” = resistivity of the conductor.

a) When conductor is stretched by four times its new length $l_2 = 4l_1$ or $l_1 l_2 = 4$
When a wire is stretched by keeping its mass constant then Rg = R_1[latex]\frac{l_2}{l_1}[/latex]^2
$\therefore R_2 = R_1 . (4)^2 = 16R_1$
So when a wire is stretched by 4 time its resistance is increased by 16 times.
b) When temperature of conductor is increased its resistance will increase.
Resistance at t°C is $R_t = R_0 (1 + \alpha t)$
where α’ = temperature coefficient of resistance of that conductor.

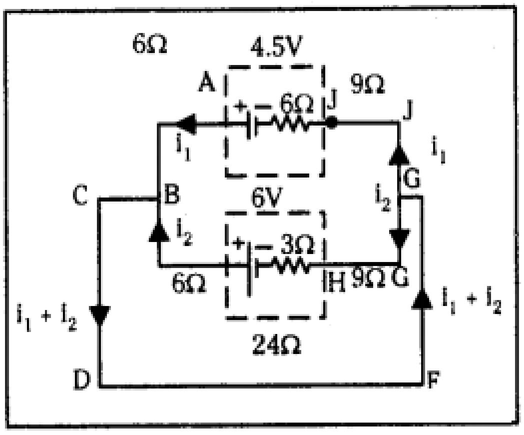
Question 6. When the resistance connected in series with a cell is havled, the current is equal to or slightly less or slightly greater than double. Why?
Answer: Let a cell of emf ‘E’ and internal resistance ‘r’ is connected with external resistance R as shown in figure.



Total resistance in circuit $R_T = R + r \rightarrow (1)$
Current in circuit $i_1 = ER+r \rightarrow (2)$

a) Now external resistance R is reduced to R2.
Total resistance in circuit R_{T_1} = R2 + r
R+2r2 → (2)
From eq (1) and (3)
R+2r2 is not equals to R+r2.
i.e., when R is reduced to R2 total resistance R_{T_1} is not equals to RT2.
So current in the circuit $i_2 \neq 2i_1$. But i_2 is slightly less than $2i_1$ it depends on the value of internal resistance ‘r’.
b) In case of ideal battery where r = 0 then R_{T_2} = R2 in this case
R_{T_2} = RT12and
current $i_2 = 2i_1$.
So when reistance R in the circuit is reduced to half of its value current in circuit is doubled or slightly less than double.

Question 7. Two cells of emfs 4.5V and 6.0V and internal resistance 6Ω and 3Ω respectively have their negative terminals joined by a wire of 18Ω and positive terminals by a wire of 12Ω resistance. A third resistance wire of 24Ω connects middle points of these wires. Using Kirchhoff s laws, find the potential difference at the ends of this third wire.
Answer: The circuit diagram as per given data is as shown



From fig for loop ABCDFGJA
$6i_1 + 24(i_1 + i_2) + 9i_1 - 6i_1 = 4.5$
$33i_1 + 24i_2 = 4.5 \rightarrow (1)$

For loop IBCDFGHI
$6i_2 + 24(i_1 + i_2) + 9i_2 - 3i_2 = 4.5$
$24i_1 + 36i_2 = 6.0 \rightarrow (2)$

eq. 1 × 3 – eq. 2 × 2

$$\begin{array}{lr} \text{eq } 1 \times 3 & 99i + 72\, i_2 = 13.5 \\ \text{eq } 2 \times 2\ (-) & 48i + 72\, i_2 = 12 \\ \hline \end{array}$$

$$51i = 1.5 \Rightarrow i_1 = \frac{1}{34} \rightarrow (3)$$

From eq. (2) $24 \times \frac{1}{34} + 36 i_2 = 6$

$$36\, i_2 = 6 - \frac{24}{34} = \frac{204 - 24}{34} = \frac{180}{34}$$

$$\Rightarrow i_2 = \frac{180}{34 \times 36} = \frac{5}{34} \quad \therefore i_2 = \frac{5}{34}$$

$$i_1 + i_2 = \frac{1}{34} + \frac{5}{34} = \frac{6}{34} = \frac{3}{17}$$

P.D across 24Ω Resistor $(i_1 + i_2)$ R =

$$\frac{24 \times 3}{17} = \frac{72}{17} = 4.235\,\text{V}$$

Question 8. Three resistors each of resistance 10 ohm are connected, in turn, to obtain (i) minimum resistance (ii) maximum resistance. Compute (a) The effective resistance in each case (b) The ratio of minimum to maximum resistance so obtained.

Answer: Resistance of each resistor R = 10Ω ;
Number of Resistors n = 3
a) In parallel combination resistance is minimum.

$$R_{min} = \frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} \Rightarrow R_{eq} = \frac{R}{3} \rightarrow (1)$$

b) In series combination resultant resistance is maximum.

$$\Rightarrow R_{max} = R_{eq} = R + R + R = 3R \rightarrow (2)$$

$$\therefore R_{maximum} = 3R;\ R_{minimum} = R/3$$

$$R_{max} : R_{min} = 3R : \frac{R}{3} = 1 : \frac{1}{9} = 9 : 1$$

Question 9. State Kirchhoff s law for an electrical network. Using these laws deduce the condition for balance in a Wheatstone bridge. [AP Mar. '19. '18. '14. May '16. '14; TS May '18. Mar. '18, '16, June '15]

Answer: Kirchhoffs Laws:

i) Junction rule :

At any junction, the sum of currents towards the junction is equal ' to sum of currents away from the junction.

(OR)

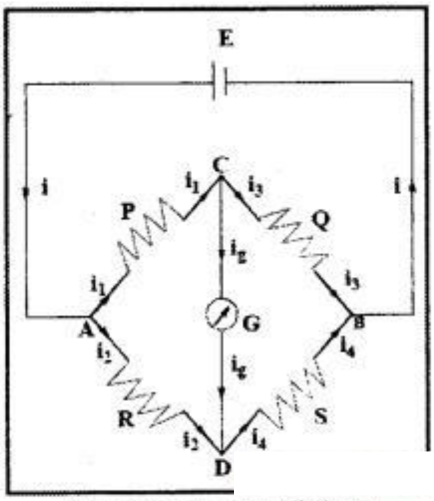
Alzebraic sum of currents around a junction is zero.

ii) Loop rule :

Alzebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero.

Applying Kirchoff's Law to Wheatstones bridge:

Wheatstones bridge consists of four resistances P, Q, R, S connected as shown in the figure and are referred as arms of the bridge.



Wheatston Bridge

A battery of emf 'E' is connected between two junctions A and B and galvanometer of resistance 'G' is connected between 'C' and 'D'.

Applying Kirchoff's first law,

at the junction C; $i_1 = i_g + i_3$ — (1)

at the junction D; $i_2 + i_g = i_4$ — (2)

Applying Kirchoff's second law for the loop ACDA

$-i_1 P - i_g G + i_2 R = 0$ — (3)

For the loop CBDC,

$-i_3 Q + i_4 S + i_g G = 0$ — (4)

If no current passes through the galvanometer then the bridge is said to be balanced.
So, $i_g = 0$, then (1), (2), (3) and (4) becomes
$i_1 = i_3$, $i_2 = i_4$, $i_1P = i_2R$ and $i_3 Q = i_4 S$.
By adjusting the above equations we get PQ=RS.
This is the balancing conditions of a Wheatstones bridge.

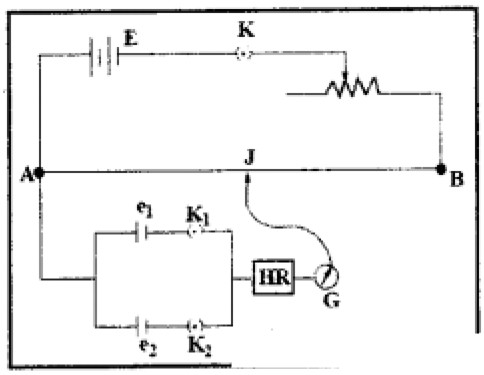
Question 10. State the working principle of potentiometer explain with the help of circuit diagram how the emf of two primary cells are compared by using the potentiometer. [AP Mar. 17,16, May ‘ 17; June ’15; TS Mar. 19, May 16]
Answer: Potentiometer working principle :
Potentiometer consists of 10 meters length of wire with uniform internal resistance. Let total length of wire is L and its total resistance is R_p.

Current through potentiometer wire $i = \frac{E}{(R_p + r)}$

Potential gradient $\phi = \frac{V}{i} = \frac{E}{(R_p + r)} \frac{R_p}{L}$

where Φ = Potential drop per unit length i.e., potential gradient.

Comparison of e.m.f. of two cells :
The circuit diagram used to compare emf of two cells is as shown in figure.
Circuit connection were given as per diagram.



The potentiometer contains two circuits, primary and secondary.

The primary circuit consists of a cell of emf ‘E’ that a plug key (K) and a rheostat (Rh). These are connected in series with potentiometer wire AB.

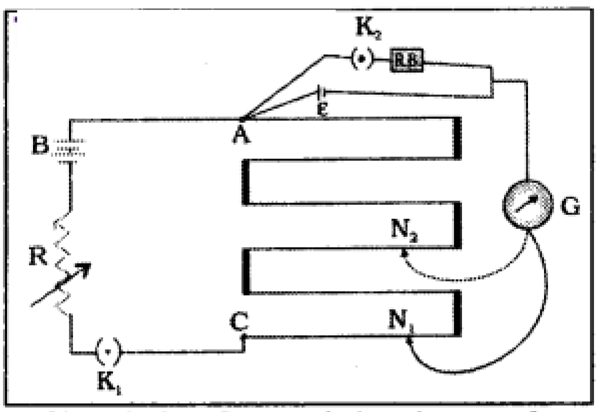
The secondary circuit consists of two cells of emf e_1 and e_2, two plug keys K_1 and K_2, a galvanometer (G) and a Jockey (J) as shown in the figure.

The positive terminals of the two cells in primary and secondary are connected to terminal A'.

Procedure:
i) The plug keys K and K_1 are closed and by adjusting Jockey on the wire, the balancing length 'l_1' is determined.
$e_1 \propto l_1$ ——- (1)

ii) Now plug key K_1 is opened and K_2 is closed. Again the Jockey is adjusted and balancing length 'l_2' is determined.
$e_2 \propto l_2$ ——- (2)
from (1) and (2) $\frac{e_1}{e_2}=\frac{l_1}{l_2}$ Ratio of emf of two cells.

Question 11. State the working principle of potentiometer explain with the help of circuit diagram how the potentiometer is used to determine the internal resistance of the given primary cell. I [AP May 18, Mar. 15; TS Mar. 17. 15, May 17]
Answer: Potentiometer working principle :
Potentiometer consists of 10 meters length of wire with uniform internal resistance. Let total length of wire is L and its total resistance is R_p.



Circuit for determining internal resistance of a cell

Current through potentiometer wire i

$$= \frac{E}{(R_p + r)}$$

Potential gradient $\phi = \frac{V}{i} = \frac{E}{(R_p + r)} \frac{R_p}{L}$

where Φ = Potential drop per unit length i.e., potential gradient.

Determination of internal resistance (r) :
Circuit diagram used to find internal resistance of battery is as shown in figure.

Battery E is connected in primary circuit through plus key k_1.

Another battery E_1 is connected in secondary circuit. A low resistance R' is connected in parallel to Battery E_1 along with key k_2.

Plug k_2 is open. Jockey J is moved on potentiometer until zero deflection is obtained. Balancing length l_1 is measured.

Now $V = \phi l_2 \rightarrow (2)$

From eq 1 & 2 $\varepsilon / V = \frac{l_1}{l_2}$.

But $\varepsilon = I(R + r)$ and V = IR.

$\therefore \frac{I(R + r)}{IR} = \frac{l_1}{l_2} \Rightarrow (R + r) l_2 = R l_1$

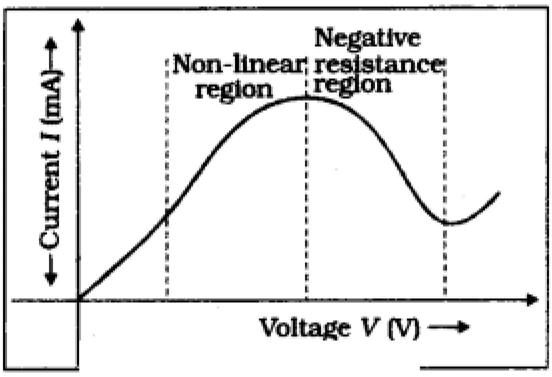
On simplification $r l_2 = (l_1 - l_2) R$

Internal resistance of battery

$$r = \frac{R(l_1 - l_2)}{l_1}$$

Plug key k_2 is closed so resistance R will come into operatioin. Again Jockey J is moved on potentiometer wire to find balancing point. When zero deflection is obtained balancing length l_2 is measured.

Question 12. Show the variation of current versus voltage graph for GaAs and mark the (i) Nonlinear region (ii) Negative resistance region.
Answer: The voltage-current characteristic graph of galium arsinide (GaAs) is as shown in figure.



Variation of current versus voltage for GaAs

GaAs is a semiconducting substance. Its V-I characteristics are non-ohmic. So V-I graph is not linear.
The region OA is linear. In which Ohm's Law is obeyed.
The region AB is a curve (i). Here voltage V is not linear with currrent (i). So It is a non-linear region.

(ii) In the region BC current I decreases even though voltage 'V' increases.
Resistance R = VI
∵ I decreases resistance in the region BC is negative.
The regions (1) and (2) are shown in figure.

Question 13. A student has two wires of iron and copper of equal length and diameter. He first joins two wires in series and passes an electric current through the combination which increases gradually. After that, he joins two wires in parallel and repeats the process of passing current. Which wire will glow first in each case?
Answer: Iron and copper wires of equal length and diameter are taken. For Iron, resistivity is ρ_i high. For copper resistivity, ρ_c is less.
∴ Resistance of Iron wire R_i is high and Resistance of copper wire R_c is less.

a) When connected in series same current flows through Iron and Copper wires. Heat produced $Q = I^2R$. So heat produced in copper wire is less and that of Iron wire is high.

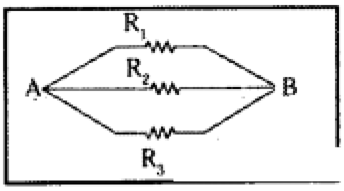
In series combination when current increases gradually than Iron wire will glow first.

b) When the two wires are connected in parallel and current is increased gradually.

In parallel combination high current flows through low resistance and low current through high resistance. They follow the relation $I_c/I_i = R_i/R_c$.

So current through copper wire is high. Heat produced $Q = i^2R \Rightarrow Q_c > Q_t$
Heat produced in copper wire is more than that in iron wire.
So in parallel combination copper wire will glow first.

Question 14. Three identical resistors are connected in parallel and total resistance of the circuit is R/3. Find the value of each resistance.
Answer:
In parallel combination when 'n' identical wires are connected parallelly equivalent resistance is given by $R_{eq} = R/n$.



Given three identical wires $\Rightarrow n = 3$.
$\therefore R_{eq} = R/3$ where R is resistance of each wire.
$\therefore$ Resistance of each wire used in parallel combination is R.

(OR) $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{3}{R}$

But $R_1 = R_2 = R_3 = R$ because they are identical.

$$\therefore \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R} = \frac{1}{R_{eq}}$$

Hence resistance of each wire used in parallel combination is R.

Long Answer **Questions**

Question 1. Under what condition is the heat produced in an electric circuit (a) directly pro-portional (b) inversely proportional to the resistance of the circuit? Compute the ratio of the total quantity of heat produced in the two cases.
Answer: Let a current I is flowing through a conductor between its ends say A and B. Let potential at A is V(A) and potential at B is V(B).

Potential difference across AB is say V = V(A) – V(B)

Let charge flowing in time Δt is $\Delta Q = I\Delta T$
Change in potential energy ΔV = Final P.E – Initial P.E
$= \Delta Q[V(B) - V(A)] = -\Delta QV = -TV\Delta t < 0 \rightarrow (1)$
Let charges are moving without collision with atoms.
Then kinetic energy of charges will also increase.
$\Delta K = -\Delta U_{Pot}$ or $\Delta K = IV\,\Delta t > 0 \rightarrow (2)$
Work done in this process $\Delta W = IV\,\Delta t \rightarrow (3)$
But power

$$P = \frac{\Delta W}{\Delta t} = IV\frac{\Delta T}{\Delta T} \Rightarrow P = IV$$

From Ohm's Law V = IR
∴ Power $P = I.I.R = I^2R$
In this case power $p \propto R$.

In this case energy of charge carriers is useful to heat the conductor. Amount of energy dissipated in conductor per second is power.

Where priority is given to current through conductor, at ordinary voltages we will say that $p \propto R$.

i) In case of transmission lines the primary purpose is to transmit electrical energy from one place to another place. While doing so a part of energy is wasted in conductor in the form of heat. Let total power to be transmitted = P. Resistance of conductor = R_c,
Line voltage = V

Power wasted in transmission or transmission losses P_c = P2RcV2. Due to this reason to reduce transmission losses we are transmitting electric power at very high voltages.
When voltage is given priority power P = V2R

In this case power P is said to be inversely proportional to resistance ‘R’.
Ratio of heats produced in the two cases is $I^2R: V^2/R$
But V = IR
∴ Ratio is I^2R = I2R2R = 1 : 1
Question 2.
Two metallic wires A and B are connected in parallel. Wire A has length L and radius r wire B has a length 2Land radius 2r. Compute the ratio of the total resistance of the parallel combination and resistance of wire A.
Answer:
Let resistivity of metallic wire A is ρ_A and that of B is ρ_B.

For wire A :
Length = L, radius = r, resistivity = ρ_R
Resistance of wire A is R_A = ρALA=ρA·Lπr2 → (1)
For wire B :
Length = 2L; radius = 2r ; resistivity = ρ_B.
Resistance of wire B is

$$R_B = \frac{\rho_B \cdot 2L}{A} = \frac{\rho_B \cdot 2L}{\pi(2r)^2}$$

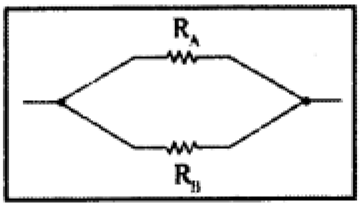
$$= \frac{\rho_B \cdot 2L}{\pi \cdot 4r^2} = \frac{1}{2}\frac{\rho_B L}{\pi r^2} \rightarrow (2)$$

a) Ratio of resistance of the wires = $R_A : R_B$

$$R_A : R_B = \frac{\rho_A L}{\pi r^2} : \frac{\rho_B L}{2\pi r^2} \text{ or}$$

$$R_A : R_B = \rho_A : \frac{\rho_B}{2}$$

b) When resistors RA and Rg are connected in parallel effective resistance



$$R_{eff} = \frac{R_A R_B}{R_A + R_B}$$

$$\therefore R_{eff} = \frac{\frac{\rho_A \cdot L}{\pi r^2} \cdot \frac{\rho_B \cdot L}{2\pi r^2}}{\left(\rho_A L/\pi r^2 + \rho_B L/2\pi r^2\right)}$$

$$= \frac{\left(L/\pi r^2\right)^2 \rho_A (\rho_B/2)}{L/\pi r^2 (\rho_A + \rho_B/2)}$$

$$\therefore R_{eff} = \frac{L/2\pi r^2 \, \rho_A \cdot \rho_B}{(\rho_A + \rho_B/2)}$$

$$= \frac{L}{2\pi r^2} \frac{\rho_A \rho_B}{\left(\frac{2\rho_A + \rho_B}{2}\right)} = \frac{L}{\pi r^2} \frac{\rho_A \rho_B}{(2\rho_A + \rho_B)}$$

c) Resistance of A is say $R_A = \frac{\rho_A \cdot L}{\pi r^2}$

Question 3. In a house three bulbs of 100 W each are lighted for 4 hours daily and six tube lights of 20W each are lighted for 5 hours daily and a refrigerator of 400 W is worked for 10 hours daily for a month of 30 days. Calculate the electricity bill if the cost of one unit is Rs. 4.00.

Answer: Electric consumption in KWH per one month

$$= \frac{(3 \times 100 \times 4 + 6 \times 20 \times 5 + 400 \times 1 \times 10)}{1000} \times 30$$

$$= \frac{1200 + 600 + 4000}{1000} \times 30$$

$$= \frac{5800 \times 30}{1000} = 174 \text{ units}$$

Electricity bill = No. of units × cost of unit = 174 × 4 = Rs. 696/-.

∴ Current bill, for that month is Rs. 696/-

Question 4. Three resistors of 4 ohms, 6 ohms and 12 ohms are connected in parallel. The combination of above resistors is connected in series to a resistance of 2 ohms and then to a battery of 6 volts. Draw a circuit diagram and calculate

a) Cureent in main circuit

b) Current flowing through each of the resistors in parallel

c) P.D and the power used by the 2 ohm resistor.

Answer: Given $R_1 = 4\Omega$, $R_2 = 6\Omega$ and $R_3 = 12\Omega$

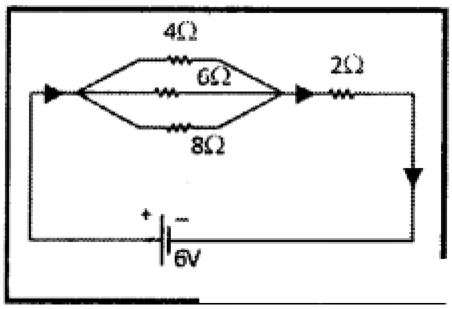
i) When R_1, R_2 and R_3 are connected in parallel effective resistance

$$R_{eff} = \frac{R_1R_2R_3}{R_1R_2 + R_2R_3 + R_3R_1}$$

$$= \frac{4 \times 6 \times 12}{(4 \times 6) + (6 \times 12) + (12 \times 4)}$$

$$= \frac{288}{(24 + 72 + 48)} = \frac{288}{144} = 2\Omega$$

ii) R_{eq} is connected to a 2Ω resistor in series and then to a battery of 6V. The circuit diagram is as shown.



Total Resistance in circuit $= R_{eq} + 2 = 2 + 2 = 4\Omega$

a) Current in main circuit I = VR=64 = 1.5 amp

b) Current through

$$R_1 = \frac{\text{total current } I \times R_{eq} \text{ of other arms}}{R + R_{eq} \text{ of other arms}}$$

$$\therefore R_{eq} = \frac{6 \times 8}{6+8} = \frac{48}{14} = 3.428$$

$$\therefore I_1 = \frac{1.5 \times 3.428}{4 + 3.428} = \frac{5.142}{7.428} = 0.692 \text{ A}$$

For $I_2, R_2 = 6$;

$$R_{eq} \text{ of } 4 \text{ \& } 8 = \frac{4 \times 8}{4+8} = \frac{32}{12} = 2.667\Omega$$

$$I_2 = \frac{1.5 \times 2.667}{6 + 2.667} = \frac{4.0}{8.667} = 0.4615 \text{ A}$$

For $I_3, R_3 = 8$;

$$R_{eq} \text{ 4 \& 6, is} = \frac{4 \times 6}{4 \times 6} = \frac{24}{10} = 2.4$$

$$\therefore I_3 = \frac{1.5 \times 2.4}{8 + 2.4} = \frac{3.6}{10.4} = 0.3462 \text{ A}.$$

c) RD across 2Ω Resistor
$i = 1.5A$, $R = 2\Omega$ ∴ P.D = iR= 1.5 × 2 = 3V
Power used $P = i^2R = 1.5 \times 1.5 \times 2 = 4.5$ watt.

Question 5. Two lamps, one rated 100 W at 220 V and the other 60 W at 220 V are connected in parallel to a 220 volt supply. What current is drawn from the supply line?
Answer: For 1st Lamp power P = 100 W at potential V = 220 V
Supply voltage V = 220 V ; Power P = VI

$$\therefore \text{Current } I = \frac{\text{Power P}}{\text{Supply voltage V}}$$

∴ I_1 = 100200
For 2nd lamp power P = 60 W at 220 V.
Supply voltage = 220 V
Current i_2 = P_2V=60200
Total current drawn by parallel combination
$I = I_1 + I_2 \Rightarrow I = 0.4545 + 2727 = 0.7272$ A
Question 6.
A light bulb is rated at 100W for a 220V supply. Find the resistance of the bulb. [IMP]

Answer:
Power P = 100 W; Potential V = 100 V

$$\text{But power } P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{R} = \frac{100 \times 100}{100} = 100\ \Omega$$

Question 7.
Estimate the average drift speed of conduction electrons in a copper wire of crosssectional area $3.0 \times 10^{-7}\ m^2$ carrying a current of 5 A. Assume that each copper atom contributes roughly one conduction electron. The density of copper is $9.0 \times 10^3\ kg/m^3$ and its atomic mass is 63.5 u.
Answer:
Area $A = 3.0 \times 10^{-7} m^2$;
Current i = 5A
Density $\rho = 9.0 \times 10^3\ kgm^{-3} = 9.0 \times 10^6 gm^{-3}$
Atomic mass m = 63.5 U
Avagadro number $NA = 6.022 \times 10^{23}$;
Charge on electron $e = 1.6 \times 10^{-19}$ C
Drift velocity $v_d = i/neA$. Where n = total number of electrons / unit volume

$$n = N_A \frac{\rho}{m} = \frac{6.022 \times 10^{23} \times 9.0 \times 10^6}{63.5}$$

$$n = 8.5 \times 10^{28}\ m^{-3}$$

$$V_d = \frac{5}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 3.0 \times 10^{-7}}$$

$$V_d = 0.122 \times 10^{-2}\ m/sec$$

$$\text{or, } V_d = 1.22\ mm/sec$$

Question 8.
Compare the drift speed obtained above with
i) Thermal speed of copper atoms at ordinary temperatures.
ii) Speed of propagation of electric field along the conductor which causes the drift motion.
Answer:
Drift velocity of electrons in copper = 1.22 m.m/s
i) Thermal speed of copper atoms $V_T = k_BT/m$———————√.
Where k_B is Boltzman's constant.
$k_B = 1.381 \times 10^{-25}$
Let T = 300 K average temperature or ordinary temperature

m = mass of copper atom, By subtituting the above values V_T = 200 m/ sec
$V_d << V_{rms}$
Thermal speed of copper atom is 10^5 times more than drift velocity of electrons.

ii) An electric field travels with velocity of light along the conductor is velocity of electromagnetic wave 3×10^8m/s.

Speed of electric field travelling along a conductor is 10^{11} times more than drift velocity of electrons.

Problems

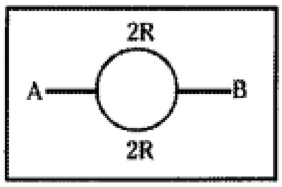
Question 1.
A 10Ω thick wire is stretched so that its length becomes three times. Assuming that there is no change in its density on stretching, calculate the resistance of the stretched wire.
Solution:
Resistance R = 10Ω ; Final length $l_2 = 3l_1$
When a wire is stretched its total volume is constant.

$$\text{Resistivity} = \boxed{\rho = \frac{RA}{l}} = \frac{R \times Al}{l^2} = \frac{Rv}{l^2}$$

(or) $R \propto l^2$ when ρ and v are constant

$$\frac{R_2}{R_1} = \frac{l_2^2}{l_1^2} \Rightarrow R_2 = \frac{9l_1^2}{l_1^2} \times 10 = 90\ \Omega$$

Question 2.
A wire of resistance 4R is bent in the form of a circle. What is the effective resistance between the ends of the diameter? [AP Mar. 19,14. May 16; TS Mar. 16]
Solution:
Resistance = 4R
The wire is bent in the form of a circle and Resistance is to be calculated along its diameter.



Between the point AB the wire is a parallel combination of 2R and 2R.

∴ Resultant resistance 1RR=12R+12R=1R

∴ Effective resistance between A & B = R.

Question 3.

Find the resistivity of a conductor which carries a current of density of 2.5 × 10^6 A m^{-2} when an electric field of 15 Vm^{-1} is applied across it.

Solution:

Current density j = 2.5 × 10^6 A

Electric field E = 15 V m^{-1}

Resistivity ρ = ? Resistivity p = E/j

$$\therefore \rho = \frac{15}{2.5 \times 10^6} = 6 \times 10^{-6} \Omega m$$

Question 4.

What is the color code for a resistor of resistance 3500Ω with 5% tolerance?

Solution:

Resistance R = 3500 Ω. Tolerance = 5%

R = 3500 First digit 4 ⇒ Orange

2nd digit 5 ⇒ Green

Last two digits represent number of zeros = 2 ⇒ Silver

Tolerance = 5% ⇒ gold colour So colour code of that resistor is orange, green, silver and gold bands.

Question 5.

You are given 8Ω resistor. What length of wire of resistivity 120 ftm should be joined in parallel with it to get a value of 6Ω?

Solution:

Resistance Rj = 8Ω, Resistivity ρ = 12Ω m

Resistance across parallel combination R_p = 6Ω

Let parallel resistance to be connected

$x = 120\, l$ metres

For parallel combination $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{x}$

(or) $\frac{1}{x} = \frac{1}{R_p} - \frac{1}{R_1}$

$$\Rightarrow \frac{1}{x} = \frac{R_1 - R_p}{R_1 R_p} \Rightarrow x = \frac{R_1 R_p}{R_1 - R_p}$$

$\therefore x = \frac{6 \times 8}{8 - 6} = \frac{48}{2} = 24\Omega$ But $x = \rho l$

$(\because \rho = \frac{RA}{l}$ (or) $R = \rho l$, when $A = 1)$

$\therefore$ Length of wire to be taken

$$l = \frac{x}{\rho} = \frac{24}{120} = 0.2\text{m}.$$

Question 6.
Three resistors 3Ω, 6Ω and 9Ω are connected to a battery. In which of them will the power dissipation be maximum if: (a) they all are connected in parallel (b) they all are connected in series? Give reasons.
Solution:
Values of resistors $R_1 = 3\ \Omega$; $R_2 = 6\ \Omega$; $R_3 = 9\ \Omega$
a) When in series $R_{eff} = R_1$</sub. $+ R_2 + R_3 = 3 + 6 + 9 = 18$
Power consumed P = V2R=V218 → (1)
b) When connected in parallel total power consumed is the sum of powers in each resistor.

$\therefore$ Total power $P = \frac{V^2}{R_1} + \frac{V^2}{R_2} + \frac{V^2}{R_3}$

$$= \frac{V^2}{3} + \frac{V^2}{6} + \frac{V^2}{9} = \frac{V^2(6+3+2)}{18}$$

$$= \frac{11V^2}{18} \rightarrow (2)$$

From eq 1 & 2 power dissipation is maximum when they are connected in parallel.

Question 7.
A silver wire has a resistance of 2.1Ω at 27.5°C and a resistance of 2.7Ω at 100°C. Determine the temperature coefficient of resistivity of silver.
Solution:

Temperature $t_1 = 27.5°C$;
Resistance $R_1 = 2.1\ \Omega$
Temperature $t_2 = 100°C$;
Resistance $R_2 = 2.7\ \Omega$
Temperature coefficient of resistivity

$$\rho = \frac{R_2 - R_1}{R_1(T_2 - T_1)} /°C$$

$$\therefore \rho = \frac{2.7 - 2.1}{2.1(100 - 27.5)} = \frac{0.6}{(72.5)2.1}$$

$$= 3.94 \times 10^{-3} /°C \cong 0.4 \times 10^{-2} /°C$$

Question 8.
If the length of a wire conductor is doubled by stretching it while keeping the potential difference constant, by what factor will the drift speed of the electrons change?
Solution:
Length of wire is doubled ⇒ $l_2 = 2l_1$
Potential V = constant ; Same material is used ⇒ electron density per unit volume is same.
Drift velocity v_d = ineA here i, n and e are constants.

when stretched $\pi r_1^2 l_1 = \pi r_2^2 l_2 \quad \because A = \pi r^2 l$

$$\therefore r_2^2 / r_1^2 = l_1 / l_2$$

$$\therefore \text{Drift speed } \frac{V_{d_2}}{V_{d_1}} = \frac{kA_1}{kA_2} = \frac{l_2}{l_1} = \frac{r_1^2}{r_2^2}$$

$$\therefore \frac{V_{d_2}}{V_{d_1}} = \frac{2l_1}{l_1} = 2 \Rightarrow V_{d_2} = 2V_{d_1} ;$$

∴ Drift velocity is doubled.
Question 9.
Two 120V light bulbs, one of 25W and another of 200W are connected in series. One bulb burnt out almost instantaneously. Which one was burnt and why?
Solution:
For 1st bulb, Power $P_1 = 25$ W; For 2nd bulb $P_2 = 200$ W
When they are connected to mains supply of 240 V in series

V_1 across 25 W bulb = $\frac{V \cdot R_1}{R_1 + R_2}$.

For 200 W bulb $V_2 = \frac{VR_2}{R_1 + R_2}$

where $R_1 = \frac{V^2}{P_1} = \frac{V^2}{25}$ and

$$R_2 = \frac{V^2}{200} = \frac{12\not{0} \times 12\not{0}}{2\not{0}\not{0}} = 72\,\Omega$$

$$= \frac{120 \times 120}{25} = 4804 = 4800\Omega$$

$$\therefore V_1 = \frac{240 \times 4800}{4800 + 72} = 236V$$

But rated voltage is 120 V only.

$$V_2 = 240 - 236 = 4V$$

In series combination voltage drop is high on high resistance and less on low resistance.

Since voltage on 25W bulb is more than rated voltage it blows off instantly.

Question 10.
A cylindrical metallic wire is stretched to increase its length by 5%.
Calculate the percentage change in resistance.
Solution:
% Increase in length = 5%

given $\frac{\Delta l}{l} \times 100 = 5\%$; But $\frac{R_2}{R_1} = \frac{l_2}{l_1} \cdot \frac{A_1}{A_2}$

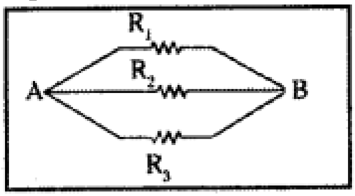
where A_1 & A_2 are areas, But $\frac{A_1}{A_2} = \frac{l_1}{l_2}$

$$\therefore \frac{R_2}{R_1} = \frac{l_2^2}{l_1^2}$$

For small changes in length change in Resistance is given by $\frac{\Delta R}{R} \times 100 = 2\frac{\Delta l}{l} \times 100$

∴ Percentage change in resistance = $2 \times 5 = 10\%$

Question 11.
Three identical resistors are connected in parallel and total resistance of the circuit is R/3. Find the value of each resistance.
Solution:
In parallel combination when 'n' identical wires are connected parallelly, equivalent resistance is given by $R_{eq} = R/n$.



Given three identical wires ⇒ n = 3.
∴ $R_{eq} = R/3$ where R is resistance of each wire.
∴ Resistance of each wire used in parallel combination is R.

(OR) $$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{3}{R}$$

But $R_1 = R_2 = R_3 = R$ because they are identical.

$$\therefore \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R} = \frac{1}{R_{eq}}$$

Hence resistance of each wire used in parallel combination is R.

Question 12.
Two wires A and B of same length and same material, have their cross sectional areas in the ratio 1 : 4. What would be the ratio of heat produced in these wires when the voltage across each is constant?
Solution:
Given lengths of wire are same ⇒ $l_1 = l_2$
Same material is used ⇒ $\rho_1 = \rho_2$
Ratio of area of cross sections $A_1 : A_2 = 1 : 4 \Rightarrow A_2 = 4A_1$
Potentail V is same.

Resistance $R = \frac{\rho l}{A} \Rightarrow R \propto \frac{1}{A}$ (OR)

$$\frac{R_A}{R_B} = \frac{A_2}{A_1} = 4$$

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

$\therefore P_A = \frac{V^2}{R_A}$ & $P_B = \frac{V^2}{R_B}$

$$\frac{P_A}{P_B} = \frac{R_B}{R_A} = \frac{1}{4} \Rightarrow P_A : P_B = 1 : 4$$

∴ Ratio of Heat produced = 1 : 4

Question 13.
Two bulbs whose resistances are in the ratio of 1 : 2 are connected in parallel to a source of constant voltage. What will be the ratio of power dissipation in these?
Solution:
Ratio of resistances ⇒ $R_1 : R_2 = 1 : 2$
⇒ $R_2 = 2R_1$
When in parallel P.D is same on each bulb.

$\therefore P_1$ = Power consumed by 1st bulb = $\frac{V^2}{R_1}$

$\therefore P_2$ = Power consumed by 2nd bulb

$$= \frac{V^2}{R_2} = \frac{V^2}{2R_1}$$

$\therefore P_1 = \frac{V^2}{R_1}$ and $P_2 = \frac{V^2}{2R_1}$, Let $\frac{V^2}{R_1} = k$ then

Ratio of powers $P_1 : P_2 = k : k/2 = 2 : 1$

Question 14.
A potentiometer wire is 5 m long and a potential difference of 6 V is maintained between its ends. Find the emf of a cell which balances against a length of 180 cm of the potentiometer wire. [AP Mar. 17, 16. June 15; TS May 16]
Solution:
Total length of potentiometer wire L = 5 m
= 500 cm

Balancing length $l_1 = 180$ cm
P.D across the terminals = 6V
In potentiometer e.m.f at balancing point
V = ElL6×180500
∴ E.m.f of cell in secondary $E_1 = 2.16$ V

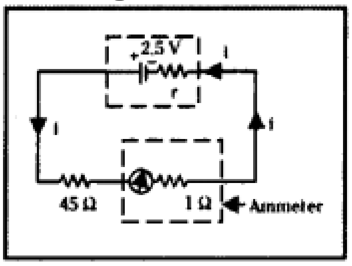
Question 15.
In a potentiometer arrangement, a cell of emf 1.25V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell?
Solution:
Emf of the cell, $E_1 = 1.25$ V
Balance point of the potentiometer, $l_1 = 35$ cm
The cell is replaced by another cell of emf E_2.
New balance point of the potentiometer, $l_2 = 63$ cm.
The balance condition is given by the
relation, $\frac{E_1}{E_2} = \frac{l_1}{l_2}$ (OR)

$$E_2 = E_1 \times \frac{l_2}{l_1} = 1.25 \times \frac{63}{35} = 2.25V$$

Therefore, emf of the second cell is 2.25V.

Question 16.
If the balancing point in a meter-bridge from the left is 60 cm, compare the resistances in left and right gaps of meter-bridge.
Solution:
Balancing point distance $l_1 = 60$ cm
∴ $l_2 = 100 - 60 = 40$ cm
Ratio of resistance R1R2=l1l2=6040=32
(or) $R_1 : R_2 = 3 : 2$
Question 17.
A battery of emf 2.5V and internal resistance r is connected in series with a resistor of 45 ohm through an ammeter of resistance 1 ohm. The ammeter reads a current of 50 mA. Draw the circuit diagram and calculate the value of r. (Internal resistance)
Solution:
E.m.f. of battery $E_1 = 2.5$ V ;
Internal resistance = r
Series Resistance R = 45 Ω;
Ammeter Resistance = 1Ω

Reading in ammeter = 50 mA = 50×10^{-3} Amp



From Kirchhoff's mesh rule

$E = iR + iR_1 - ir$

$2.5 = i\,45 + i \times 1 - ir$

$\Rightarrow ir = 45\,i + i - ir \Rightarrow E - 46i = -ir$

$\therefore 2.5 - 46 \times 50 \times 10^{-3} = -50 \times 10^{-3}\, r \Rightarrow 2.5 - 2.3 = -ir$

$\therefore r = -0.250 \times 10{-3}$ -ve sign indicates current in opposite direction.

$\therefore$ Internal resistance of battery

$r = 20050 = 4\Omega$

Question 18.

Amount of charge passing through the cross section of a wire is $q(t) = at^2 + bt + c$. Write the dimensional formula for a, b and c. If the values of a, b and c in SI unit are 6, 4, 2 respectively, find the value of current at t = 6 seconds.

Solution:

Given $q\,(t) = at^2 + bt + c$

But current $i = ddt\, q(t) = ddt\, (at^2 + bt + c) = 2at + b \rightarrow (1)$

Put a = 6, b = 4, c = 2 and t = 6 in eq – (1)

$\therefore$ Current i = 2x6x6 + 4 = 72 + 4 = 76 Amp

Intext **Question** and Answer

Question 1.

The storage battery of a car has an emf of 12V. If the internal resistance of the battery is 0.4Ω, what is the maximum current that can be drawn from the battery?

A. Emf of the battery, E = 12 V ;

Internal resistance of the battery, r = 0.4Ω

Maximum current drawn from the battery = I ; According to Ohm's law,

E = Ir

$I = Er = 120.4 = 30$ A

The maximum current drawn from the given battery is 30 A.

Question 2.

A potentiometer wire is 5 m long and a potential difference of 6V is maintained between its ends. Find the emf of a cell which balances against a length of 180 cm of the potentiometer wire. [TS May '16]

Answer:

Total length of potentiometer wire L = 5 m = 500 cm

Balancing length l_1 = 180 cm
P.D across the terminals = 6V
In potentiometer e.m.f at balancing point
El 6×180
V = ElL=6×180500
∴ E.m.f of cell in secondary E_1 = 2.16 V
Question 3.
A battery of emf 10 V and internal resistance 3Ω is connected to a resistor (R). If the current in the circuit is 0.5 A, what is the resistance (K) of the resistor? What is the terminal voltage of the battery when the circuit is closed? [(IMP) TS Mar, '15]
Answer:
Emf of the battery, E = 10 V ;
Internal resistance of the battery, r = 3 Ω
Current in the circuit, 1 = 0.5 A ;Resistance of the resistor = R
The relation for current using Ohm s law is,
I = ER+r ⇒ R + r = EI = 100.5 = 20 Ω;
∴ R = 20 – 3 = 17 Ω
Terminal voltage of the resistor = V
According to Ohm's law,
V = IR = 0.5 × 17 = 8.5 V
Therefore, the resistance of the resistor is 17 Ω and the terminal voltage is 8.5 V.

Question 6.
A negligibly small current is passed through a wire of length 15 m and uniform crosssection $6.0 \times 10^{-7} m^2$, and its resistance is measured to be 5.0 Ω. What is the resistivity of the material at the temperature of the experiment?
Answer:
Length of the wire, l = 15 m
Area of cross-section of the wire, a = $6.0 \times 10^{-7} m^2$
Resistance of the material of the wire.
R = 5.0 Ω
Resistivity of the material of the wire = ρ
Resistance is related with the resistivity as

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

$$\rho = \frac{RA}{l} = \frac{5 \times 6 \times 10^{-7}}{15} = 2 \times 10^{-7}\ \Omega m$$

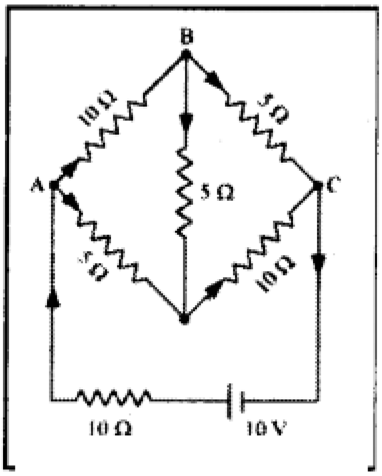
Therefore, the resistivity of the material is $2 \times 10^{-7}\ \Omega$ m.

Question 5.
A silver wire has a resistance of 2.1 Ω at 27.5 °C, and a resistance of 2.7 Ω at 100 °C. Determine the temperature coefficient of resistivity of silver.
Answer:
Temperature, $T_1 = 27.5°C$;
Resistance of the silver wire at T_1, $R_1 = 2.1\ \Omega$
Temperature, $T_2 = 100°C$;
Resistance of the silver wire at T_2, $R_2 = 2.7\ \Omega$
Temperature coefficient of silver = α
It is related with temperature and resistance as

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)} = \frac{2.7 - 2.1}{2.1(100 - 27.5)} = 0.0039°C^{-1}$$

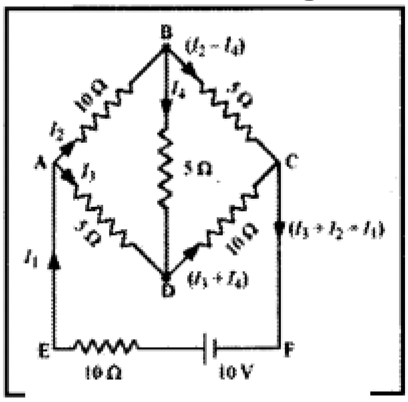
Therefore, the temperature coefficient of silver is $0.0039°C^{-1}$.

Question 6.
Determine the current in each branch of the network shown in fig:



Answer:
Current flowing through various branches of the circuit is represented in the given figure.
I_1 = Current flowing through the outer circuit
I_2 = Current flowing through branch AB
I_3 = Current flowing through branch AD
$I_2 - I_4$ = Current flowing through branch BC
$I_3 - I_4$ = Current flowing through branch CD

I_4 = Current flowing through branch BD



For the closed circuit ABDA, potential is zero i.e.,
$10I_2 + 5I_4 - 5I_3 = 0$ (OR) $\Rightarrow 2I_2 + I_4 - I_3 = 0$
$I_3 = 2I_2 + I_4$ …… (1)
For the closed circuit BCDB, potential is zero i.e.,
$5(I_2 - I_4) - 10(I_3 + I_4) - 5I_4 = 0$ (OR)
$5I_2 + 5I_4 - 10I_3 - 10I_4 - 5I_4 = 0$
$5I_2 - 10I_3 - 20I_4 = 0$; $I_2 = 2I_3 + 4I_4$ ….. (2)
For the closed circuit ABCFEA, potential is zero i.e.,
$-10 + 10(I_1) + 10(I_2) + 5(I_2 - I_4) = 0$
$10 = 15I_2 + 10I_2 - 5I_4 \Rightarrow 3I_2 + 2I_1 - I_4 = 2$ ….. (3)
From equations (1) and (2), we obtain
$I_3 = 2(2I_3 + 4I_4) + I_4$; $I_3 = 4I_3 + 8I_4 + I_4 - 3I_3 = 9I_4 \Rightarrow -3I_4 = +I_3$ ….. (4)
Putting equation (4) in equation (1), we obtain
$I_3 = 2I_2 + I_4$ (OR) $\Rightarrow -4I_4 = 2I_2$; $I_2 = -2I_4$ …… (5)
It is evident from the given figure that,
$I_1 = I_3 + I_2$ ……. (6)
Putting equation (6) in equation (1), we obtain
$3I_2 + 2(I_3 + I_2) - I_4 = 2$
$5I_2 + 2I_3 - I_4 = 2$ ….. (7)
Putting equations (4) and (5) in equation (7), we obtain $5(-2I_4) + 2(-3I_4) - I_4 = 2 - 10I_4 - 6I_4 - I_4 = 2$ (OR) $17I_4 = -2$
$\Rightarrow I_4 = -217$ A

Equation (4) reduces to $I_3 = -3(I_4)$ = -3−217=617A

$$I_2 = -2(I_4) = -2\left(\frac{-2}{17}\right) = \frac{4}{17}A$$

$$I_2 - I_4 = \frac{4}{17} - \left(\frac{-2}{17}\right) = \frac{6}{17}A \text{ (or)}$$

$$I_3 + I_4 = \frac{6}{17} + \left(\frac{-2}{17}\right) = \frac{4}{17}A$$

$$\therefore I_1 = I_3 + I_2 = \frac{6}{17} + \frac{4}{17} = \frac{10}{17}A$$

Therefore, current in branch $AB = \frac{4}{17}$ A;

In branch $BC = \frac{6}{17}A$

In branch $CD = \frac{-4}{17}A$; In branch $AD = \frac{6}{17}A$

In branch $BD = \left(\frac{-2}{17}\right)A$;

Total current

$$= \frac{4}{17} + \frac{6}{17} + \frac{-4}{17} + \frac{6}{17} + \frac{-2}{17} = \frac{10}{17}A$$

Question 7.

In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell? [(IMP) AP Mar. '15]

Answer:

Emf of the cell, $E_1 = 1.25$ V

Balance point of the potentiometer, $l_1 = 35$ cm

The cells is replaced by another cell of emf E_2.

New balance point of the potentiometer, $l_2 = 63$ cm

The balance condition is given by the

relation, $\frac{E_1}{E_2} = \frac{l_1}{l_2}$ (OR)

$$E_2 = E_1 \times \frac{l_2}{l_1} = 1.25 \times \frac{63}{35} = 2.25V$$

Therefore, emf of the second cell is 2.25V.

Question 8.

The number density of free electrons in a copper conductor estimated in Example 6.1 is 8.5×10^{28} m^{-3}. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is 2.0×10^{-6} m^2 and it is carrying a current of 3.0 A.

Answer:

Number density of free electrons in a copper conductor, $n = 8.5 \times 10^{28}$ m^{-3},
Length of the copper wire, l = 3.0 m
Area of cross-section of the wire, $A = 2.0 \times 10^{-6}$ m^2
Current carried by the wire, I = 3.0 A, which is given by the relation,
$I = nAeV_d$
Where, e = Electric charge $= 1.6 \times 10^{-19}$ C
v_d = Drift velocit

$$= \frac{\text{Length of the wire } (l)}{\text{Time taken to cover } (t)};$$

$$I = nAe\frac{l}{t} \text{ (OR) } t = \frac{nAel}{I}$$

$$= \frac{3 \times 8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}{3.0}$$

$$= 2.7 \times 10^4 \text{ s}$$

Therefore, the time taken by an electron to drift from one end of the wire to the other is 2.7×10^4 s.