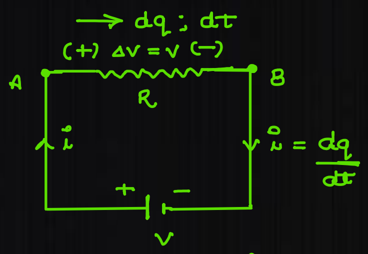
Electric Current

01 August 2020 11:30

Thermal Power appeared in the resistance :→

—www— ⇒ Symbol of Resistance

Let dq amount of charge pass from the resistor in time dt



so work done by the emf of the battery in this process

$$dW = dq \times \Delta V$$

$$\Rightarrow dW = dq \times V$$

$$= i \times dt \times V$$

$$\Rightarrow dW = V \times i \times dt$$

$$\Rightarrow \frac{dW}{dt} = P = V \times i \quad \text{——} (1)$$

as $V = i \times R$ (from ohm's Law)

$$\therefore P = i^2 \times R \quad \text{——} (2)$$

also: $i = \frac{V}{R}$

$$\therefore P = \frac{V^2}{R} \quad \text{——} (3)$$

from (1), (2) & (3)

Thermal Power appeared across the resistor

$$\boxed{P_{Th.} = i^2 \cdot R = V \cdot i = \frac{V^2}{R}} \text{ watt} \quad \text{——} (\star)$$

Heat appeared across the resistor $H = \int P_{Th.} \cdot dt$ $\left(\text{as } P_{Th.} = \frac{dH}{dt}\right)$

$$\Rightarrow H = \int_{t_1}^{t_2} i^2 \cdot R \cdot dt = \int_{t_1}^{t_2} V \cdot i \cdot dt = \int_{t_1}^{t_2} \frac{V^2}{R} \cdot dt$$

Joules

for the Battery :→

Work done by the battery to displace dq charge across it self

$$dW_{Batt.} = dq \times \Delta V_{Batt}$$

$$= dq \times V$$

$$\Rightarrow dW_{Batt} = i \times dt \times V$$

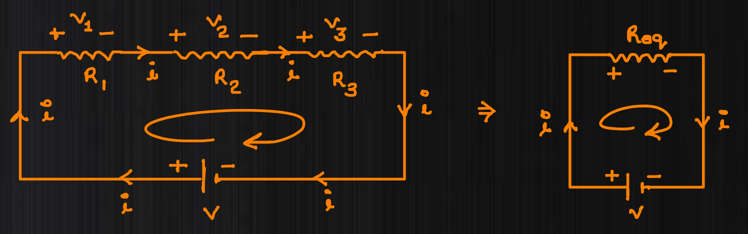
Electric power delivered by the Battery or consumed by the circuit resistance $\Rightarrow \frac{dW_{Batt}}{dt} = P = V \cdot i$ or $i^2 \cdot R$ or $\frac{V^2}{R}$ watt ——(★)

so $P_{Battery} = P_{thermal}$: Hence no energy is saved in the circuit, entire work done by the battery dissipates as heat the circuit, entire work done by the battery dissipates as heat

combination of Resistances :→

i) Series combination :→

In this type of combination current through each resistor is same.



$$V = V_1 + V_2 + V_3$$

$$\Rightarrow i \cdot R_{eq} = iR_1 + i \cdot R_2 + i \cdot R_3$$

formula of equivalent resistance in series combination ⇒ $\boxed{R_{eq} = R_1 + R_2 + R_3}$ — ⊛

for 'n' resistors in series : $R_{eq} = R_1 + R_2 + R_3 + \cdots\cdots + R_n$

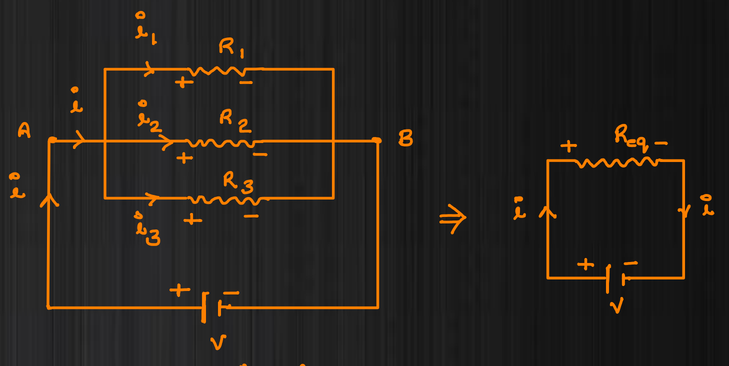
for 'n' identical resistors each of radius 'R' in series

$$R_{eq} = R + R + R + \cdots\cdots \text{ ntimes}$$

$$\Rightarrow R_{eq} = n \cdot R \text{ — ⊛}$$

2) parallel combination:→

in this type of combination P.D. across each resistor is same.



at junction A

$$i = i_1 + i_2 + i_3$$

$$\Rightarrow \frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

formula for equivalent Resistance in parallel combination $\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$ — ⊛

for 'n' resistors in parallel :

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots\cdots + \frac{1}{R_n}$$

for 'n' identical Resistance in parallel

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + \cdots\cdots \text{ ntimes}$$

$$\therefore R_{eq} = \frac{R}{n}$$

Kirchoff's Laws for electric current :→

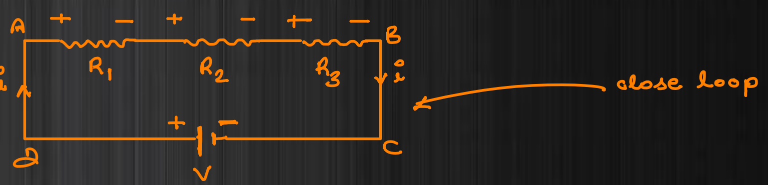
1) Kirchoff's current Law (KVL) :→ According to this Law, sum of all incoming currents at any junction is equal to the sum of all outgoing currents

ie: $\sum i_{incoming} = \sum i_{outgoing}$

$\Rightarrow i_1 + i_2 + i_3 = i_4 + i_5 + i_6$

it is based upon the Law of conservation of charge.

2) Kirchoff's voltage Law (KVL) :→ According to this Law, total P.D. across any close loop is equal to zero.



Drop across R_1 + Drop across R_2 + Drop across R_3 + Rise across Battery = 0

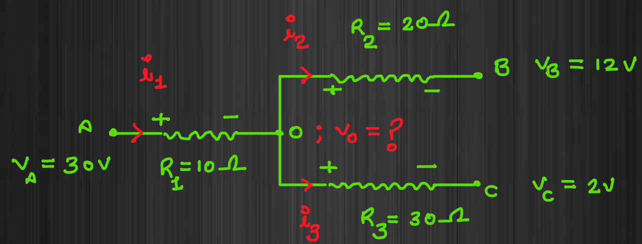
Drop → −ve

Rise → +ve

$\Rightarrow (-iR_1) + (-iR_2) + (-iR_3) + V = 0$

This Law is based upon conservation of energy.

Q:→ find the current in each branch.



at junction O;

from KCL

$$i_1 = i_2 + i_3$$

$$\frac{(V_A - V_0)}{R_1} = \frac{(V_0 - V_B)}{R_2} + \frac{(V_0 - V_C)}{R_3}$$

$$\Rightarrow \frac{(30 - V_0)}{10} = \frac{(V_0 - 12)}{20} + \frac{(V_0 - 2)}{30}$$

$$\Rightarrow 180 - 6V_0 = 3V_0 - 36 + 2V_0 - 4$$

$$\Rightarrow 220 = 11V_0$$

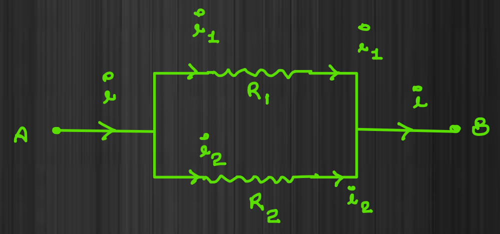
so $V_0 = 20$ volt ; potential at the jn.

$$\therefore \quad i_1 = \frac{(V_A - V_0)}{R_1} = \frac{(30 - 20)}{10} = 1A$$

$$i_2 = \frac{(V_0 - V_B)}{R_2} = \frac{(20 - 12)}{20} = \frac{8}{20} = 0.4A$$

$$i_3 = \frac{(V_0 - V_C)}{R_3} = \frac{(20 - 2)}{30} = \frac{18}{30} = 0.6A$$

imp concept :→ Distribution of electric current at any junction always takes place in inverse ratio of the resistance of the branches.

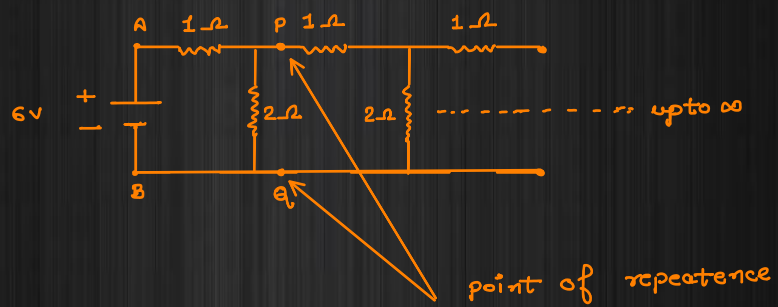


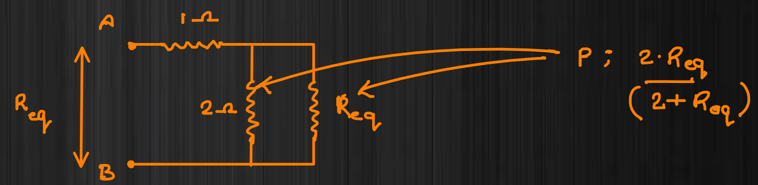
$\Rightarrow \quad \Delta V_1 = \Delta V_2$

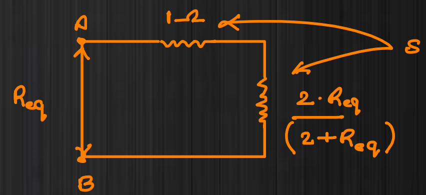
$\Rightarrow \quad i_1 \cdot R_1 = i_2 \cdot R_2$

$$\Rightarrow \quad \boxed{\frac{i_1}{i_2} = \frac{R_2}{R_1}} \longrightarrow \oplus$$

Q:→ find the equivalent resistance b/w points A & B & the current in the 2 Ω Resistance closest to the Battery.







$\therefore \quad R_{eq} = 1 + \frac{2 \cdot R_{eq}}{(2+R_{eq})}$

$\Rightarrow \quad 2R_{eq} + R_{eq}^2 = 2 + R_{eq} + 2R_{eq}$

$\Rightarrow \quad R_{eq}^2 - R_{eq} - 2 = 0$

$\Rightarrow \quad (R_{eq} - 2) \cdot (R_{eq} + 1) = 0$

$\because$ Resistance cannot be negative

$\therefore \quad R_{eq} = 2\,\Omega$

$i = \frac{V}{R_{eq}} = \frac{6}{2} = 3\,A$

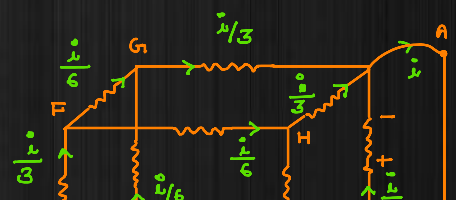
at junction C :→

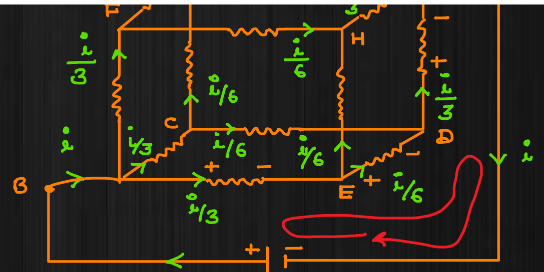
$\frac{i_1}{i_2} = \frac{R_{eq}}{2} = \frac{2}{2} = 1$

$i_1 + i_2 = i = 3\,A$

$\Rightarrow \quad i_1 = i_2 = \frac{i}{2} = \frac{3}{2}$ or 1.5 A

Q: Each side of the cube is of resistance R Ω. find the equivalend resistance b/w points A & B. find current in each branch if V = 5 volt & R = 1 Ω





$i = \dfrac{V}{R_{eq}}$ $V = 5\,\text{volt}$

applying KVL in loop BEDAB :→

$$\left(-\frac{i}{3}\times R\right) + \left(-\frac{i}{6}\times R\right) + \left(-\frac{i}{3}\times R\right) + V = 0$$

$$\Rightarrow -\frac{5iR}{6} + V = 0$$

$$\Rightarrow V = \frac{5iR}{6}$$

$$\Rightarrow i\cdot R_{eq} = \frac{5iR}{6}$$

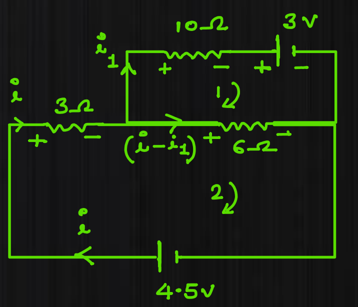
$$\therefore R_{eq} = \frac{5R}{6} = \frac{5}{6}\,\Omega$$

$$\because i = \frac{V}{R_{eq}} = \frac{5}{5/6} = 6\,A \text{ (current drawn from the battery)}$$

$$i_{BC} = i_{BF} = i_{BE} = i_{GA} = i_{DA} = i_{HA} = \frac{i}{3} = \frac{6}{3} = 2A$$

$$i_{FH} = i_{CG} = i_{CD} = i_{EH} = i_{ED} = i_{FG} = \frac{i}{6} = \frac{6}{6} = 1A$$

Q: calculate the power appeared in the resistor $10\,\Omega$.



(major Battery)

from KVL in loop 1

$$-10i_1 - 3 + 6(i - i_1) = 0$$

$$\Rightarrow 6i - 16i_1 = 3 \quad \text{—— (1)}$$

KVL in loop 2

$$-3i - 6(i - i_1) + 4.5 = 0$$

$$\Rightarrow 9i - 6i_1 = 4.5 \quad \text{—— (2)}$$

eqn (2) × 2 − eq. (1) × 3

$$18i - 12i_1 = 9$$

$$\underline{18i - 48i_1 = 9}$$
$$\;\;\; - \;\;\;\; + \;\;\;\;\; -$$

$$0 + 36i_1 = 0$$

$$\Rightarrow i_1 = 0$$

so no current in $10\,\Omega$

$$\therefore P_{10\Omega} = i_1^2 \times R = 0\,\text{watt}$$

[redacted]