HIGHER SECONDARY
SECOND YEAR

PHYSICS

UNIT -2

CURRENT ELECTRICITY

PROBLEMS AND SOLUTIONS

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EXAMPLE PROBLEMS

1. Compute the current in the wire if a charge of 120 C is flowing through a copper wire in 1 minute.

Solution :- $t = 1\, min = 60\, s$; $q = 120\, C$; $I = ?$

- By definition, electric current (i.e.) rate of flow of charge is given by,

$$I = \frac{q}{t} = \frac{120}{60} = \mathbf{2\, A}$$

2. If an electric field of magnitude 570 N C⁻¹, is applied in the copper wire, find the acceleration experienced by the electron.

Solution :- $E = 570\, N\, C^{-1}$; $e = 1.6\, X\, 10^{-19}\, C$; $m = 9.1\, X\, 10^{-31}\, kg$; $a = ?$

- From Newton's second law, force is given by ; $F = m\, a$
- Hence the acceleration,

$$a = \frac{F}{m} = \frac{e\,E}{m} = \frac{1.6\, X\, 10^{-19}\, X\, 570}{9.1\, X\, 10^{-31}} = \frac{912}{9.1}\, X\, 10^{12} = 100.1\, X\, 10^{12}$$

$$\mathbf{a = 1.001\, X\, 10^{14}\, m\, s^{-2}}$$

3. A copper wire of cross-sectional area 0.5 mm² carries a current of 0.2 A. If the free electron density of copper is 8.4 × 10²⁸ m⁻³ then compute the drift velocity of free electrons.

Solution :- $A = 0.5\, mm^2 = 0.5\, X\, 10^{-6}\, m^2$; $I = 0.2\, A$; $n = 8.4\, X\, 10^{28}\, m^{-3}$

- The relation between drift velocity of electrons and current in a wire of cross-sectional area A is ; $I = n\, A\, e\, v_d$
- Hence, the drift velocity ; $v_d = \frac{I}{n\, A\, e}$

$$v_d = \frac{0.2}{8.4\, X\, 10^{28}\, X\, 0.5\, X 10^{-6} X\, 1.6\, X\, 10^{-19}} = \frac{0.2\, X\, 10^{-3}}{6.72}$$

$$v_d = 2.976\, X\, 10^{-2} X\, 10^{-3} = 2.976\, X\, 10^{-5}\, m\, s^{-1}$$

$$\mathbf{v_d = 0.02976\, X\, 10^{-3}\, m\, s^{-1} \approx 0.03\, X 10^{-3}\, m\, s^{-1}}$$

No	Log
0.2 6.72	$\bar{1}.3010$ 0.8274
(-) ALog	$\bar{2}.4736$ $2.976\, X\, 10^{-2}$

4. Determine the number of electrons flowing per second through a conductor, when a current of 32 A flows through it.

Solution :- $I = 32\, A$; $t = 1\, s$; $e = 1.6\, X\, 10^{-19}$; $n = ?$

- By definition, current (rate of flow of charge) is given by ; $I = \frac{q}{t} = \frac{n\, e}{t}$
- Hence the number of electrons flowing per second ;

$$n = \frac{I\, t}{e} = \frac{32\, X\, 1}{1.6\, X\, 10^{-19}} = 20\, X\, 10^{19} = \mathbf{2\, X\, 10^{20}\, electrons}$$

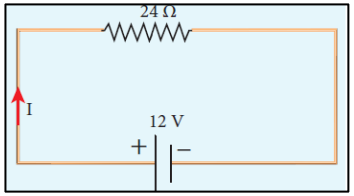
5. A potential difference across 24 Ω resistor is 12 V. What is the current through the resistor?

Solution :- R = 24 Ω ; V = 12 V ; I = ?

- From Ohm's law;

$$I = \frac{V}{R} = \frac{12}{24} = \frac{1}{2}$$

$$\mathbf{I = 0.5\, A}$$



6. The resistance of a wire is 20 Ω. What will be new resistance, if it is stretched uniformly 8 times its original length?

Solution :- $R_1 = 20\, \Omega$; $l_1 = l$; $l_2 = 8\, l$; $R_2 = ?$

- Though the wire is stretched, its volume remains unchanged.(i.e.)

Initial volume = final volume

$$A_1 l_1 = A_2 l_2$$

$$A_1\, l = A_2\, (8\, l)$$

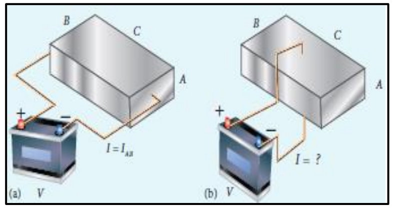
$$\frac{A_2}{A_1} = \frac{1}{8} \quad ------- \;(1)$$

- Initial resistance ; $R_1 = \rho\, \frac{l_1}{A_1}$
- New resistance ; $R_2 = \rho\, \frac{l_2}{A_2}$
- Hence the ratio ; $\frac{R_1}{R_2} = \frac{l_1}{A_1}\frac{A_2}{l_2} = \frac{A_1}{A_1}\frac{l_1}{l_2} = \frac{1}{8}\, X\, \frac{l}{8\, l} = \frac{1}{64}$

$$\therefore \quad R_2 = 64\, R_1 = 64\, X\, 20 = \mathbf{1280\, \Omega}$$

- Hence, stretching the length of the wire has increased its resistance.

7. Consider a rectangular block of metal of height A, width B and length C as shown in the figure. If a potential difference of *V* is applied between the two faces A and B of the block [figure (a)], the current I_{AB} is observed. Find the current that flows if the same potential difference *V* is applied between the two faces B and C of the block [figure (b)]. Give your answers in terms of I_{AB}.



Solution :-

- In first case ; length =C and area = AB. Hence resistance and current

$$R_{AB} = \rho\, \frac{length}{area} = \rho\, \frac{C}{AB}$$

$$I_{AB} = \frac{V}{R_{AB}} = \frac{V}{\left[\rho\, \frac{C}{AB}\right]} = \frac{V\,(AB)}{\rho\, C} \quad ---- \;(1)$$

- In second case ; length =A and area = BC. Hence resistance and current

$$R_{BC} = \rho\, \frac{length}{area} = \rho\, \frac{A}{BC}$$

$$I_{BC} = \frac{V}{R_{BC}} = \frac{V}{\left[\rho\, \frac{A}{BC}\right]} = \frac{V\,(BC)}{\rho\, A} \quad ---- \;(2)$$

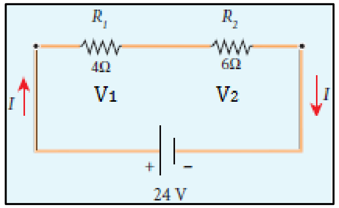
- Divide equation (2) by (1), we get

$$\frac{I_{BC}}{I_{AB}} = \frac{[V\,(BC)/\rho\, A]}{[V\,(AB)/\rho\, C]} = \frac{V\,(BC)}{\rho\, A}\, X\, \frac{\rho\, C}{V\,(AB)} = \frac{C^2}{A^2}$$

$$\mathbf{I_{BC} = \frac{C^2}{A^2}\, I_{AB}}$$

- Since $C > A$, the current $\mathbf{I_{BC} > I_{AB}}$

8. Calculate the equivalent resistance for the circuit which is connected to 24 V battery and also find the potential difference across each resistors in the circuit.



Solution :- $R_1 = 4\,\Omega$; $R_2 = 6\,\Omega$; V = 24 V

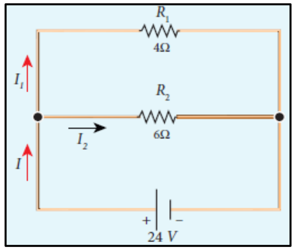
- Effective resistance in series circuit,

$$R_S = R_1 + R_2 = 4 + 6 = \mathbf{10\,\Omega}$$

- From Ohm's law, current in the circuit ; $I = \frac{V}{R_S} = \frac{24}{10} = \mathbf{2.4\ A}$
- Hence voltage across the resistors,

$$V_1 = I\,R_1 = 2.4\ X\ 4 = \mathbf{9.6\ V}$$
$$V_2 = I\,R_2 = 2.4\ X\ 6 = \mathbf{14.4\ V}$$

9. Calculate the equivalent resistance in the following circuit and also find the values of current I, I_1 and I_2 in the given circuit.



Solution :- $R_1 = 4\,\Omega$; $R_2 = 6\,\Omega$; V = 24 V

- Effective resistance in parallel circuit,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{4} + \frac{1}{6} = \frac{6+4}{24} = \frac{10}{24} = \frac{1}{2.4}$$

(or) $\mathbf{R_P = 2.4\,\Omega}$

- Then current flows through the resistors,

$$I_1 = \frac{V}{R_1} = \frac{24}{4} = \mathbf{6\ A}$$
$$I_2 = \frac{V}{R_2} = \frac{24}{6} = \mathbf{4\ A}$$

- The current I is the sum of the currents in the two branches. Then

$$I = I_1 + I_2 = 6 + 4 = \mathbf{10\ A}$$

10. Two resistors when connected in series and parallel, their equivalent resistances are 15 Ω and $\frac{56}{15}$ Ω respectively. Find the values of the resistances.

Solution :- $R_S = 15\,\Omega$; $R_P = \frac{56}{15}\,\Omega$; $R_1 = ?$; $R_2 = ?$

- Effective resistance in series circuit ; $R_S = R_1 + R_2$

$$15 = R_1 + R_2 \qquad ---------- \quad (1)$$

- Effective resistance in parallel circuit ; $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 R_2}$

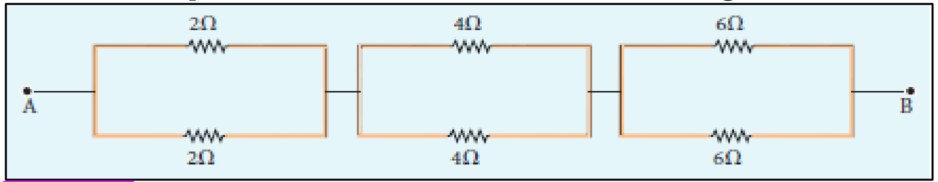
$$\frac{15}{56} = \frac{R_1 + R_2}{R_1 R_2} = \frac{15}{R_1\,R_2} \qquad [\because \text{by eqn } (1)]$$
$$\therefore \quad 56 = R_1\,R_2 \qquad --------- \quad (2)$$

- From equation (1) & (2) ; $R_1 + R_2 = 15$ and $R_1 R_2 = 56$, we get

$$R_1 = 7 \quad \& \quad R_2 = 8 \quad (or) \quad R_1 = 8 \quad \& \quad R_2 = 7$$

- If $R_1 = 7$ then, $R_2 = 15 - R_1 = 15 - 7 = 8$. So $\mathbf{R_1 = 7\,\Omega}$; $\mathbf{R_2 = 8\,\Omega}$
- If $R_1 = 8$ then, $R_2 = 15 - R_1 = 15 - 8 = 7$. So $\mathbf{R_1 = 8\,\Omega}$; $\mathbf{R_2 = 7\,\Omega}$

11. Calculate the equivalent resistance between A and B in the given circuit.

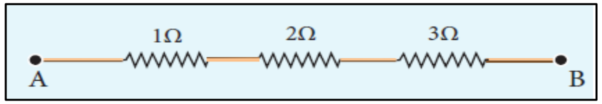


Solution :- $R_{AB} = ?$

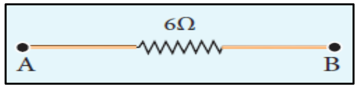
- Here, 2 Ω and 2 Ω , 4 Ω and 4 Ω, 6 Ω and 6 Ω are in parallel, then

$$\frac{1}{R_{P1}} = \frac{1}{2} + \frac{1}{2} = 1 \quad (or) \quad R_{P1} = 1\,\Omega$$
$$\frac{1}{R_{P2}} = \frac{1}{4} + \frac{1}{4} = \frac{1}{2} \quad (or) \quad R_{P2} = 2\,\Omega$$
$$\frac{1}{R_{P3}} = \frac{1}{6} + \frac{1}{6} = \frac{2}{6} \quad (or) \quad R_{P2} = \frac{6}{2} = 3\,\Omega$$

- Thus the above circuit becomes,



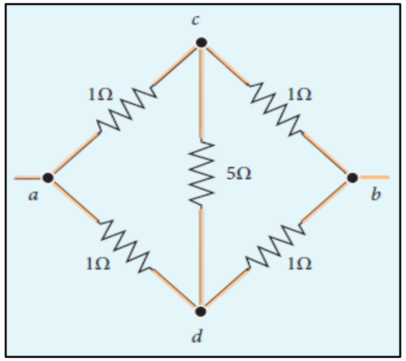
- Here, 1 Ω, 2 Ω and 3 Ω are in series, then the effective resistance becomes,



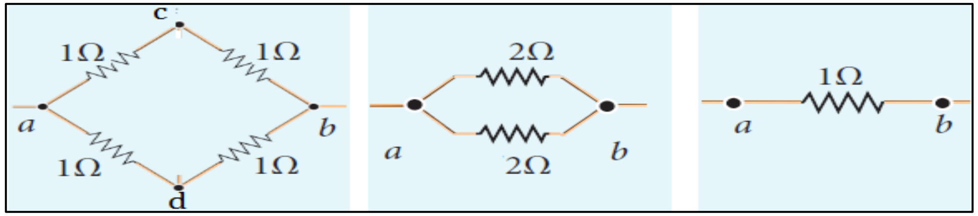
$$R_{AB} = R_{P1} + R_{P2} + R_{P3} = 1 + 2 + 3$$
$$\mathbf{R_{AB} = 6\,\Omega}$$

12. Five resistors are connected in the configuration as shown in the figure. Calculate the equivalent resistance between the points a and b.

Solution :-



- Let us assume that a current is entering the junction at a.
- Since all the resistances in the outside loop are the same (1Ω), the current in the branches ac and ad must be equal. Hence the points C and D are at the same potential and no current through 5 Ω.
- It implies that the 5 Ω has no role in determining the equivalent resistance and it can be removed. So the circuit is simplified as shown in the figure.



- Effective resistance in series connection is,

$$\boldsymbol{R_{S1}} = R_{ac} + R_{cb} = 1 + 1 = 2\,\Omega$$
$$\boldsymbol{R_{S2}} = R_{ad} + R_{db} = 1 + 1 = 2\,\Omega$$

- Effective resistance in parallel connection is,

$$\frac{1}{R_{ab}} = \frac{1}{R_{S1}} + \frac{1}{R_{S2}} = \frac{1}{2} + \frac{1}{2} = 1$$
$$\boldsymbol{R_{ab} = 1\,\Omega}$$

13. If the resistance of coil is 3 Ω at 200 C and α = 0.004/^{0}C then determine its resistance at 100 ^{0}C.

Solution :- $T_o = 20\,°C$; $T = 100\,°C$; $R_o = 3\,\Omega$; $R_T = ?$

- Resistance at $T\,°C$; $R_T = R_o\,[1 + \alpha\,(T - T_o)]$

$$R_T = 3\,[\,1 + 0.004\,(100 - 20)] = 3\,[1 + 0.004\,X\,80]$$
$$R_T = 3\,[\,1 + 0.32] = 3\,X\,1.32$$
$$\boldsymbol{R_T = 3.96\,\Omega}$$

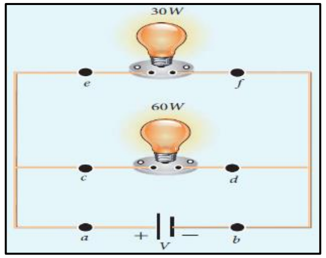
14. Resistance of a material at 20^{0}C and 40^{0}C are 45 Ω and 85 Ω respectively. Find its temperature coefficient of resistivity.

Solution :- $T_o = 20°\,C$; $T = 40°\,C$; $R_o = 45\,\Omega$; $R_T = 85\,\Omega$; $\alpha = ?$

- The temperature coefficient of resistivity is

$$\alpha = \frac{1}{R_o}\frac{\Delta R}{\Delta T} = \frac{1}{R_o}\frac{(R_T - R_o)}{(T - T_o)}$$
$$\alpha = \frac{1}{45}\,X\,\frac{(85-45)}{(40-20)} = \frac{1}{45}\,X\,\frac{40}{20} = \frac{1}{45}\,X\,2$$
$$\boldsymbol{\alpha = 0.044\,/\,°C}$$

15. A battery of voltage V is connected to 30 W bulb and 60 W bulb as shown in the figure. (a) Identify brightest bulb (b) which bulb has greater resistance? (c) Suppose the two bulbs are connected in series, which bulb will glow brighter?



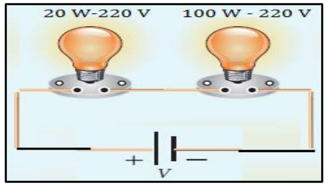
Solution :- $P_1 = 30\,W$; $P_2 = 60\,W$

(a) The power delivered by the battery ; $P = V\,I$.
Since the bulbs are connected in parallel, the voltage drop across each bulb is the same. If the voltage is kept fixed, then the power is directly proportional to current ($P \propto I$). Since $P_1 < P_2$, we have $I_1 < I_2$. So 60 W bulb draws twice as much as current as 30 W and hence ***60 W bulb will glow brighter than 30 W bulb***.

(b) The power delivered by the battery ; $P = V\,I = \frac{V^2}{R}$. Hence $P \propto \frac{1}{R}$
Since $P_1 < P_2$, we have $R_1 > R_2$. It implies that, the ***30W has twice as much as resistance as 60 W bulb***.

(c) When the bulbs are connected in series, the current passing through each bulb is the same. It is equivalent to two resistors connected in series. The bulb which has higher resistance has higher voltage drop. So ***30W bulb will glow brighter than 60W bulb.*** So the higher power rating does not always imply more brightness and it depends whether bulbs are connected in series or parallel.

16. Two electric bulbs marked 20 W – 220 V and 100 W – 220 V are connected in series to 440 V supply. Which bulb will get fused?



Solution :-

- To check which bulb will get fused, the voltage drop across each bulb has to be calculated.
- The power delivered by the battery ; $P = V\,I = \frac{V^2}{R}$
- Hence the resistance of the bulbs,

$$R_1 = \frac{{V_1}^2}{P_1} = \frac{220^2}{20} = \frac{48400}{20} = 2420\,\Omega$$
$$R_2 = \frac{{V_2}^2}{P_2} = \frac{220^2}{100} = \frac{48400}{100} = 484\,\Omega$$

No	Log
440 2904	2.6435 3.4630
(-) ALog	$\bar{1}.1805$ $1.515\,X\,10^{-1}$

- The two bulbs are connected in series, effective resistance

$$R_{tot} = 2420 + 484 = 2904\,\Omega$$

No	Log
0.1515 2420	$\bar{1}.1805$ 3.3838
(+) ALog	2.5643 $3.667\,X\,10^2$

- When the bulbs are connected in series, the current passing through each bulb is the same and it is given by,

$$I = \frac{V}{R_{tot}} = \frac{V_1 + V_2}{R_{tot}} = \frac{220 + 220}{2904} = \frac{440}{2904}\,A$$
$$I = 1.515\,X\,10^{-1}\,A = 0.1515\,A$$

No	Log
0.1515 484	$\bar{1}.1805$ 2.6848
(+) ALog	1.8653 $7.333\,X\,10^1$

- The voltage drop across the 20W bulb is

$$V_1 = I\,R_1 = 0.1515\,X\,2420 = 3.667\,X\,10^2 = \boldsymbol{366.7\,V}$$

- The voltage drop across the 100W bulb is

$$V_2 = 0.1515\,X\,484 = 7.333\,X\,10^1 = \boldsymbol{73.33\,V}$$

- ***The 20 W bulb will get fused*** because the voltage across it is more than the voltage rating.

17. A battery has an emf of 12 V and connected to a resistor of 3 Ω. The current in the circuit is 3.93 A. Calculate (a) terminal voltage and the internal resistance of the battery (b) power delivered by the battery and power delivered to the resistor

Solution :- I = 3.93 A ; ϵ = 12 V ; R = 3 Ω

(a) The terminal voltage of the battery is equal to voltage drop across the resistor

$$\boldsymbol{V} = I\,R = 3.93\,X\,3 = \boldsymbol{11.79\,V}$$

Internal resistance of the battery,

$$r = \left[\frac{\epsilon - V}{V}\right] R = \left[\frac{12 - 11.79}{11.79}\right] X\,3$$
$$\boldsymbol{r} = \frac{0.21 X\,3}{11.79} = \frac{0.63}{11.79} = 5.341\,X\,10^{-2}\,\Omega = \boldsymbol{0.05341\,\Omega}$$

(b) The power delivered by the battery,

$$P = \epsilon\,I = 12\,X\,3.93 = 47.16\,W$$

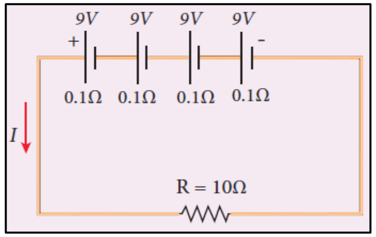
The power delivered to the resistor

$$P = V\,I = 11.79\,X\,3.93 = 46.33\,W$$

The remaining power P = 47.16 − 46.33 = **0.83 *W*** is delivered to the internal resistance and cannot be used to do useful work. (It is equal to $I^2 r$).

18. From the given circuit, Find

(a) Equivalent emf of the combination
(b) Equivalent internal resistance
(c) Total current
(d) Potential difference across external resistance
(e) Potential difference across each cell



Solution :- $n = 4$; $\in = 9\,V$; $r = 0.1\,\Omega$

(a) Equivalent emf of the combination ; $\in_{tot} = n\,\in = 4\,X\,9 = \mathbf{36\,V}$

(b) Equivalent internal resistance ; $r_{tot} = n\,r = 4\,X\,0.1 = \mathbf{0.4\,\Omega}$

(c) Total current ;

$$I = \frac{n\,\in}{R + n\,r} = \frac{4\,X\,9}{10 + 4\,X\,0.1}$$

$$I = \frac{36}{10 + 0.4} = \frac{36}{10.4} = \mathbf{3.462\,A}$$

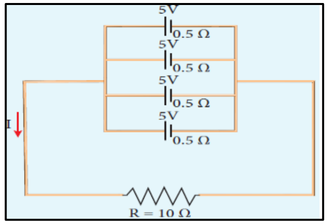
No	Log
36 10.4	1.5563 1.0170
(-) ALog	0.5393 3.462 X 10⁰

(d) Potential difference across external resistance ; $V = I\,R = 3.462\,X\,10 = \mathbf{34.62\,V}$

(e) Potential difference across each cell ; $\mathbf{v} = \frac{V}{4} = \frac{34.62}{4} = \mathbf{8.655\,V}$

19. From the given circuit. Find

(a) Equivalent emf
(b) Equivalent internal resistance
(c) Total current (I)
(d) Potential difference across each cell
(e) Current from each cell



Solution :-

(a) Equivalent emf ; $\in_{tot} = \in = \mathbf{5\,V}$

(b) Equivalent internal resistance ; $r_{tot} = \frac{r}{n} = \frac{0.5}{4} = \mathbf{0.125\,\Omega}$

(c) Total current ; $I = \frac{\in}{R + \frac{r}{n}} = \frac{5}{10 + \frac{0.5}{4}}$

$$I = \frac{5}{10 + 0.125} = \frac{5}{10.125}$$

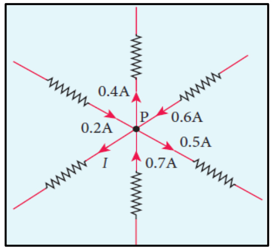
$$I = 4.939\,X\,10^{-1}\,A = \mathbf{0.4939\,A} \approx \mathbf{0.5\,A}$$

No	Log
5 10.125	0.6990 1.0054
(-) ALog	1.6936 4.939 X 10⁻¹

(d) Potential difference across each cell ; $V = I\,R = 0.5\,X\,10 = \mathbf{5\,V}$

(e) Current from each cell ; $I^1 = \frac{I}{n} = \frac{0.5}{4} = \mathbf{0.125\,A}$

20. For the given circuit find the value of I.

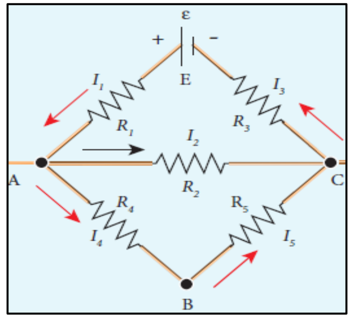


Solution :-

- From Kirchoff's first law, at junction P ; $\sum I = 0$

$$0.2 + (-0.4) + 0.6 + (-0.5) + 0.7 + (-I) = 0$$
$$0.2 - 0.4 + 0.6 - 0.5 + 0.7 - I = 0$$
$$\therefore \quad I = 0.2 - 0.4 + 0.6 - 0.5 + 0.7$$
$$\mathbf{I = 1.5 - 0.9 = 0.6\,A}$$

21. The following figure shows a complex network of conductors which can be divided into two closed loops like EACE and ABCA.



Solution :-

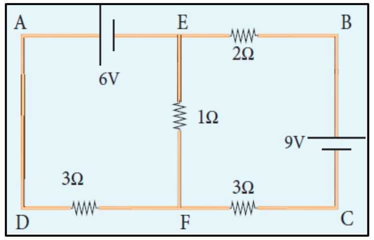
- Apply Kirchhoff's voltage rule (KVR) in **EACE**

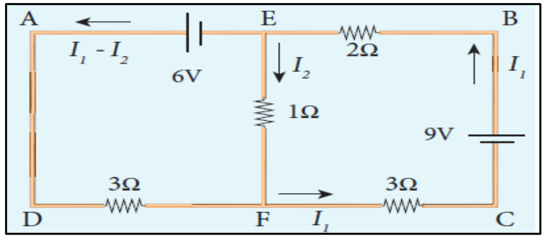
$$\sum I\,R = \sum \in$$
$$I_1R_1 + I_2R_2 + I_3R_3 = \in$$

- Apply Kirchhoff's voltage rule (KVR) in **ABCA**

$$\sum I\,R = \sum \in$$
$$I_4R_4 + I_5R_5 - I_3R_3 = 0$$

22. Calculate the current that flows in the 1 Ω resistor in the following circuit.





Solution :-

- We can denote the current that flows from 9V battery as I_1 and it splits up into I_2 and $(I_1 - I_2)$ at the junction E according Kirchhoff 's current rule (KCR).
- Now consider the loop **EADFE** and apply KVR, we get

$$\sum I\,R = \sum \in$$
$$3\,(I_1 - I_2) - I_2 = 6$$
$$3\,I_1 - 3\,I_2 - I_2 = 6$$
$$3\,I_1 - 4\,I_2 = 6 \qquad ------\ (1)$$

- Now consider the loop **EFCBE** and apply KVR, we get

$$\sum I\,R = \sum \in$$
$$I_2 + 3\,I_1 + 2\,I_1 = 9$$
$$5\,I_1 + I_2 = 9 \qquad -------\ (2)$$

(2) X 4 ⇒ $20\,I_1 + 4\,I_2 = 36 \qquad -------\ (3)$

- (1) + (3) ⇒ $23\,I_1 = 42$

$$\mathbf{I_1} = \frac{42}{23} = \mathbf{1.826\,A}$$

- Put , $I_1 = 1.826$ in equation (1)

$$3\,(1.826) - 4\,I_2 = 6$$
$$5.478 - 4\,I_2 = 6$$
$$-4\,I_2 = 6 - 5.478 = 0.522$$
$$(or) \quad 4\,I_2 = -0.522$$
$$\mathbf{I_2} = -\frac{0.522}{4} = \mathbf{-0.1305\,A}$$

- It implies that the current in the **1 Ω** resistor flows from F to E.

23. In a Wheatstone's bridge $P = 100\ \Omega$, $Q = 1000\ \Omega$ and $R = 40\ \Omega$. If the galvanometer shows zero deflection, determine the value of S.

Solution :-

- From the balanced condition of Wheatstone's bridge,

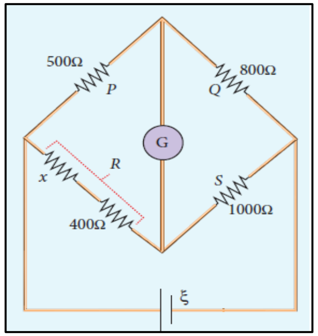
$$\frac{P}{Q} = \frac{R}{S}$$

$$\boldsymbol{S} = \frac{R\,Q}{P} = \frac{40\ X\ 1000}{100} = \mathbf{400\ \Omega}$$

24. What is the value of x when the Wheatstone's network is balanced?

Solution :- $P = 500\ \Omega$, $Q = 800\ \Omega$, $R = x + 400$, $S = 1000\ \Omega$

- From the balanced condition of Wheatstone's bridge,



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

$$\frac{500}{800} = \frac{x + 400}{1000}$$

$$\frac{5}{8} = \frac{x + 400}{1000}$$

$$5000 = 8\,(x + 400)$$

$$5000 = 8\,x + 3200$$

$$8\,x = 5000 - 3200 = 1800$$

$$\boldsymbol{x} = \frac{1800}{8} = \mathbf{225\ \Omega}$$

25. In a meter bridge experiment with a standard resistance of 15 Ω in the right gap, the ratio of balancing length is 3:2. Find the value of the other resistance.

Solution :- $Q = 15\ \Omega$; $l_1 : l_2 = 3 : 2$; $P = ?$

- From the theory of meter bridge ; $\frac{P}{Q} = \frac{l_1}{l_2}$

$$(or)\qquad P = Q\,\frac{l_1}{l_2} = 15\ X\ \frac{3}{2} = \frac{45}{2}$$

$$\boldsymbol{P} = \mathbf{22.5\ \Omega}$$

26. In a meter bridge experiment, the value of resistance in the resistance box connected in the right gap is 10 Ω. The balancing length is l_1 = 55 cm. Find the value of unknown resistance.

Solution :- $Q = 10\ \Omega$; $l_1 = 55\ cm$; $l_2 = 100 - l_1 = 45\ cm$; $P = ?$

- From the theory of meter bridge ; $\frac{P}{Q} = \frac{l_1}{l_2}$

$$(or)\qquad P = Q\,\frac{l_1}{l_2} = 10\ X\ \frac{55}{45} = \frac{550}{45}$$

$$\boldsymbol{P} = \mathbf{12.22\ \Omega}$$

27. Find the heat energy produced in a resistance of 10 Ω when 5 A current flows through it for 5 minutes.

Solution :- $R = 10\ \Omega$; $I = 5\ A$; $t = 5\ min = 300\ s$; $H = ?$

- From Joule's law of heating,

$$H = I^2\,R\,t = 5^2\ X\ 10\ X\ 300 = 25\ X\ 3000$$

$$\boldsymbol{H = 75000\ J = 75\ k\,J}$$

28. An electric heater of resistance 10 Ω connected to 220 V power supply is immersed in the water of 1 kg. How long the electrical heater has to be switched on to increase its temperature from 30°C to 60°C. (Specific heat capacity of water is s = 4200 J kg^{-1} K^{-1})

Solution :- $R = 10\ \Omega$; $V = 220\ V$; $m = 1\ kg$; $T_1 = 30°C$; $T_2 = 60°C$; $t = ?$

- From Joule's law of heating ; $H = I^2\,R\,t = \frac{V^2}{R}\,t$
- Heat absorbed by the water ; $H = m\,s\,\Delta T = m\,s\,(T_2 - T_1)$
- Here, heat produced by the heater in time 't' is equal to the heat absorbed by the water to increase its temperature (i.e.)

$$\frac{V^2}{R}\,t = m\,s\,(T_2 - T_1)$$

$$t = \frac{R}{V^2}\,m\,s\,(T_2 - T_1)$$

$$t = \frac{10}{220^2}\ X\ 1\ X\ 4200\ X\ (60 - 30)$$

$$t = \frac{10}{220\ X\ 220}\ X\ 4200\ X\ 30$$

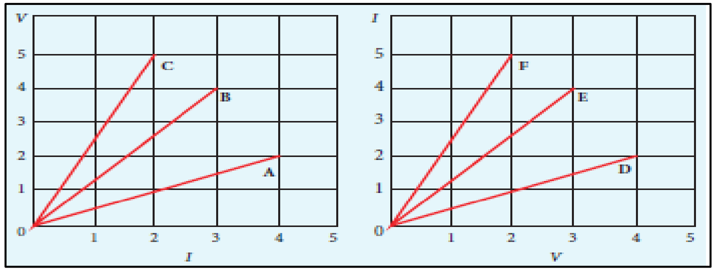
$$t = \frac{4200\ X\ 3}{22\ X\ 22} = \frac{12600}{484} = 2.604\ X\ 10^1$$

$$\boldsymbol{t = 26.04\ s}$$

No	Log
12600 484	4.1004 2.6848
(-) ALog	1.4156 2.604 X 10^1

EXERCISE PROBLEMS

1. **The following graphs represent the current versus voltage and voltage versus current for the six conductors A,B,C,D,E and F. Which conductor has least resistance and which has maximum resistance?**



Solution :-

Figure (1) :

- Resistance of conductor - A ; $R_A = \frac{\Delta V}{\Delta I} = \frac{2}{4} = 0.5\,\Omega$

  Resistance of conductor - B ; $R_B = \frac{\Delta V}{\Delta I} = \frac{4}{3} = 1.33\,\Omega$

  Resistance of conductor - C ; $R_C = \frac{\Delta V}{\Delta I} = \frac{5}{2} = 2.5\,\Omega$

Figure (2) :

- Resistance of conductor - D ; $R_D = \frac{\Delta V}{\Delta I} = \frac{4}{2} = 2\,\Omega$

  Resistance of conductor - E ; $R_E = \frac{\Delta V}{\Delta I} = \frac{3}{4} = 0.75\,\Omega$

  Resistance of conductor - F ; $R_F = \frac{\Delta V}{\Delta I} = \frac{2}{5} = 0.4\,\Omega$

- Thus conductor F has least resistance (i.e.) $\boldsymbol{R_F = 0.4\,\Omega}$

  And conductor C has maximum resistance (i.e.) $\boldsymbol{R_C = 2.5\,\Omega}$

2. **Lightning is very good example of natural current. In typical lightning, there is 10^9 J energy transfer across the potential difference of 5×10^7 V during a time interval of 0.2 s. Using this information, estimate the following quantities**
(a) total amount of charge transferred between cloud and ground (b) the current in the lightning bolt (c) the power delivered in 0.2 s.

Solution :- $V = 5\,X\,10^7\,V$; $t = 0.2\,s$; $U = 10^9\,J$

(a) Total charge ; $\boldsymbol{Q} = \frac{U}{V} = \frac{10^9}{5\,X\,10^7} = \frac{1}{5}\,X\,10^2 = 0.2\,X\,10^2 = \boldsymbol{20\,C}$

(b) Current ; $\boldsymbol{I} = \frac{Q}{t} = \frac{20}{0.2} = \frac{200}{2} = \boldsymbol{100\,A}$

(c) Power ; $\boldsymbol{P} = \frac{U}{t} = \frac{10^9}{0.2} = \boldsymbol{5\,X\,10^9\,W = 5\,G\,W}$

3. **A copper wire of 10^{-6} m² area of cross section, carries a current of 2 A. If the number of free electrons per cubic meter in the wire is 8×10^{28}, calculate the current density and average drift velocity of electrons.**

Solution :- $A = 10^{-6}\,m^2$; $I = 2\,A$; $n = 8\,X\,10^{28}$; $J = ?$; $v_d = ?$

- Current density ;

$$\boldsymbol{J} = \frac{I}{A} = \frac{2}{10^{-6}} = \boldsymbol{2\,X\,10^6\,A\,m^{-2}}$$

- Aveage drift velocity ;

$$v_d = \frac{I}{n\,A\,e} = \frac{J}{n\,e}$$

$$v_d = \frac{2\,X\,10^6}{8\,X\,10^{28}\,X\,1.6\,X\,10^{-19}} = \frac{1}{6.4}\,X\,10^{-3}$$

$$\boldsymbol{v_d = 1.562\,X\,10^{-4}\,m\,s^{-1} = 15.62\,X\,10^{-5}\,m\,s^{-1}}$$

No	Log
1. 6.4	0.0000 0.8062
(-) ALog	$\bar{1}.1938$ $1.562\,X\,10^{-1}$

4. **The resistance of a nichrome wire at 20⁰C is 10 Ω. If its temperature coefficient of resistivity of nichrome is 0.004/⁰C, find the resistance of the wire at boiling point of water. Comment on the result.**

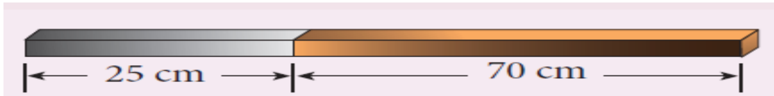
Solution :- $T_o = 0\,°C$; $T = 100\,°C$; $R_o = 10\,\Omega$; $R_T = ?$

- Resistance of the conducting wire at T ⁰C is,

$$R_T = R_o\,[1 + \alpha\,(T - T_o)]$$
$$R_T = 10\,[\,1 + 0.004\,(100 - 0)]$$
$$R_T = 10\,[1 + 0.004\,X\,100]$$
$$R_T = 10\,[\,1 + 0.4] = 10\,X\,1.4$$
$$\boldsymbol{R_T = 14\,\Omega}$$

- As the temperature increases the resistance of the wire also increases.

5. **The rod given in the figure is made up of two different materials. Both have square cross sections of 3 mm side. The resistivity of the first material is 4×10^{-3} Ωm and that of second material has resistivity of 5×10^{-3} Ωm. What is the resistance of rod between its ends?**



Solution :- $A = 3mmX3mm = 9\,mm^2 = 9\,X\,10^{-6}\,m^2$; $l_1 = 25\,cm = 25\,X\,10^{-2}\,m$
$l_2 = 70\,cm = 70\,X\,10^{-2}\,m$; $\rho_1 = 4\,X\,10^{-3}$; $\rho_2 = 5\,X\,10^{-3}$

- Resistance of first material ;

$$R_1 = \frac{\rho_1\,l_1}{A} = \frac{4\,X\,10^{-3}\,X\,25\,X\,10^{-2}}{9\,X\,10^{-6}} = \frac{1000}{9}\,\Omega$$

- Resistance of second material ;

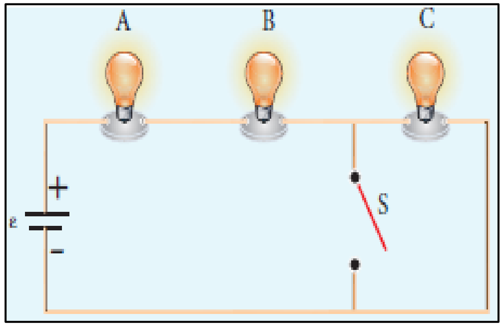
$$R_2 = \frac{\rho_2\,l_2}{A} = \frac{5\,X\,10^{-3}\,X\,70\,X\,10^{-2}}{9\,X\,10^{-6}} = \frac{3500}{9}\,\Omega$$

- Since the two materials are in series, their effective resistance,

$$R_{tot} = R_1 + R_2 = \frac{1000}{9} + \frac{3500}{9} = \frac{1000 + 3500}{9} = \frac{4500}{9}$$

$$\boldsymbol{R_{tot} = 500\,\Omega}$$

6. Three identical lamps each having a resistance R are connected to the battery of emf ϵ as shown in the figure Suddenly the switch S is closed. (a) Calculate the current in the circuit when S is open and closed (b) What happens to the intensities of the bulbs A,B and C. (c) Calculate the voltage across the three bulbs when S is open and closed (d) Calculate the power delivered to the circuit when S is opened and closed (e) Does the power delivered to the circuit decrease, increase or remain same?



Solution :-

(a) **Current** :

- When S is open, all the bulbs A, B and C are in series, and hence their effective resistance becomes ; $R_T = R + R + R = 3\,R$. Thus from Ohm's law,

$$\boldsymbol{I} = \frac{\epsilon}{R_T} = \frac{\boldsymbol{\epsilon}}{\boldsymbol{3\,R}}$$

- When S is closed, only the bulbs A and B are in series and hence their effective resistance becomes $R_T = R + R = 2\,R$ and no current flows through bulb C. Thus from Ohm's law,

$$\boldsymbol{I} = \frac{\epsilon}{R_T} = \frac{\boldsymbol{\epsilon}}{\boldsymbol{3\,R}}$$

(b) **Intensity** :

- When S is open, all the bulbs A, B and C are in series. Here current through all the bulbs are same. So all the bulbs glow with equal intensity.
- When S is closed, only the bulbs A and B are in series . The intensities of the bulbs A and B equally increase. Bulb C will not glow since no current pass through it.

(c) **Voltage (Potential difference)** :

- When S is open,

$$\boldsymbol{V_A} = I\,R_A = \frac{\epsilon}{3\,R}\,X\,R = \frac{\boldsymbol{\epsilon}}{\boldsymbol{3}}$$

$$\boldsymbol{V_B} = I\,R_B = \frac{\epsilon}{3\,R}\,X\,R = \frac{\boldsymbol{\epsilon}}{\boldsymbol{3}}$$

$$\boldsymbol{V_C} = I\,R_C = \frac{\epsilon\epsilon}{3\,R}\,X\,R = \frac{\boldsymbol{\epsilon}}{\boldsymbol{3}}$$

- When S is closed,

$$\boldsymbol{V_A} = I\,R_A = \frac{\epsilon}{2\,R}\,X\,R = \frac{\boldsymbol{\epsilon}}{\boldsymbol{2}}$$

$$\boldsymbol{V_B} = I\,R_B = \frac{\epsilon}{2\,R}\,X\,R = \frac{\boldsymbol{\epsilon}}{\boldsymbol{2}}$$

$$\boldsymbol{V_C} = 0$$

(d) **Power delivered** :

- When S is open,

$$\boldsymbol{P_A} = V_A\,I = \frac{\epsilon}{3}\,X\,\frac{\epsilon}{3\,R} = \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{9\,R}}$$

$$\boldsymbol{P_B} = V_B\,I = \frac{\epsilon}{3}\,X\,\frac{\epsilon}{3\,R} = \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{9\,R}}$$

$$\boldsymbol{P_C} = V_C\,I = \frac{\epsilon}{3}\,X\,\frac{\epsilon}{3\,R} = \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{9\,R}}$$

Total power delivered; $\boldsymbol{P_{tot} = P_A + P_B + P_C = 3\left(\frac{\epsilon^2}{9\,R}\right) = \frac{\epsilon^2}{3\,R}}$

- When S is closed,

$$\boldsymbol{P_A} = V_A\,I = \frac{\epsilon}{2}\,X\,\frac{\epsilon}{2\,R} = \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{4\,R}}$$

$$\boldsymbol{P_B} = V_B\,I = \frac{\epsilon}{2}\,X\,\frac{\epsilon}{2\,R} = \frac{\boldsymbol{\epsilon^2}}{\boldsymbol{4\,R}}$$

$$\boldsymbol{P_C} = 0$$

Total power delivered; $\boldsymbol{P_{tot} = P_A + P_B + P_C = 2\left(\frac{\epsilon^2}{4\,R}\right) = \frac{\epsilon^2}{2\,R}}$

(e) When S is suddenly closed, **the power delivered to the circuit will increases.**

7. An electronics hobbyist is building a radio which requires 150 Ω in her circuit. But she has only 220 Ω, 79 Ω and 92 Ω resistors available. How can she connect the available resistors to get the desired value of resistance?

Solution :-

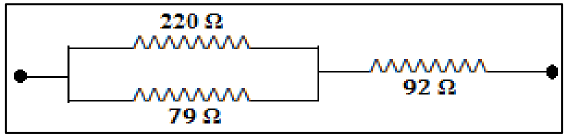
- The value of equivalent resistance in series connection will be greater than each individual resistance. Similarly the value of equivalent resistance in parallel connection will be lesser than each individual resistance**.**
- When all the three resistors are connected in series, their effective resistance will be greater than **220 Ω** and when all the three resistors are connected in parallel, their effective resistance will be less than **79 Ω**
- Initially first two resistors **220 Ω** and **79 Ω** are connected in parallel and their effective value,

$$\frac{1}{R_P} = \frac{1}{220} + \frac{1}{79} = \frac{220 + 79}{220\,X\,79} = \frac{299}{17380}$$

$$\therefore \quad R_P = \frac{17380}{299} = 5.811\,X\,10^1\ \Omega \approx \mathbf{58\ \Omega}$$

No	Log
17380	4.2400
299	2.4757
(-) ALog	1.7643 5.811 X 10^1

- Now 58 Ω and third resistor 92 Ω are connected in series its effective value, $R_S = 58 + 92 = 150\ \Omega$
- Thus in order to get **150 Ω** resistance, **220 Ω** and **79 Ω** are connected in parallel and this combination is connected in series with 92 **Ω**



8. A cell supplies a current of 0.9 A through a 2 Ω resistor and a current of 0.3 A through a 7 Ω resistor. Calculate the internal resistance of the cell.

Solution :- $I_1 = 0.9\,A$; $I_2 = 0.3\,A$; $R_1 = 2\,\Omega$; $R_2 = 7\,\Omega$; r = ?

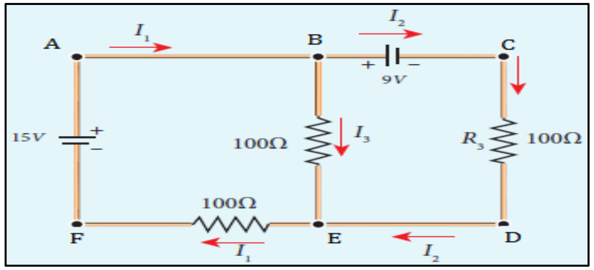
- From Ohm's law (V = I R),

$$\epsilon = I_1(R_1 + r) = 0.9\,(2 + r) ---- (1)$$
$$\epsilon = I_2(R_2 + r) = 0.3\,(7 + r) ---- (2)$$

- From equation (1) and (2)

$$0.9\,(2 + r) = 0.3\,(7 + r)$$
$$1.8 + 0.9\,r = 2.1 + 0.3\,r$$
$$0.9\,r - 0.3\,r = 2.1 - 1.8$$
$$0.6\,r = 0.3$$
$$r = \frac{0.3}{0.6} = \frac{1}{2} = \mathbf{0.5\,\Omega}$$

9. Calculate the currents in the following circuit.



Solution :-

- Apply Kirchoff's current law at the junction B,

$$I_1 = I_2 + I_3 \qquad ------- (1)$$

- Apply Kirchoff's voltage law to the closed loop ABEFA and BCDEB,

$$100\,I_3 + 100\,I_1 = 15 \qquad ------- (2)$$
and $$100\,I_2 - 100\,I_3 = -9 \qquad ------- (3)$$

- Put equation (1) in (2)

$$100\,I_3 + 100(I_2 + I_3) = 15$$
$$100\,I_3 + 100\,I_2 + 100\,I_3 = 15$$
$$100\,I_2 + 200\,I_3 = 15 \qquad ------- (4)$$
$$(4) - (3) \Longrightarrow \quad 300\,I_3 = 24$$
$$I_3 = \frac{24}{300} = \frac{8}{100} = 0.08\,A$$

- Put this in equation (3)

$$100\,I_2 - 100\,(0.08) = -9$$
$$100\,I_2 - 8 = -9$$
$$100\,I_2 = -9 + 8 = -1$$
$$I_2 = -\frac{1}{100} = -0.01\,A$$

- Then equation(1) becomes,

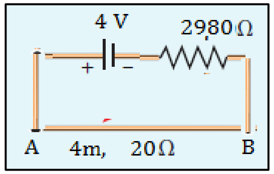
$$I_1 = -0.01 + 0.08 = 0.07\,A$$

- Thus , $\mathbf{I_1 = 0.07\,A}$; $\mathbf{I_2 = -0.01\,A}$; $\mathbf{I_3 = 0.08\,A}$

10. A potentiometer wire has a length of 4 m and resistance of 20 Ω. It is connected in series with resistance of 2980 Ω and a cell of emf 4 V. Calculate the potential gradient along the wire.

Solution :- $l = 4\,m$; $R = 20\,\Omega$; $R_{ex} = 2980\,\Omega$; $\epsilon = 4\,V$; $V = ?$

- Resistance per unit length of the potentiometer wire, $r = \frac{20}{4} = 5\,\Omega\,m^{-1}$
- From Ohm's law ; $I = \frac{\epsilon}{(R + R_{ex})} = \frac{4}{(20+2980)} = \frac{4}{3000}$



$$I = \frac{4}{3\,X\,10^3} = 1.33\,X\,10^{-3}\,A$$

- Potential difference across the potentiometer wire

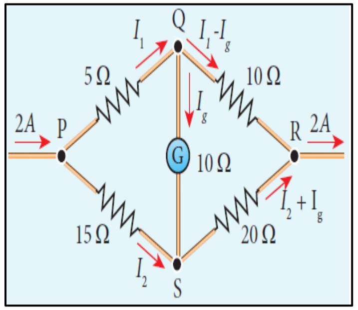
$$V = I\,R = 1.33\,X\,10^{-3}\,X\,20 = 26.6\,X\,10^{-3}\,V$$

- Then the potential gradient along the wire

$$\boldsymbol{V = I\,r} = 1.33\,X\,10^{-3}\,X\,5 = \mathbf{6.65\,X\,10^{-3}\,Vm^{-1}}$$

11. Determine the current flowing through the galvanometer (G) as shown in the figure.

Solution :-



- Apply Kirchoff's current law at the junction P,

$$2 = I_1 + I_2 \quad (or)$$
$$I_2 = 2 - I_1 \qquad ------- (1)$$

- Apply Kirchoff's voltage law to the closed loop PQSP ,

$$5\,I_1 + 10\,I_g - 15\,I_2 = 0$$
$$5\,I_1 + 10\,I_g - 15\,(2 - I_1) = 0$$
$$5\,I_1 + 10\,I_g - 30 + 15\,I_1 = 0$$
$$20\,I_1 + 10\,I_g - 30 = 0$$
$$20\,I_1 + 10\,I_g = 30 \qquad ------- (2)$$

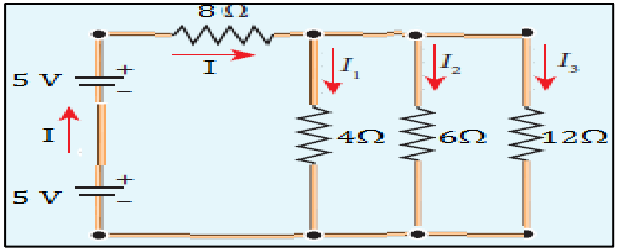
- Similarly Apply Kirchoff's voltage law to the closed loop QRSQ,

$$10\,(I_1 - I_g) - 10\,I_g - 20\,(I_2 + I_g) = 0$$
$$10\,I_1 - 10\,I_g - 10\,I_g - 20\,I_2 - 20\,I_g = 0$$
$$10\,I_1 - 40\,I_g - 20\,I_2 = 0$$
$$10\,I_1 - 40\,I_g - 20\,(2 - I_1) = 0$$
$$10\,I_1 - 40\,I_g - 40 + 20\,I_1 = 0$$
$$30\,I_1 - 40\,I_g - 40 = 0$$
$$30\,I_1 - 40\,I_g = 40 \qquad ------ (3)$$
$$(2) X\,3 \Longrightarrow \quad 60\,I_1 + 30\,I_g = 90 \qquad ------ (4)$$
$$(3) X\,2 \Longrightarrow \quad 60\,I_1 - 80\,I_g = 80 \qquad ------ (5)$$
$$(4) - (5) \Longrightarrow \quad 110\,I_g = 10$$
$$11\,I_g = 1$$
$$\boldsymbol{I_g = \frac{1}{11}\,A}$$

12. Two cells each of 5V are connected in series with a 8 Ω resistor and three parallel resistors of 4 Ω, 6 Ω and 12 Ω. Draw a circuit diagram for the above arrangement. Calculate (i) the current drawn from the cells (ii) current through each resistor

Solution :-

- Circuit diagram for the above arrangement,



(i) <u>The current drawn from the cells</u> :

- Here, 4Ω, 6 Ω and 12 Ω all are in parallel, their effective resistance,

$$\frac{1}{R_P} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} = \frac{3+2+1}{12} = \frac{6}{12} = \frac{1}{2} \quad (or) \quad R_P = 2\,\Omega$$

- Also, 8 Ω and 2 Ω are in series, their effective resistance, ன்

$$R_S = 8 + 2 = 10\,\Omega$$

- Total potential difference(voltage) ; $V = 5 + 5 = 10\,V$
- Then current in the circuit,

$$\boldsymbol{I} = \frac{V}{R_S} = \frac{10}{10} = \boldsymbol{1\,A}$$

- The potential difference across parallel combination of effective resistance $R_P = 2\,\Omega$ is ; $V_P = I\,R_P = 1\,X\,2 = 2\,V$

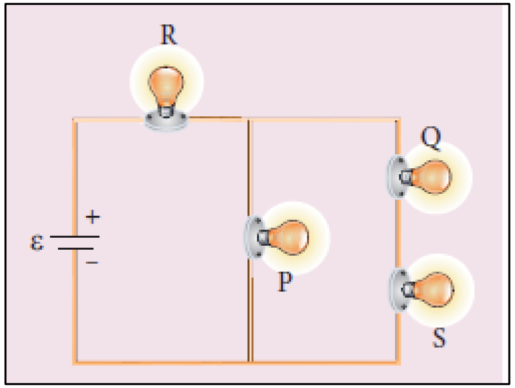
(ii) <u>Current through each resistor</u> :

- Current through 8 Ω resistor ; $\boldsymbol{I = 1\,A}$
- Current through 4 Ω resistor ; $\boldsymbol{I_1} = \frac{V_P}{4} = \frac{2}{4} = \boldsymbol{0.5\,A}$
- Current through 6 Ω resistor ; $\boldsymbol{I_2} = \frac{V_P}{6} = \frac{2}{6} = \boldsymbol{0.33\,A}$
- Current through 12 Ω resistor ; $\boldsymbol{I_3} = \frac{V_P}{12} = \frac{2}{12} = \boldsymbol{0.17\,A}$

13. Four bulbs P, Q, R, S are connected in a circuit of unknown arrangement. When each bulb is removed one at a time and replaced, the following behavior is observed. Draw the circuit diagram for these bulbs.

	P	Q	R	S
P removed	*	on	on	on
Q removed	on	*	on	off
R removed	off	off	*	off
S removed	on	off	on	*

Solution :-



14. In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63 cm, what is the emf of the second cell?

Solution :- : $\epsilon_1 = 1.25\,V$; $l_1 = 35\,cm$; $l_2 = 63\,cm$; $\epsilon_2 = ?$

- The ratio of emf's of two cells using potentiometer,

$$\frac{\epsilon_1}{\epsilon_2} = \frac{l_1}{l_2}$$

$$\epsilon_2 = \epsilon_1 \frac{l_2}{l_1}$$

$$\epsilon_2 = 1.25\,X\,\frac{63\,X\,10^{-2}}{35\,X\,10^{-2}} = \frac{78.75}{35}$$

$$\boldsymbol{\epsilon_2 = 2.25\,V}$$