# Kirchhoff's laws and Wheatstone bridge

CLASS-XII

**SUBJECT : PHYSICS**
**CHAPTER NUMBER: 03**
**CHAPTER NAME : CURRENT ELECTRICITY**



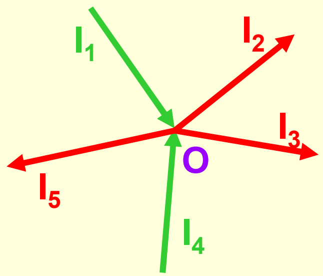
Website: www.odmegroup.org
Email: info@odmps.org

Toll Free: **1800 120 2316**
Sishu Vihar, Infocity Road, Patia, Bhubaneswar- 751024

# KIRCHHOFF'S LAWS:

## I Law or Current Law or Junction Rule:

The algebraic sum of electric currents at a junction in any electrical network is always zero.




$$I_1 - I_2 - I_3 + I_4 - I_5 = 0$$

**Sign Conventions:**

1. The incoming currents towards the junction are taken positive.
2. The outgoing currents away from the junction are taken negative.

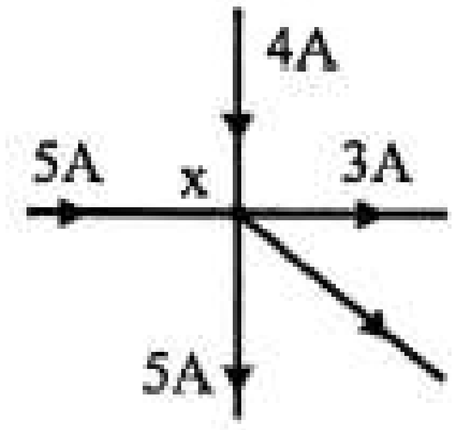
**Note:** The charges cannot accumulate at a junction. The number of charges that arrive at a junction in a given time must leave in the same time in accordance with conservation of charges.

## Numerical

**Question:** In the given figure what is the current through the arm shown

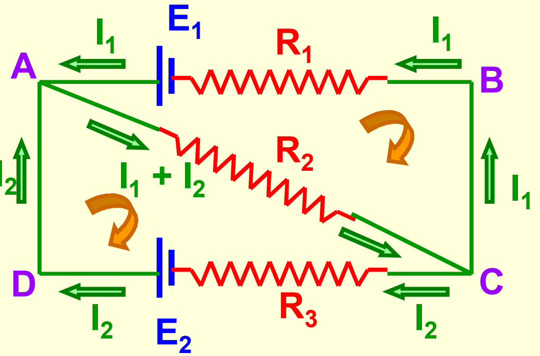
**Solution :**

Unknown current = 5A+4A-5A-3A=1A



## II Law or Voltage Law or Loop Rule:

The algebraic sum of all the potential drops and emf's along any closed path in an electrical network is always zero.




**Loop ABCA:**

$$- E_1 = - I_1.R_1 - (I_1 + I_2).R_2$$

**Loop ACDA:**

$$E_2 = (I_1 + I_2).R_2 + I_2.R_3$$

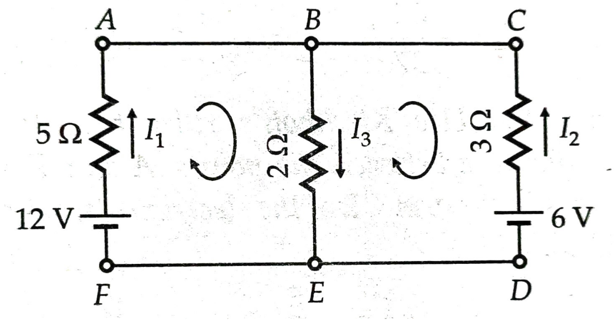
**Sign Conventions:**

1. The **emf** is taken **negative** when we traverse from positive to negative terminal of the cell through the electrolyte.
2. The **emf** is taken **positive** when we traverse from negative to positive terminal of the cell through the electrolyte.

**Note:** The path can be traversed in clockwise or anticlockwise direction of the loop.

# Numerical

**Question:** Using Kirchhoff's laws obtain the values of $I_1, I_2 and I_3$ , as in the given figure.



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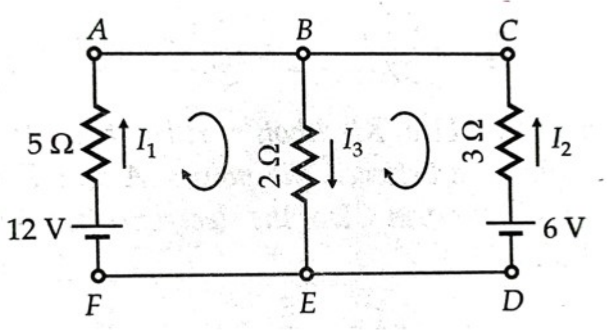



**Solution:** In the figure using KCL; $I_3 = I_1 + I_2$.....(i)

Using KVL in the loop ABEFA;

$5I_1 + 2I_3 = 12 \Rightarrow 5I_1 + 2(I_1 + I_2) = 12 \Rightarrow 7I_1 + 2I_2 = 12$ ...(ii)

In the loop BCDEB;

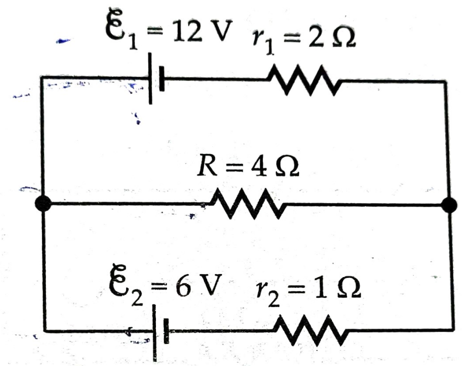
$3I_2 + 2I_3 = 6 \Rightarrow 3I_2 + 2(I_1 + I_2) = 6 \Rightarrow 2I_1 + 5I_2 = 6$......(iii)

On solving equations (ii) and (iii) we have $I_1 = \frac{48}{31}A$ and $I_2 = \frac{18}{31}A$

Using the values in equation (i) we have ; $I_3 = I_1 + I_2 = \frac{48}{31}A + \frac{18}{31}A = \frac{66}{31}A$

## Numerical

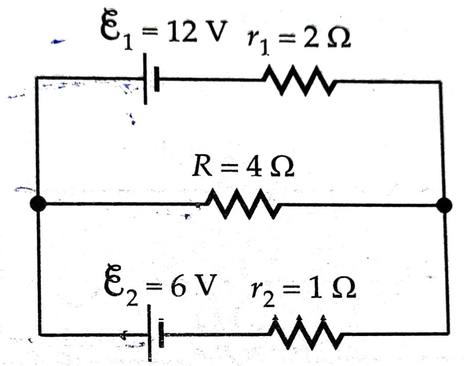
**Question:** Using Kirchhoff's laws obtain the potential difference across each cell and also find the rate of energy dissipation in R.



## Numerical

**Question:** Using Kirchhoff's laws obtain the potential difference across each cell and also find the rate of energy dissipation in R.

**Solution :**




Using KCL current is distributed and shown in the figure.

Using KVL in the loop ABCDA ;

$4(I_1 + I_2) + 2I_1 = 12 \Rightarrow 6I_1 + 4I_2 = 12 \Rightarrow 3I_1 + 2I_2 = 6$...(i)

Using KVL in the loop CDEFC; $4(I_1 + I_2) + 1.I_2 = 6 \Rightarrow 4I_1 + 5I_2 = 6$

Solving equations (i) and (ii) we get

$I_1 = \frac{18}{7}A$ and $I_2 = -\frac{6}{7}A$ i.e. $\frac{6}{7}A$ from E to F.

$$\therefore V_{AB} = E_1 - I_1 r_1 = 12 - \frac{18}{7} \times 2 = \frac{48}{7}V = V_{EF}$$

$$\therefore P_{4\Omega} = (I_1 + I_2)^2 \times 4\Omega = \left(\frac{12}{7}A\right)^2 \times 4\Omega = \frac{576}{49}W$$

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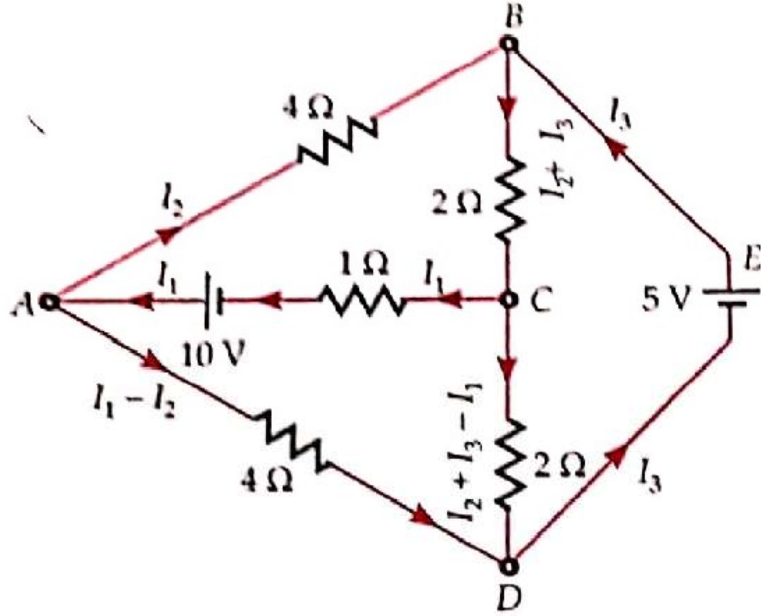
## Numerical

**Question:- Determine the current in each branch of the network shown in the figure.**



## Numerical

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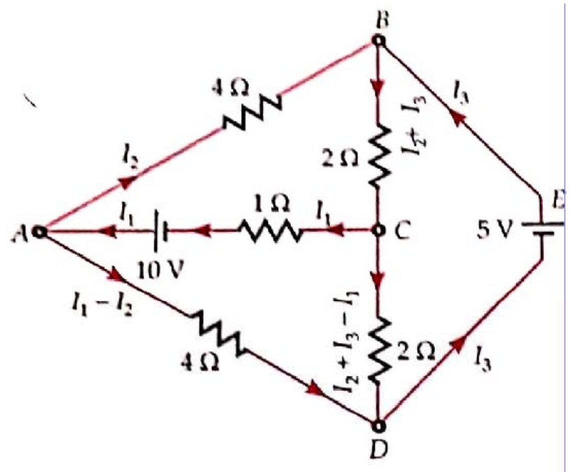



**Solution :**

The current distribution is shown by using KCL.

Using KVL, in the loop ABCA, $4I_2 + 2(I_2 + I_3) + 1(I_1) = 10$

$\Rightarrow I_1 + 6I_2 + 2I_3 = 10$ ...........(i)

In the loop ADCA, $1(I_1) - 2(I_2 + I_3 - I_1) + 4(I_1 - I_2) = 10$

$\Rightarrow 7I_1 - 6I_2 - 2I_3 = 10$ ...........(ii)

In the loop BCDB, $2(I_2 + I_3) + 2(I_2 + I_3 - I_1) = 5 \quad \Rightarrow -2I_1 + 4I_2 + 4I_3 = 5$ ...........(iii)

## Numerical

**Solution :**

Now adding equations (i) and (ii) we get, $8I_1 = 20 \Rightarrow I_1 = \frac{20}{8}A = \frac{5}{2}A$ ..............(iv)

Now equation (i) x 2 ⇒ $2I_1 + 12I_2 + 4I_3 = 20$ equation (iii) ⇒ $-2I_1 + 4I_2 + 4I_3 = 5$

Subtracting the two we have ; $4I_1 + 8I_2 = 15 \Rightarrow 4 \times \frac{5}{2} + 8I_2 = 15 \Rightarrow I_2 = \frac{5}{8}A$

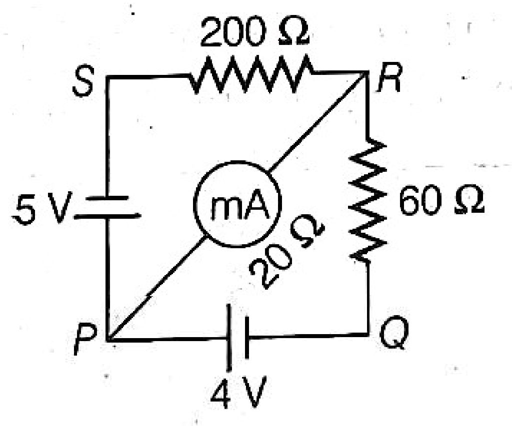
Using values of $I_1$ and $I_2$ in equation (i) we get, $I_3 = \frac{15}{8}A$

Now for each arm; $CA = I_1 = 5/2A;$ $AB = I_2 = 5/8A;$ $DEB = I_3 = 15/8A$

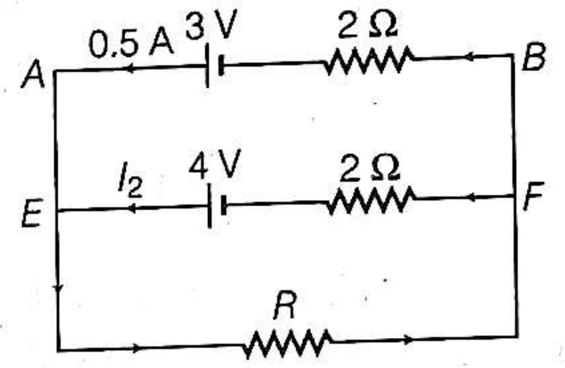
$AD = I_1 - I_2 = 5/2 - 5/8 = 15/8A$; $BC = I_2 + I_3 = 5/8 + 15/8 = 5/2A$; $CD = I_2 + I_3 - I_1 = 0$

# HOME ASSIGNMENT

1. The network PQRS, shown in the circuit diagram, has the batteries of 4 V and 5 V and negligible internal resistance. A milliammeter of $20\Omega$ resistance is connected between P and R. Calculate the reading in the milliammeter.




2. Using Kirchhoff's rules in the given circuit, determine
   a) the current $I_2$ in the arm EF
   b) the voltage drop across the unknown resistor R

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# THANKING YOU

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