CURRENT ELECTRICITY

KIRCHHOFF'S RULES

KIRCHHOFF'S LAWS FOR CIRCUIT ANALYSIS:

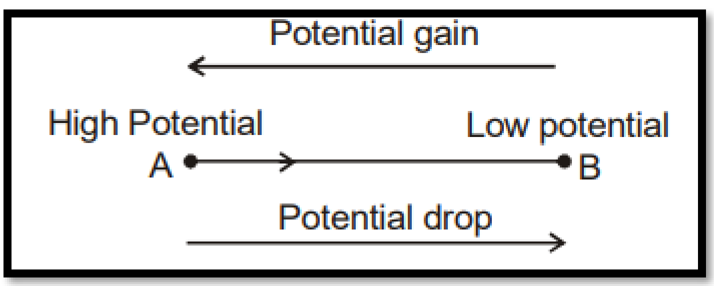
Before moving on to the statement of Kirchhoff's law, we state some conventions to be followed in circuit analysis:

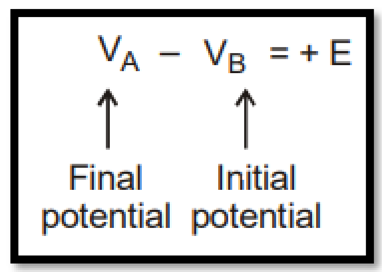
(1) Direction of conventional current is from high potential to low potential terminal.

(2) Current flows from high potential node A to low potential node B. if we traverse from point A to B

There is drop of potential; similarly, from B to A, there is gain of potential.

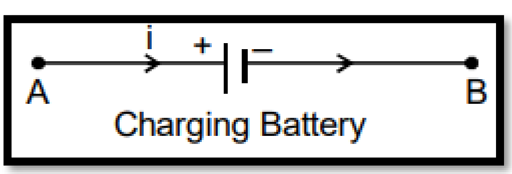
If we traverse from point A to B, there is drop of potential; similarly, from B to A, there is gain of potential. If a source of emf is traversed from negative to positive terminal, the change in potential is +E.

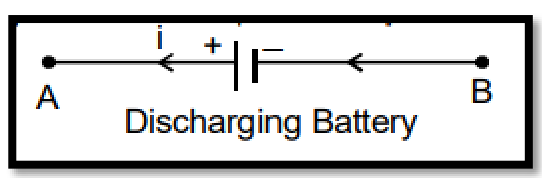


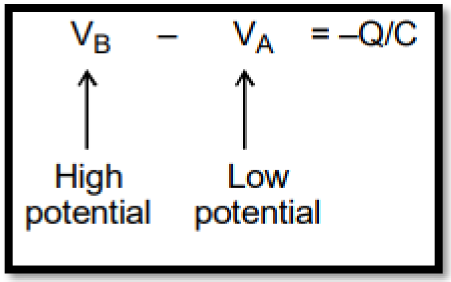


While discharging, current is drawn from the battery, the current comes out from positive terminal and enters negative terminal, while charging of battery current is forced from positive terminal of the battery to negative terminal. Irrespective of direction of current through a battery the sign convention mentioned above holds.

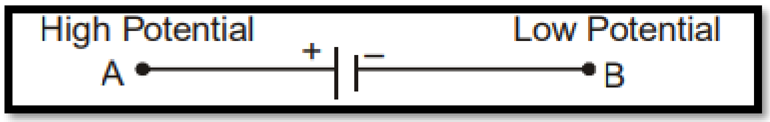
The positive plate of a capacitor is at high potential and negative plate at low potential. If we traverse a capacitor from positive plate to negative plate, the change in potential is ñQ/C

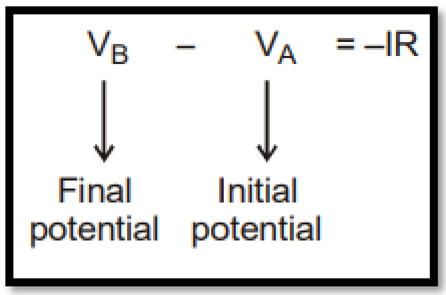


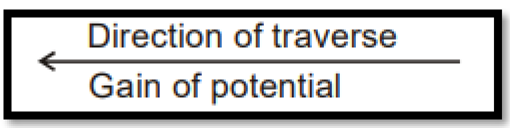


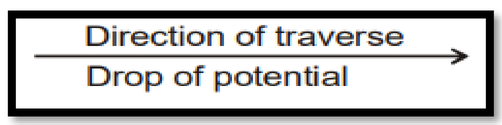


If we traverse a resistor in the direction of current, the change in potential is ñIR.

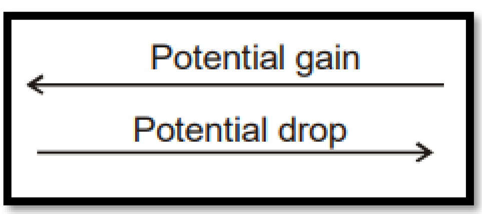


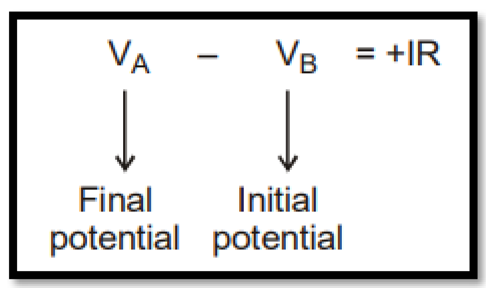


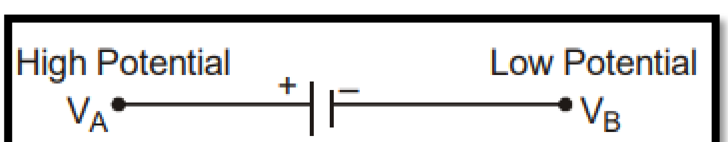




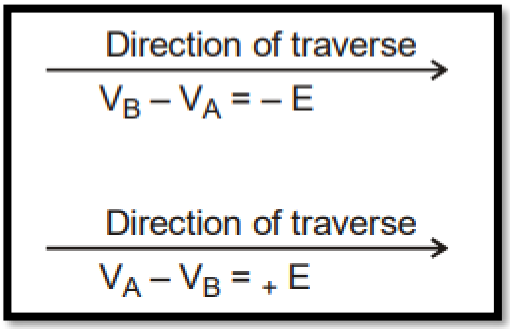
If we traverse a resistor in the direction opposite to the direction of current, the change in potential is +IR

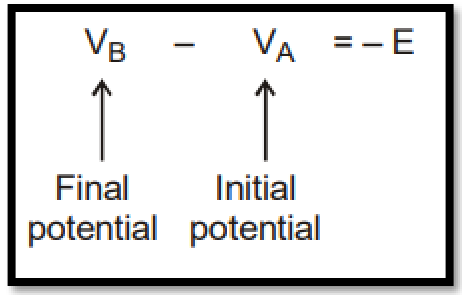




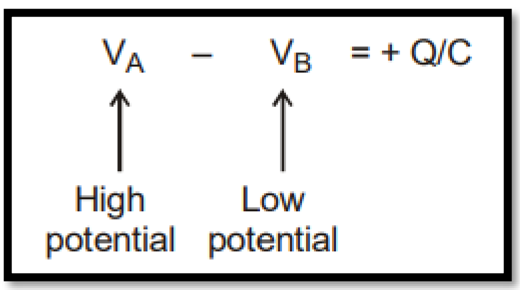


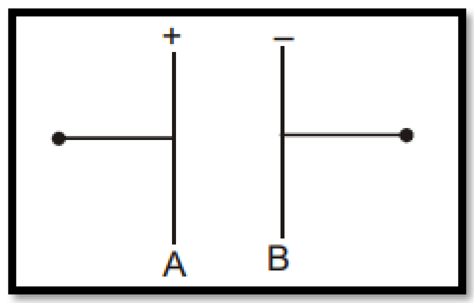
Positive terminal of source of emf is at high potential and negative terminal at low potential. If we traverse a source of emf from the positive terminal to negative terminal, the change in potential is ñE.





If a capacitor is traversed from negative plate to positive plate, the change in potential is +Q/C.

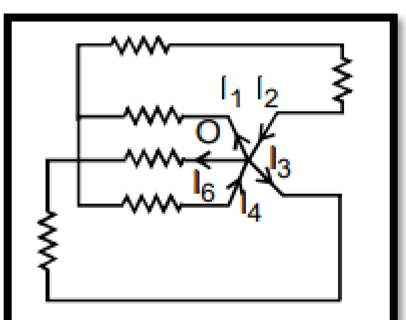


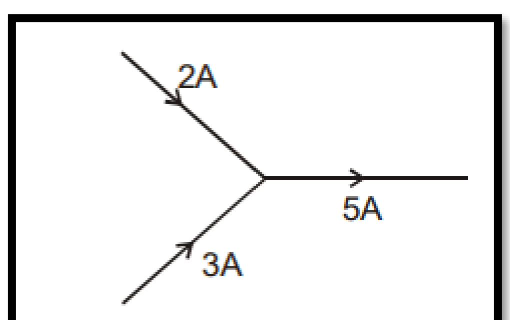


THE KIRCHHOFF'S CURRENT LAW:

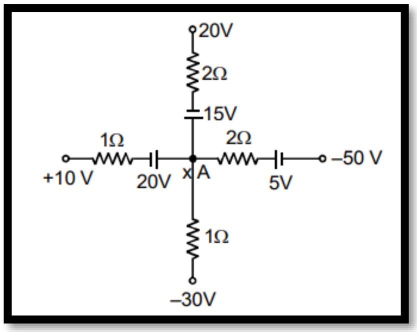
The Kirchhoff's current law (KCL) states that the algebraic sum of the currents entering the junction must equal to sum of the currents leaving the junction. From the standard point of physics, KCL is a statement of charge conservation. The KCL applied to junction O yields

$$\underbrace{I_1 + I_5 + I_3}_{\text{Outgoing current}} = \underbrace{I_2 + I_4}_{\text{Incoming current}}$$





Ex. Find the potential at point A



Sol. Let potential at A = x, applying

kirchhoff current law at junction A

$$\frac{x-20-10}{1}+\frac{x-15-20}{2}+\frac{x-5+50}{2}+\frac{x+30}{1}=0$$

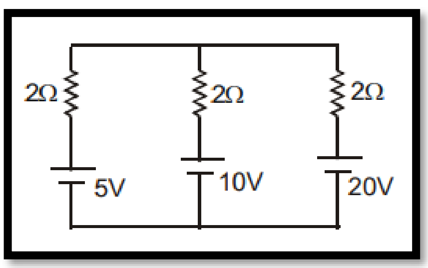
$$\Rightarrow \frac{2x-60+x-35+x+45+2x+60}{2}$$

$$\Rightarrow 6x+10=0$$

$$\Rightarrow x=\frac{5}{3}$$

Potential at $A=\frac{-5}{3}V$

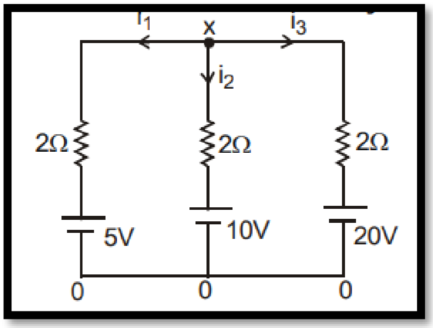
Ex. Find the current in every branch?



Sol. Let we assume x potential at the top junction & zero potential at lower Junction As from KCL, net current on a junction is O

$$i_1+i_2+i_3=0$$

$$\frac{x-5}{2}+\frac{x-10}{2}+\frac{x-20}{2}=0$$

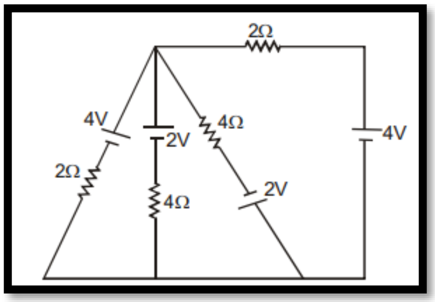


$$3x=35 \Rightarrow x=\frac{35}{3}$$

$$\therefore\ i_1=\frac{\frac{35}{3}-5}{2}=\frac{10}{3}A$$

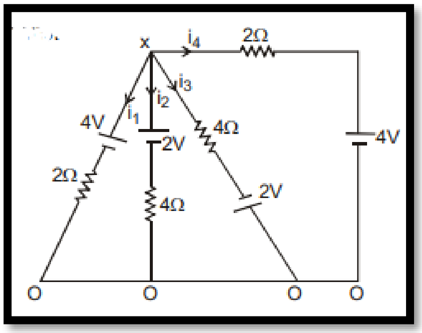
Similarly, $i_2=\frac{5}{6}A$; $i_3=-\frac{25}{6}A.$

Ex. Find the current in every branch?



Sol. Assume x potential at the upper junction & zero potential at the lower junction. By KCl, we know that net current on a junction is zero.

$$\therefore\ i_1+i_2+i_3+i_4=0$$



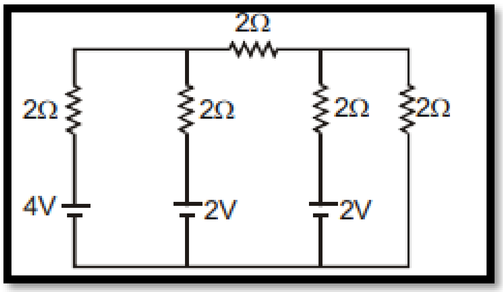
$$\frac{x-4}{2}+\frac{x-2}{4}+\frac{x-2}{4}+\frac{x-4}{2}=0$$

$$2x-8+x-2+x+2+2x-8=0$$

$$6x-16=0$$

$$\therefore\ i_1=-\frac{2}{3}A\ ,\ i_2=+\frac{1}{6}A\ ,\ i_3=\frac{7}{6}A\ ,\ _4=-\frac{2}{3}A$$

Ex. Find the current in every branch?



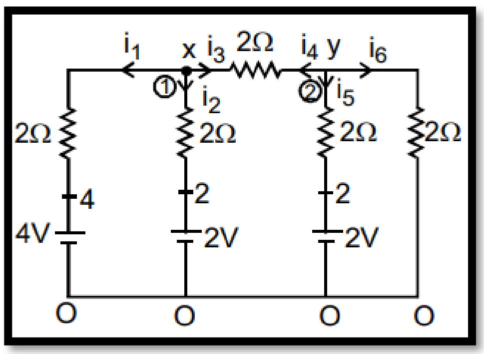
Sol. The above question could be solved by assuming potential x & y at the top Junctions & zero potential at lower junctions

At the junction 1 applying KCL,

$$i_1 + i_2 + i_3 = 0$$

$$\frac{x-4}{2} + \frac{x-2}{2} + \frac{x-y}{2} = 0$$

$$\Rightarrow 3x - y = 6 \qquad ...(1)$$



At the junction 2 applying KCL,

$$i_4 + i_5 + i_6 = 0$$

$$\frac{y-x}{2} + \frac{y-2}{2} + \frac{y}{2} = 0$$

$$\Rightarrow 3y - x = 2 \qquad ...(2)$$

Solving (1) & (2)

$$9x - 3y = 18 \Rightarrow 3y - x = 2$$

$$\Rightarrow \; 8x = 20$$

$$x = \frac{5}{2} \; , \; y = \frac{3}{2}$$

Just put the values of x & y & then the evaluate the current in every branch

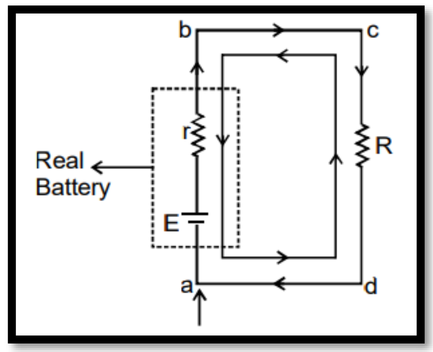
THE KIRCHHOFF'S VOLTAGE LAW:

The Kirchhoff's voltage law (KVL) states that the algebraic sum of the potential difference around ancylosed loop of an electric circuit is zero. The KVL is a statement of conservation of energy. The KVL reflects that electric force is conservative, the work done by a conservative force on a charge taken around a closed path is zero.

We can move clockwise or anticlockwise, it will make no difference because the overall sum of the potential difference is zero.

We can start from any point on the loop, we just have to finish at the same point.

An ideal battery is modelled by an independent voltage source of emf E and an internal resistance r as shown in figure A real battery always absorbs power when there is a current through it, thereby offering resistance to flow of current

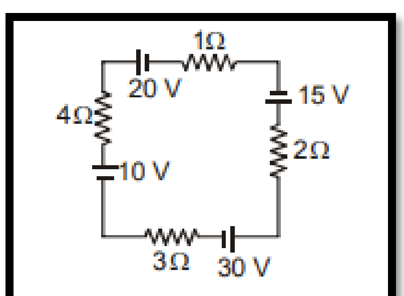


Applying KVL around the single loop in anticlockwise direction, starting from point A, we have

$$\underbrace{+IR}_{\text{In the opposite direction to current}} + \underbrace{Ir}_{\text{In the opposite direction to current}} - \underbrace{E}_{\text{From positive to negative terminal}} = 0$$

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

Ex. Find current in the circuit



Sol. all the elements are connected in series

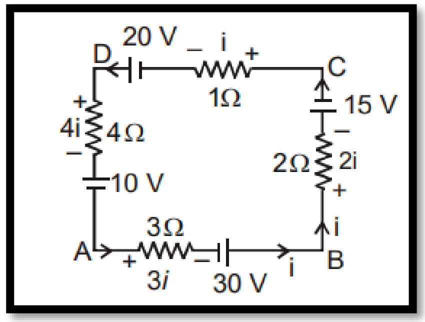
Current in all of them will be same

Let current = i

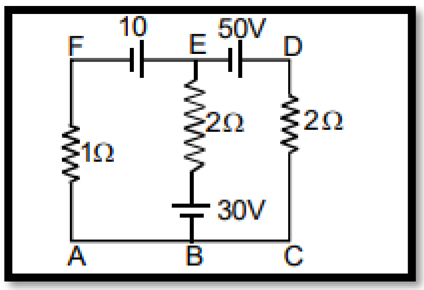
Applying Kirchhoff voltage law in ABCDA loop

$10 + 4i - 20 + i + 15 + 2i - 30 + 3i = 0$

$10\,i = 25 \Rightarrow i = 2.5$ A



Ex. Find the current in each wire applying only Kirchhoff voltage law



Sol. Applying Kirchhoff voltage law in loop ABEFA

$i_1 + 30 + 2\,(i_1 + i_2) - 10 = 0$

$3i_1 + 2i_2 + 20 = 0$ ... (i)

Applying Kirchhoff voltage law in BCDEB

$+ 30 + 2(i_1 + i_2) + 50 + 2i_2 = 0$

$4i_2 + 2i_1 + 80 = 0$

$2i_2 + i_1 + 40 = 0$ ... (ii)

Solving (i) and (ii)

$3[-40 - 2i_2] + 2i_2 + 20 = 0$

$-120 - 4i_2 + 20 = 0$

$i_2 = - 25$ A

And $i_1 = 10$ A

$\therefore\ i_1 + i_2 = - 15$ A

Current in wire AF = 10 A from A to E

Current in wire EB = 15 A from B to E

Current in wire DE = 25 A from D to C