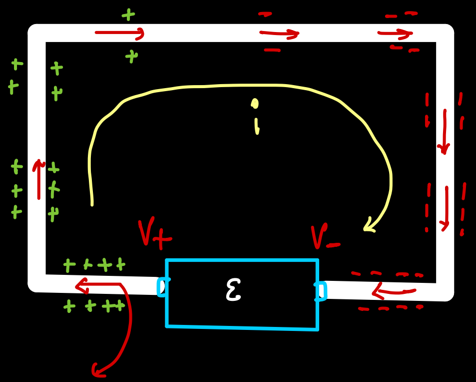
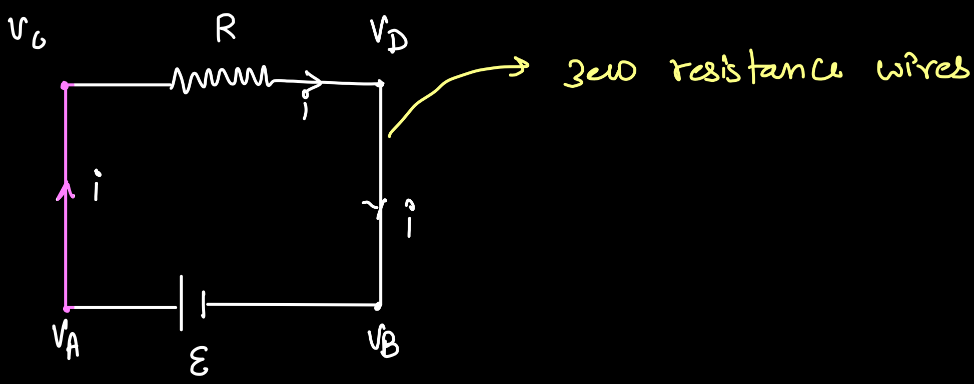
Electric circuits



Electric field is created due to charges appearing on the surface of the wire

Emf of battery $\varepsilon = V_+ - V_-$



Ohm's law

$V_A - V_C = i \cancel{R}^{\,0}$ $\qquad V_A = V_C$

Potential at every point on a zero resistance wire is same.

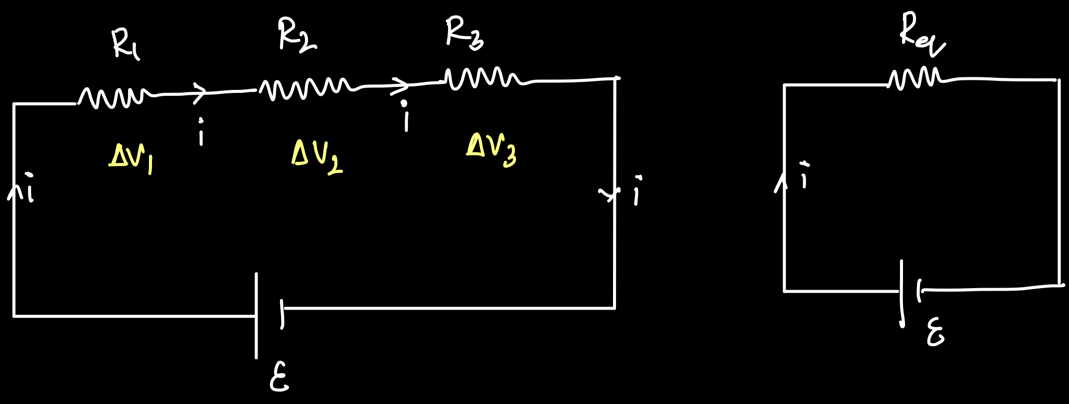
For R

$$V_C - V_D = iR$$

$$V_A - V_B = iR$$

$$\boxed{\varepsilon = iR}$$

Resistances in Series

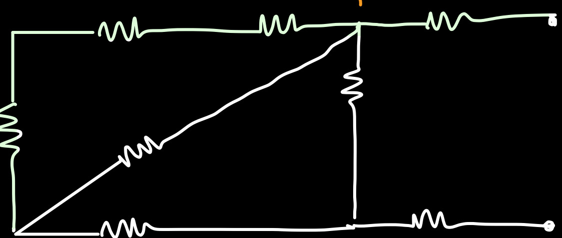


$$\Delta V_1 + \Delta V_2 + \Delta V_3 = \varepsilon$$

$$iR_1 + iR_2 + iR_2 = iR_{eq}$$

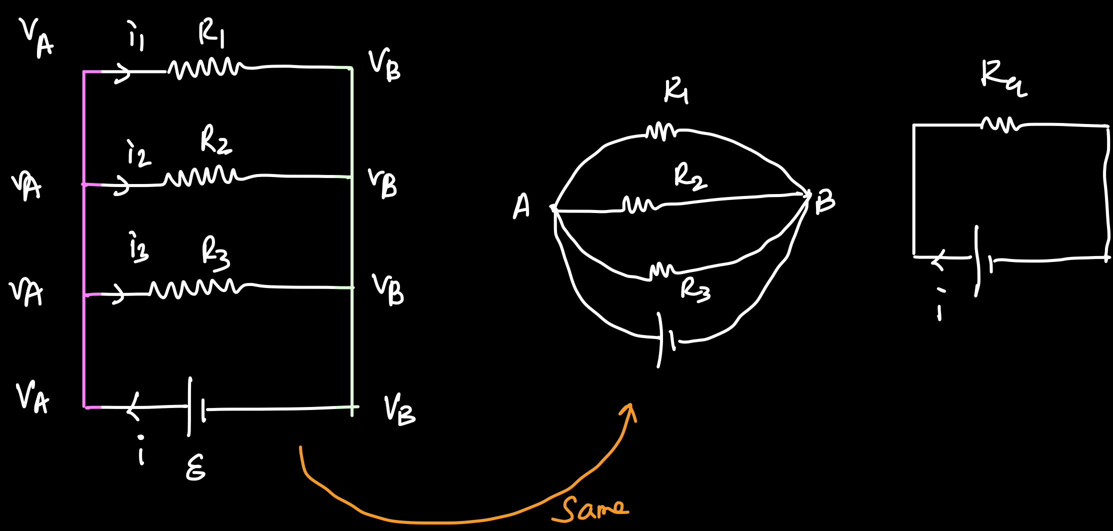
$$\boxed{R_{eq} = \sum R_i}$$

When can we say that resistances are in series?



not in series because as we move along this path we cross a junction

Resistances in parallel



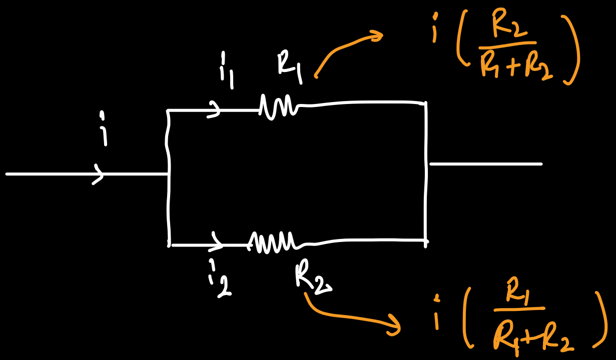
Potential difference across all resistors is equal

$$i = i_1 + i_2 + i_3$$

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

$$\boxed{\frac{1}{R_{eq}} = \sum \frac{1}{R_i}}$$

Note: (i)



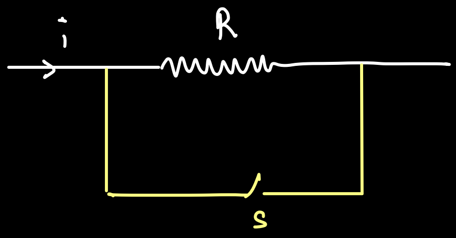
$$\Delta V_1 = \Delta V_2$$

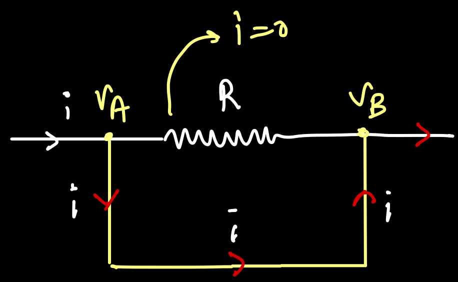
$$i_1 R_1 = i_2 R_2$$

$$\frac{i_1}{i_2} = \frac{R_2}{R_1}$$

Current i is divided in reverse ratio of resistance

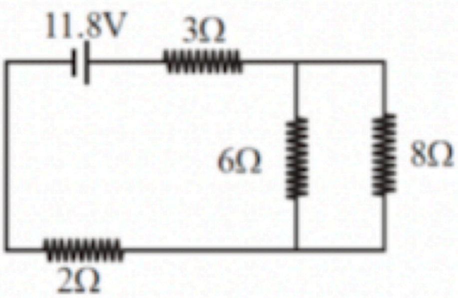
(ii) Short circuit



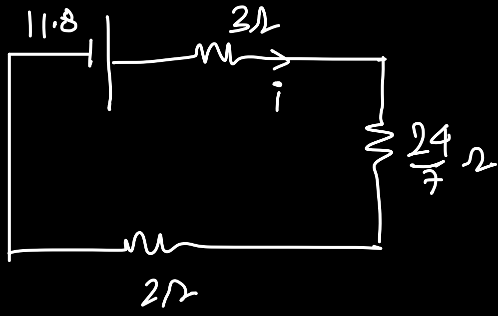


$V_A = V_B$

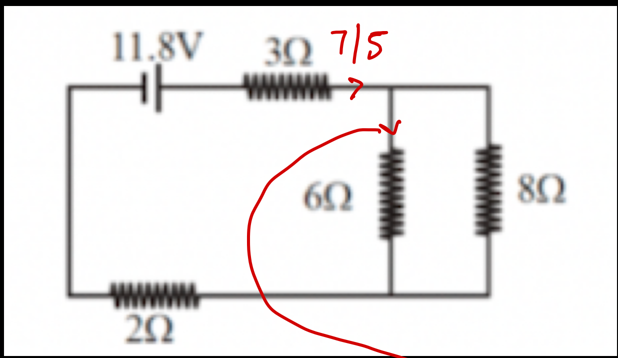
In the network, the current in the resistor 6Ω is :



(A) $\frac{7}{5}$ A (B) $\frac{4}{5}$ A (C) $\frac{3}{5}$ A (D) zero

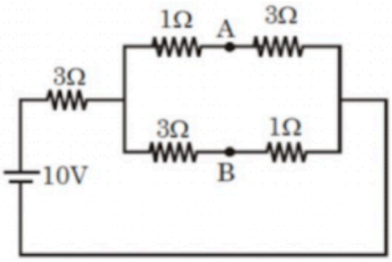


$$i = \frac{11.8}{\frac{24}{7} + 5} = \frac{7}{5}\,A$$

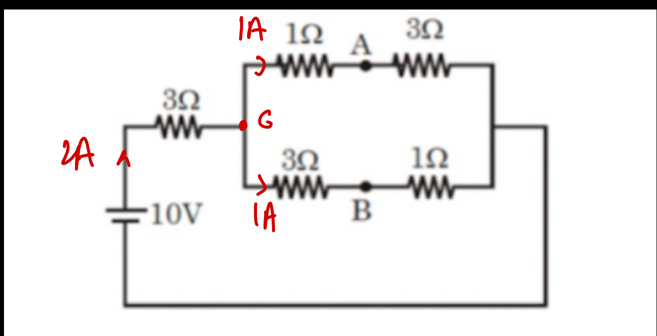


$$7/5\left(\frac{8}{8+6}\right) = \frac{4}{5}\,A \text{ Ans}$$

A battery of emf 10V is connected to resistances as shown in figure. The potential difference $V_A - V_B$ between the points A and B is :-

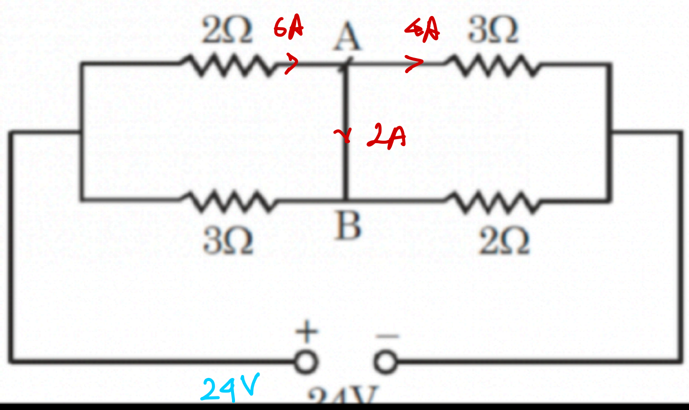


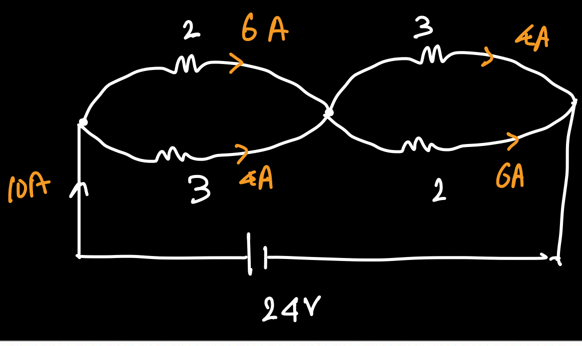
(A) 2V (B) –2V (C) 5V (D) $\frac{20}{11}$ V



$$V_C - V_B = 1(3)$$
$$-\quad V_C - V_A = 1(1)$$
$$V_A - V_B = 3 - 1 = 2$$

Consider circuit as shown in figure. The current through wire AB is

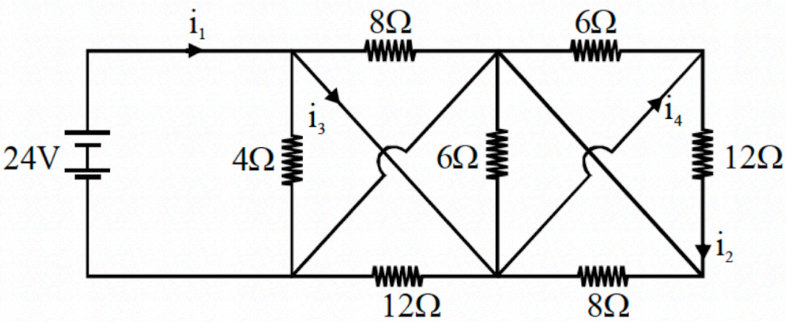




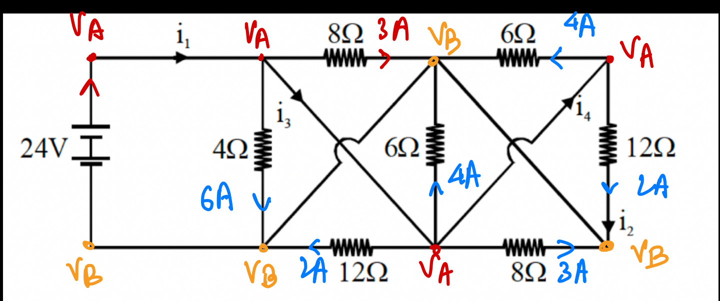
$i = \frac{24}{R_{eq}} = 10A$

$R_{eq} = \frac{12}{5}$

For the circuit shown in figure



(A) $i_1 = 24$ A   (B) $i_2 = 2$A   (C) $i_3 = 15$A   (D) $i_4 = 6$A

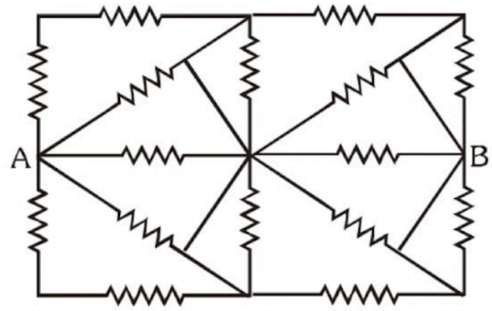


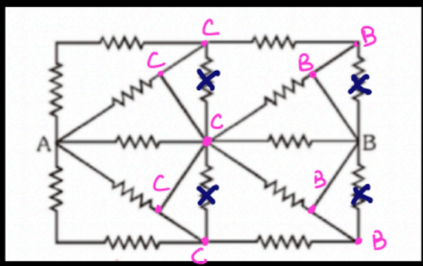
$\frac{1}{R_{eq}} = \frac{2}{8} + \frac{2}{6} + \frac{2}{12} + \frac{1}{4}$

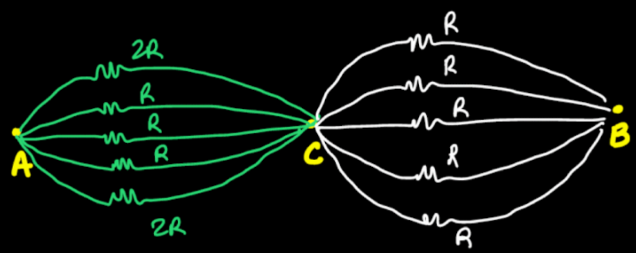
$R_{eq} = 1\,\Omega$

$i_1 = \frac{\varepsilon}{R_{eq}} = \frac{24}{1} = 24A$

In the given circuit all resistors are identical. Each resistance is equal to 20Ω. Find the equivalent resis
between A & B in Ω.

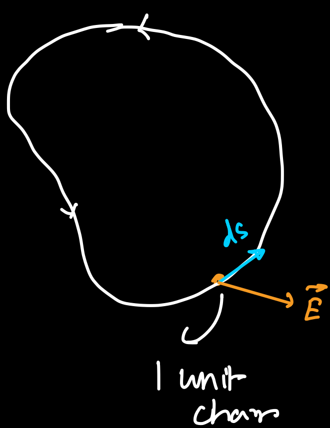






Kirchoff's laws

(i) Kirchoff's voltage law (KVL)



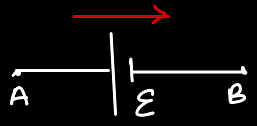
$$\oint (1)\vec{E}\cdot d\vec{s} = \int -dV = 0$$

Total work done by electric field on a closed path is zero

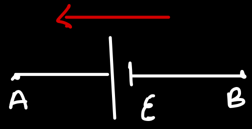
$\boxed{\text{Total change in potential in a closed path is zero}}$

Sign Convention

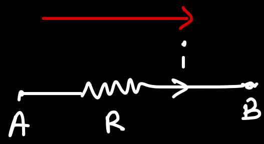
Change in potential



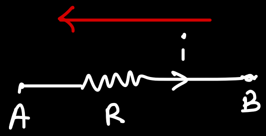
$-\varepsilon$ — pot dec since going from high pot to lower pot



$+\varepsilon$ — pot inc since going from lower pot to higher pot

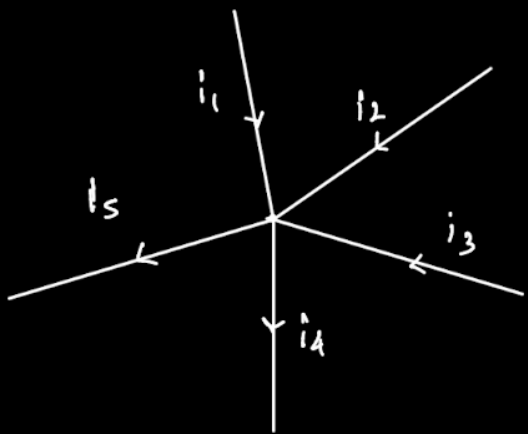


$-iR$ — In direction of current pot decreases



$+iR$ — opp to direction of current pot increases

Kirchoff's current law



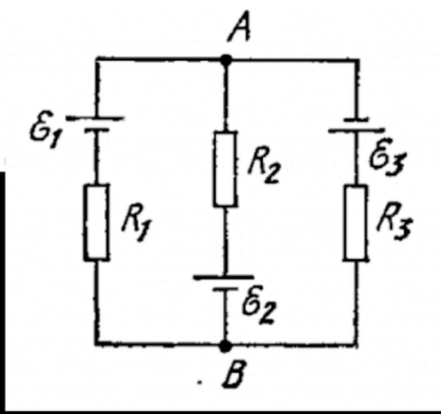
$$i_1 + i_2 + i_3 = i_4 + i_5$$

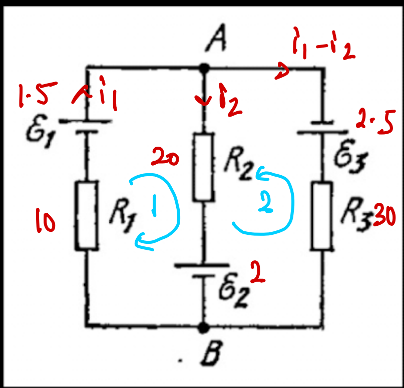
$$\sum i_{in} = \sum i_{out}$$

3.182. In the circuit shown in Fig. 3.45 the sources have emf's $\mathcal{E}_1 = 1.5$ V, $\mathcal{E}_2 = 2.0$ V, $\mathcal{E}_3 = 2.5$ V, and the resistances are equal to $R_1 = 10\,\Omega$, $R_2 = 20\,\Omega$, $R_3 = 30\,\Omega$. The internal resistances of the sources are negligible. Find:

(a) the current flowing through the resistance R_1;

(b) a potential difference $\varphi_A - \varphi_B$ between the points A and B.



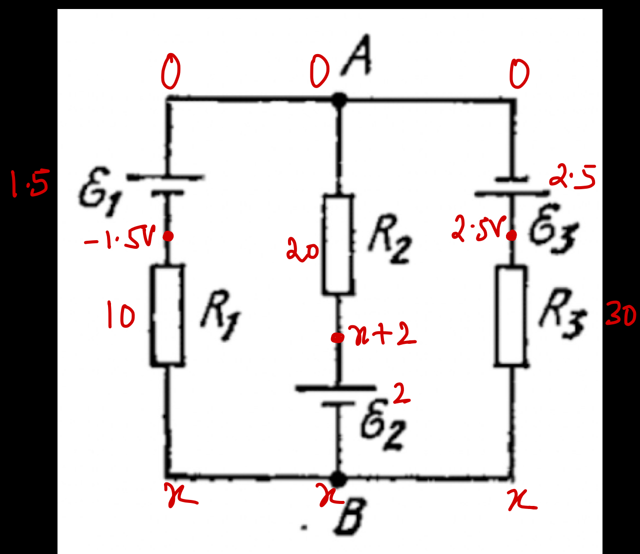


$$V_A - i_2(20) - 2 = V_B$$

1) $-10 i_1 + 1.5 - 20 i_2 - 2 = 0$

2) $+(i_1 - i_2)30 - 2.5 - i_2(20) - 2 = 0$

Nodal Analysis / junction potential method



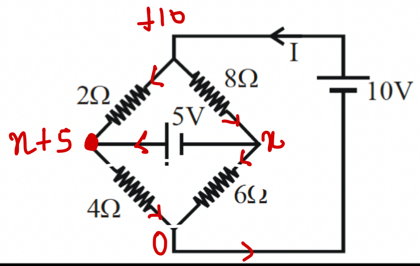
Step 1 Assign potential to all nodes or junctions

Step 2: Write KCL at B

Net outgoing current at B = 0

$$\frac{x-(-1.5)}{10} + \frac{(x+2)-0}{20} + \frac{x-2.5}{30} = 0$$

The current supplied to the circuit by 10 V cell is I ampere. Assume both cells as ideal find 4I.



$$I = \frac{\frac{12}{5}}{6} + \frac{\frac{12}{5}+5}{4}$$
$$= 45/20 = 9/4$$

$$\frac{10-(x+5)}{2} + \left(\underbrace{\frac{10-x}{8} - \frac{x-0}{6}}\right) = \frac{(x+5)-0}{4}$$

current through 5 V battey

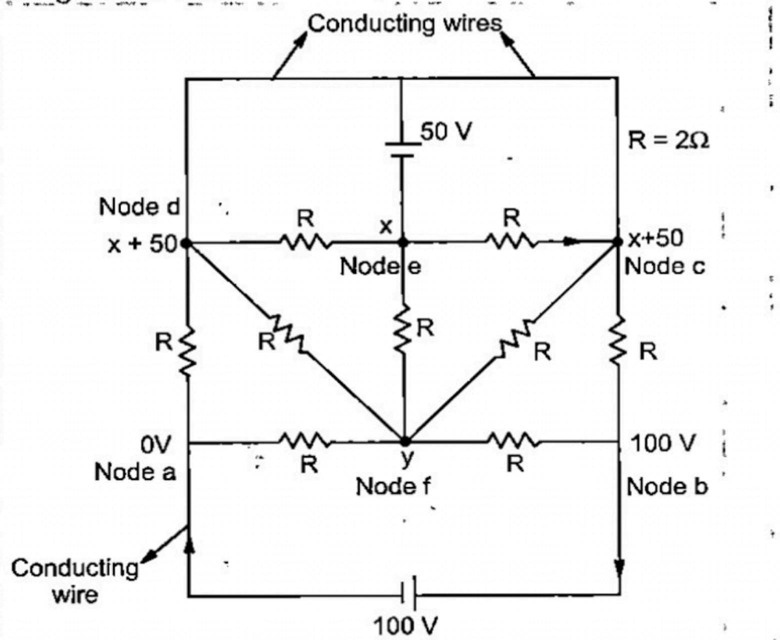
$$5 - \frac{x}{2} - \frac{5}{2} + \cancel{\frac{5}{4}} - \frac{x}{8} - \frac{x}{6} = \frac{x}{4} + \cancel{5/4}$$

$$\frac{5}{2} = x\left(\frac{1}{4}+\frac{1}{2}+\frac{1}{8}+\frac{1}{6}\right)$$

$$\frac{5}{2} = x\left(\frac{6+12+3+4}{24}\right)$$

$$\frac{12}{5} = x$$

In the given circuit we wish to determine the current through resistor given in box.



$$x = \frac{-25}{2},\quad y = \frac{125}{2} \text{ and } i = \frac{75}{2}\,\text{A}$$

Solution:

Step-1: Assign voltage at all the nodes as shown in figure. Here x and y are unknown voltage at node e and f.

Step-2: Apply KCL at node f

$$\frac{y-100}{2}+\frac{y-(x+50)}{2}+\frac{y-x}{2}+\frac{y-(x+50)}{2}+\frac{y}{2}=0 \quad \text{...(1)}$$

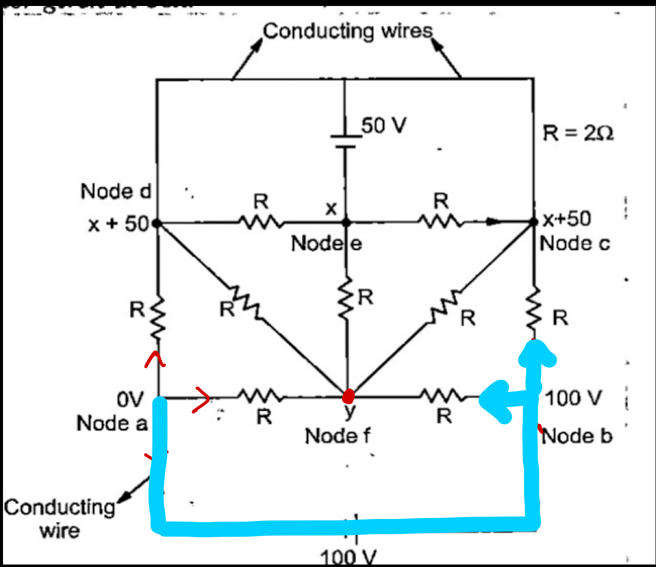
Step-3: Note that outgoing current at b is equal to incoming current at node a, thus we get

$$\frac{100-(x+50)}{2}+\left(\frac{100-y}{2}\right)=-\left[\left(\frac{0-y}{2}\right)+\frac{0-(x+50)}{2}\right] \quad \text{...(2)}$$

Note that we require first two equations to get x and y.

Solve x and y to get current in R as $\frac{y-x}{2}$.

$$x = \frac{-25}{2},\quad y = \frac{125}{2} \text{ and } i = \frac{75}{2}\,\text{A}$$



Node f

$$\frac{y-0}{R} + \frac{y-100}{R} + \frac{y-x}{R} + \frac{y-(x+50)}{R} \times 2 = 0$$

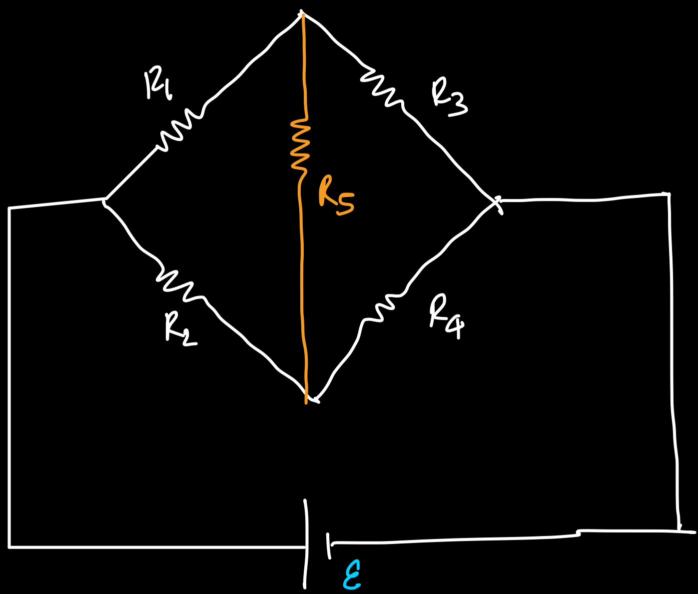
$$5y - 3x = 200$$

Node a

$$\frac{0-(x+50)}{R} + \frac{0-y}{R} + \frac{100-(x+50)}{R} + \frac{100-y}{R} = 0$$

$$x + y = 50$$

Wheatstone bridge



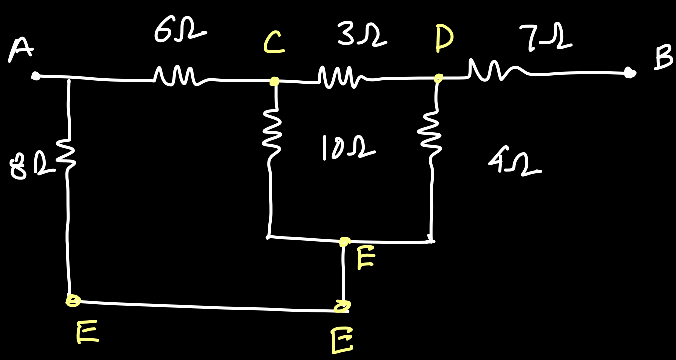
If

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

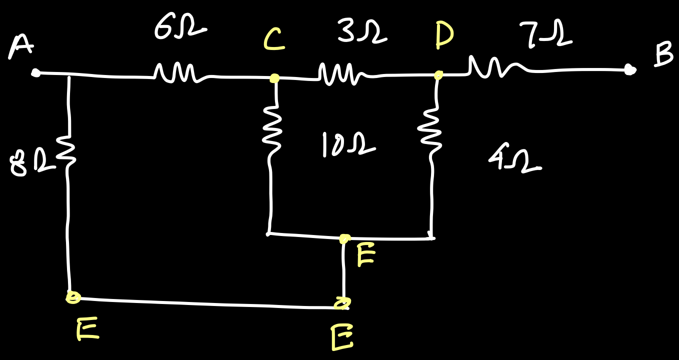
Then the circuit is called a balanced Wheatstone bridge

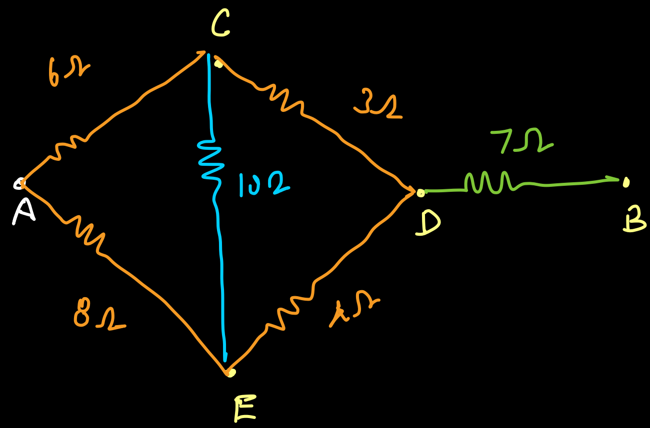
current in R_5 is zero

Ex.

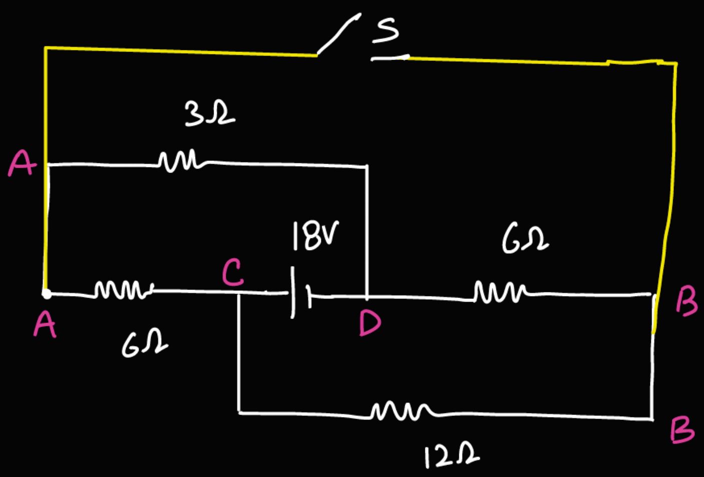


Find equivalent resistance between A & B



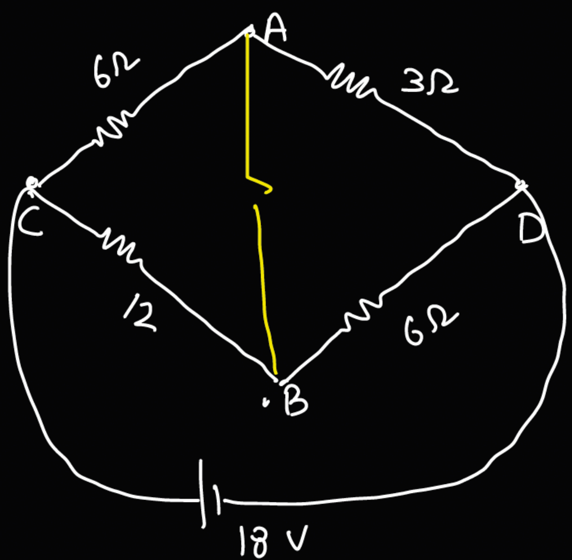


Ex



Find the current through the battery when switch is

(a) open (b) closed



Balanced wheatstone bridge

$\Rightarrow$ It doesn't matter if switch is closed or open

$$i = \frac{18}{R_{eq}} = 3A$$

Homework

Ex 1 Q 29 – 47

Ex 2 Q 16 – 24, 25, 26, 29 – 45

Ex 3 Q 9

Ex 4 Q 5, passage 2, Q 60