Simple Electric Circuits

Kirchoff's Law:

Kirchoff current law: states that the net current on a junction in an electrical circuit will be zero. It is based on the conservation of charge.

Kirchoff Voltage Law: states that the algebraic sum of all potential difference along a closed loop is Zero. It is based on conservation of energy.

Electric Cell:

- An electric cell is a device which converts chemical energy into electrical energy.
- Electric cell is of two types:
    a. Primary cell: cannot be charged. Voltaic, Daniell and Leclanche cells are primary cells.
    b. Secondary cell: can be charged again & again. Acid and alkali accumulators are secondary cells.

Solved Examples

1. A current of 0.75 A is drawn by the filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit.

a. 400C b. 500C
c. 450C d. 550C

Solution: c
Given, I= 0.75 A, t=10 minutes= 600 s
We know, $Q = I \times t = 0.75 \times 600$
Therefore, Q= 450C

2. What constitutes current in a metal wire?

a. Electrons b. Protons
c. Atoms d. Molecules

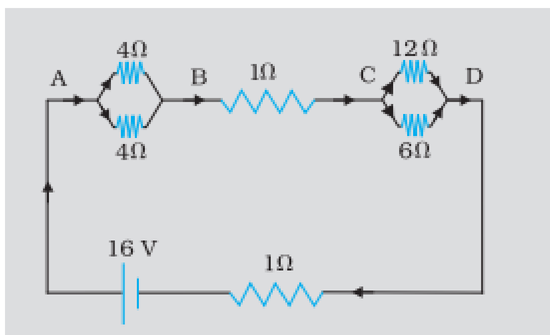
Solution: a.
Electrons. Electric current is the flow of electric charge. The electric charge mainly constitutes the electrons.

3. An electric lamp of 100 watt is used for 10 hours per day. The 'units' of energy consumed in one day by the lamp is

a. 1 unit b. 0.1 unit
c. 10 units d. 100 units

Solution: a
Total Power = 100 x 10 = 1000 watts = 1 kWh = 1 unit

Directions for next 4 Questions:
A network of resistors is connected to a 16 V battery with internal resistance of 1Ω, as shown in Fig.



4. The equivalent resistance of the network.

a. 6 Ω b. 11 Ω
c. 7 Ω d. 8 Ω

Solution: c
The network is a simple series and parallel combination of resistors. First the two 4Ω resistors in parallel are equivalent to a resistor = [(4 × 4)/(4 + 4)] Ω = 2 Ω.

In the same way, the 12 Ω and 6 Ω resistors in parallel are equivalent to a resistor of [(12 × 6)/(12 + 6)] Ω = 4 Ω.

The equivalent resistance R of the network is obtained by combining these resistors (2 Ω and 4 Ω) with 1 Ω in series, that is,

$R = 2\ \Omega + 4\ \Omega + 1\ \Omega = 7\ \Omega$.

5. Obtain the current in 4 Ω resistor.

a. 3 A	b. 4 A
c. 1 A	d. 5A

Solution: c

The total current I in the circuit is
$I=\varepsilon/(R+r)=16V/(7+1)\Omega = 2A$.
Consider the resistors between A and B. If I_1 is the current in one of the 4 Ω resistors and I_2 the current in the other,
$I_1 \times 4 = I_2 \times 4$
that is, $I_1 = I_2$, which is otherwise obvious from the symmetry of the two arms. But $I_1 + I_2 = I = 2A$. Thus,
$\mathbf{I_1 = I_2 = 1A}$
that is, current in each 4 Ω resistor is 1 A. Current in 1 Ω resistor between B and C would be 2A.

6. Obtain the current in 6 Ω resistor.

a. 3/4 A	b. 4/3 A
c. 10/3 A	d. 5/6A

Solution:b

Now, consider the resistances between C and D. If I_3 is the current in the 12 Ω resistor, and I_4 in the 6 Ω resistor,
$I_3 \times 12 = I_4 \times 6$, i.e., $I_4 = 2I_3$
But, $I_3 + I_4 = I = 2A$
Thus, $I_3 = 2/3$ A, $\mathbf{I_4 = 4/3\ A}$
that is, the current in the 12 Ω resistor is (2/3) A, while the current in the 6 Ω resistor is (4/3) A.

7. Find the voltage drops V_{AB}, V_{BC} and V_{CD}.

a. 4, 4 and 4 V	b. 1, 2 and 4 V
c. 2, 2 and 4 V	d. 4, 2 and 8 V

Solution: d

The voltage drop across AB is $V_{AB} = I_1 \times 4 = 1\ A \times 4\ \Omega = 4\ V$, This can also be obtained by multiplying the total current between A and B by the equivalent resistance between A and B, that is,

$\mathbf{V_{AB} = 2\ A \times 2\ \Omega = 4\ V}$

The voltage drop across BC is

$\mathbf{V_{BC} = 2\ A \times 1\ \Omega = 2\ V}$

Finally, the voltage drop across CD is $\mathbf{V_{CD} = 12\ \Omega \times I_3 = 12\ \Omega \times 2/3\ \ A = 8\ V.}$

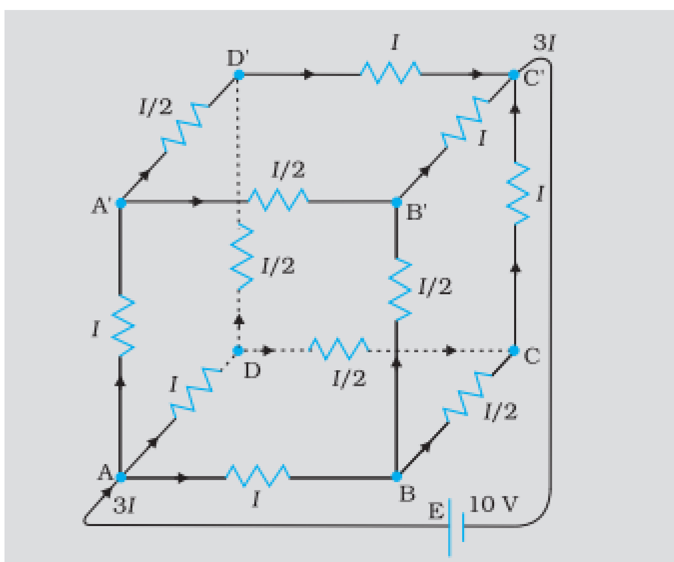
This can alternately be obtained by multiplying total current between C and D by the equivalent resistance between C and D, that is, $V_{CD} = 2\ A \times 4\ \Omega = 8\ V$

Note that the total voltage drop across AD is 4 V + 2 V + 8 V = 14 V.

Thus, the terminal voltage of the battery is 14 V, while its emf is 16 V. The loss of the voltage (= 2 V) is accounted for by the internal resistance 1 Ω of the battery [2 A × 1 Ω = 2 V].

Directions for next 2 Questions:

A battery of 10 V and negligible internal resistance is connected across the diagonally opposite corners of a cubical network consisting of 12 resistors each of resistance 1 Ω (Fig.).



8. What is the equivalent resistance of the network ?

a. 5/6 Ω b. 6/5 Ω

c. 12 Ω d. 6 Ω

Solution: a

9. What is the current along the edge D'C' of the cube?

a. 3 A b. 4 A
c. 10/3 A d. 5/6A

Solution: b
The network is not reducible to a simple series and parallel combinations of resistors. There is, however, a clear symmetry in the problem which we can exploit to obtain the equivalent resistance of the network.

The paths AA′, AD and AB are obviously symmetrically placed in the network. Thus, the current in each must be the same, say, I. Further, at the corners A′, B and D, the incoming current I must split equally into the two outgoing branches. In this manner, the current in all the 12 edges of the cube are easily written down in terms of I, using Kirchhoff's first rule and the symmetry in the problem.

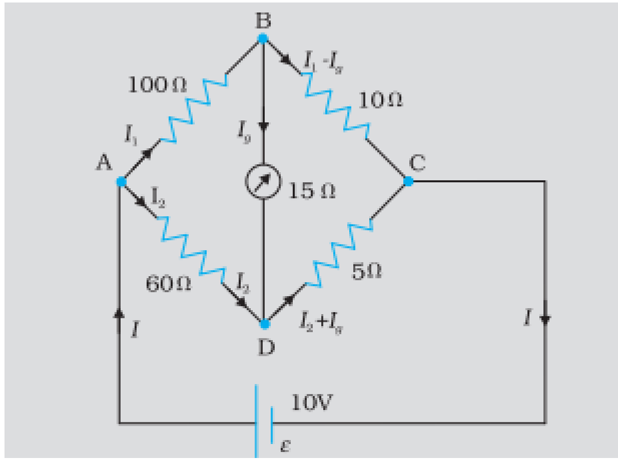
Next take a closed loop, say, ABCC′EA, and apply Kirchhoff's second rule:

$-IR - (1/2)IR - IR + \varepsilon = 0$
where R is the resistance of each edge and ε the emf of battery. Thus,
$\varepsilon = 5/2\ I \times R$

The equivalent resistance R_{eq} of the network is
$\mathbf{R_{eq} = \varepsilon/3I = 5/6\ R}$

For R = 1 Ω, $\mathbf{R_{eq} = (5/6)\ \Omega}$ and for ε = 10 V, the total current (= 3I) in the network is
3I = 10 V/(5/6) Ω = 12 A, i.e., **I = 4 A**

10. The four arms of a Wheatstone bridge (Fig.) have the following resistances: AB = 100Ω, BC = 10Ω, CD = 5Ω, and DA = 60Ω.



A galvanometer of 15Ω resistance is connected across BD. What is the current through the galvanometer(I_g) when a potential difference of 10 V is maintained across AC.

a. 4.87 A b. 4.87 mA
c. 100 mA d. 1 A

Solution: b

Considering the mesh BADB, we have

$100\ I_1 + 15\ I_g – 60I_2 = 0$

or $20\ I_1 + 3\ I_g – 12\ I_2 = 0$ [3.84(a)]

Considering the mesh BCDB, we have

$10\ (I_1 – I_g) – 15\ I_g – 5\ (I_2 + I_g) = 0$

$10\ I_1 – 30\ I_g –5\ I_2 = 0$

$2\ I_1 – 6\ I_g – I_2 = 0$ [3.84(b)]

Considering the mesh ADCEA,

$60\ I_2 + 5\ (I_2 + I_g) = 10$

$65\ I_2 + 5\ I_g = 10$

$13\ I_2 + I_g = 2$ [3.84(c)]

Multiplying Eq. (3.84b) by 10

$20\ I_1 – 60\ I_g – 10\ I_2 = 0$ [3.84(d)]

From Eqs. (3.84d) and (3.84a) we have

$63\ I_g – 2\ I_2 = 0$

$I_2 = 31.5\ I_g$ [3.84(e)]

Substituting the value of I_2 into Eq. [3.84(c)], we get

$13\ (31.5\ I_g) + I\ g = 2$

$410.5\ I_g = 2$

$I_g = 4.87$ mA.