SHORT QUESTIONS

13.1 A potential difference is applied across the ends of a copper wire. What is the effect on the drift velocity of free electron by?

(i) Increasing the potential difference.

(ii) Decreasing the length and the temperature of the wire.

Ans. (i) As we know that the drift velocity of free electrons is directly proportional to the potential difference i.e.,

$$V_d \propto E$$

Therefore if potential difference is increases then the drift velocity of free electrons is also increases.

(ii) As the resistance depends (i.e., directly proportional) upon temperature and length of the conductor. So on decreasing the temperature and length of the conductors, the resistance decreases. So drift velocity increases.

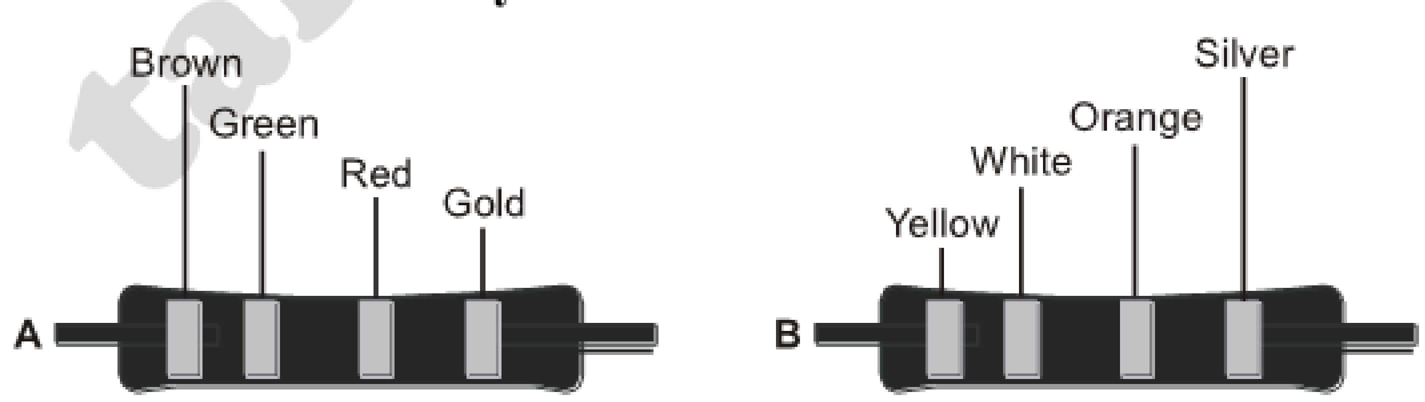
13.2 Do bends in a wire affect its electrical resistance? Explain.

Ans. The resistance of conductor of length L and cross-sectional area A is given by

$$R = \frac{\rho L}{A}$$

Where ρ is the resistivity whose value depends upon the nature of the conductor. If length L and cross-sectional area A of the wire is unchanged after bending then its electrical resistance will remain same.

13.3 What are the resistances of the resistors given in the figures A and B? What is the tolerance of each? Explain what is meant by the tolerance?



Ans. Figure A as we know that first three bands on the left show values of resistance and the extreme band gives tolerance of the resistance. Thus in this figure.

1^{st} band in brown = 1

2^{nd} band in green = 5

3^{rd} band is red = 2 = No of zeros = 00

4^{th} band is gold which shows tolerance = ±5%

So the actual value of resistance = 1500 ± 5%

Figure B

1^{st} band is yellow = 4

2^{nd} band is white = 9

3^{rd} band is orange $=$ 3 $=$ No of zeros $=$ 000

4^{th} band is silver $=$ Which shows tolerance

$= \pm 10\%$

So the actual resistance $= 49000 \pm 10\%$

Tolerance Tolerance means the possible variation from the marked value. For example, 1500Ω resistance with a tolerance of ±5% will have an actual value of resistance b/w 1425 to 1575.

13.4 Why does the resistance of a conductor rise with temperature?

Ans. As we know that resistance offered by a conductor to the flow of current is due to the collisions, of free electrons with atoms of lattice. As temperature of the conductor rises, the amplitude of vibration of the atoms in the lattice increases and hence the probability of their collisions with free electrons also increases. Hence resistance of conductor rise with temperature.

13.5 What are the difficulties in testing whether the filament of a lighted bulb obeys Ohm's law?

Ans. According to Ohm's law current is directly proportional to applied potential difference providing physical state of conductor must remain constant therefore when current passes through the filament of bulb, initially the temperature of filament is low and its resistance remains constant hence filament Obey's Ohm's law but with the passage of time, its temperature increases, so resistance of filament increases therefore Ohm's law is not valid due to increase in temperature.

13.6 Is the filament resistance lower or higher in a 500W, 220 V light bulb than in a 100W, 220V bulb?

Ans. As we know that

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P}$$

For 1^{st} case

$$R_1 = \frac{(220)^2}{500} = 96.8\Omega$$

For 2^{nd} case

$$R_2 = \frac{(220)^2}{100} = 484\Omega$$

(OR)

As $$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P}$$

If $$V = \text{Constant}$$

$$R \propto \frac{1}{P}$$

$\therefore$ 500 watt bulb has less resistance than 100 W.

So the resistance of 500 watt bulb is less than the resistance of 100 watt. But 500 watt bulb will draw more current as compared to 100 watt bulb.

13.7 Describe a circuit, which will give a continuously varying potential?

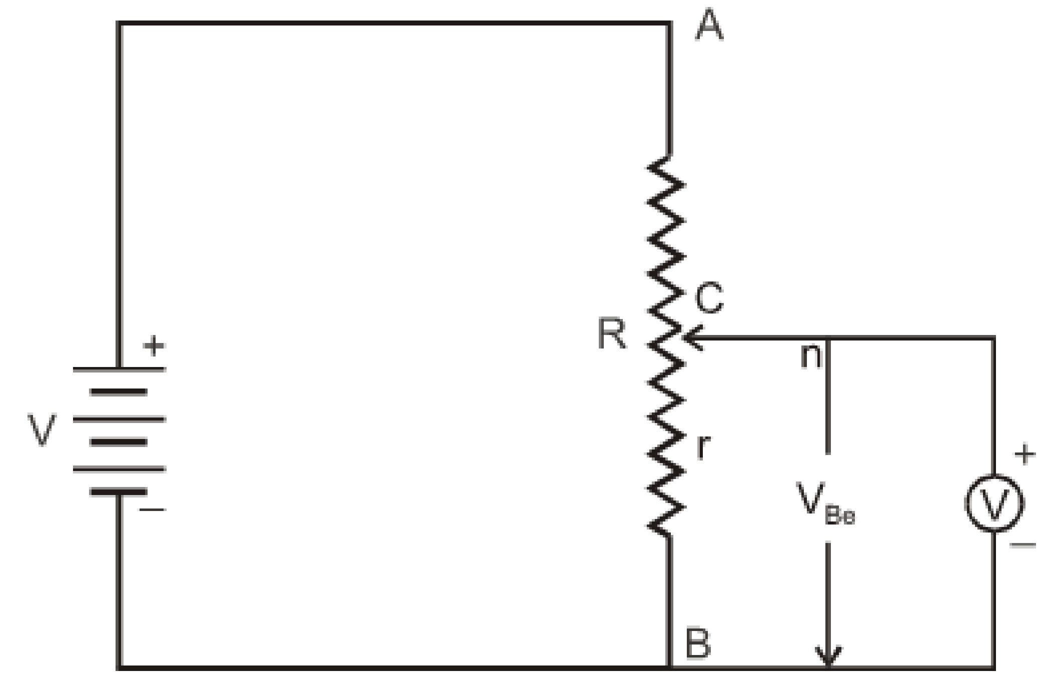
Ans. For continuously varying potential, we can use

(i) Rheostat as potential divider.

(ii) Potentiometer as potential divider.

Here we describe **rheostat as potential divider**.

A potential difference V is applied across the ends A and B of the rheostat as shown in figure.



The current I passing through R is

$$I = V/R$$

The potential difference between B and C is

$$V_{BC} = Ir$$

Putting values of I

$$\therefore \quad V_{BC} = \frac{V}{R} r$$

$$= \frac{r}{R} V$$

Where R = Resistance of wire AB.

r = Resistance of portion BC of wire

The circuit shown can provide its output potential difference varying from zero to full potential difference of battery depending on position of sliding contact C. From the equation we see that as we move from B to A the potential difference will change from zero to V.

13.8 Explain why the terminal potential difference of a battery decreases when the current drawn from it is increased?

Ans. We know that the relation between terminal potential difference and emf is

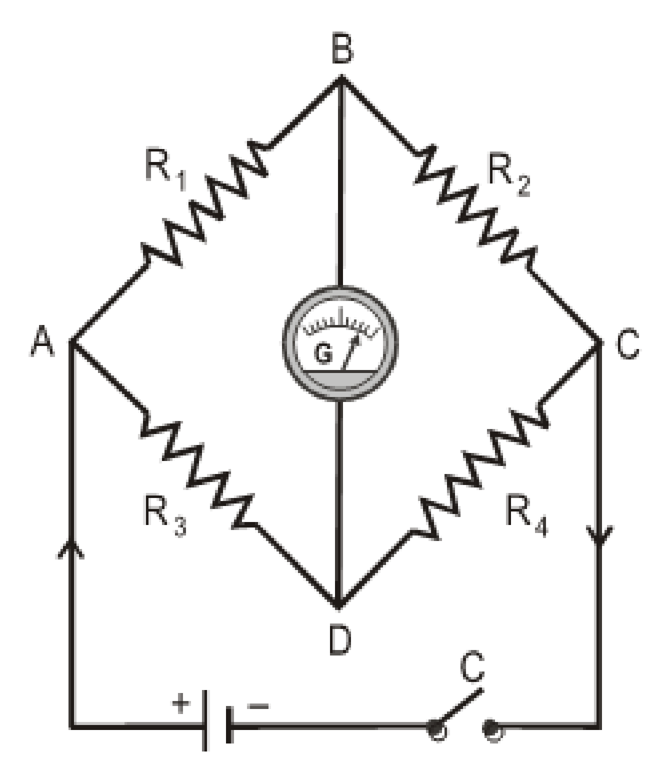
$$V_t = E - Ir$$

Here r is the internal resistance of cell.

It is clear that when current I is large, the factor Ir becomes large and V_t becomes small. Thus the potential difference of a battery decreases when current drawn from it increases.

13.9 What is Weatstone bridge? How can it be used to determine an unknown resistance?

Ans. Wheatstone bridge is an electrical circuit which is used to find unknown resistance of a wire.



Whenever bridge is balanced that is, galvanometer shows no deflection then following condition is satisfied.

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

In this circuit R_1, R_2, R_3 are known. If R_4 is unknown then

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

PROBLEMS WITH SOLUTIONS

PROBLEM 13.1

How many electrons pass through an electric bulb in one minute if the 300 mA current is passing through it?

Data

Electric current $= I = 300\text{ m A}$

$= 300 \times 10^{-3}\text{ A}$

Time $= t = 1\text{ min.}$

$= 60\text{ sec.}$

To Find

Number of electrons $= N = ?$

SOLUTION

By formula

$$Ne = Q$$

$$\boxed{N = \frac{Q}{e}} \qquad \ldots\ldots \text{(i)}$$

But $e = 1.6 \times 10^{-19}\text{ C}$

$$Q = I \times t$$

$$= 300 \times 10^{-3} \times 60$$

$$= 18000 \times 10^{-3}$$

$$Q = 18\text{ C}$$

Putting in eq. (i)

So $N = \dfrac{18}{1.6 \times 10^{-19}}$

$$= 11.25 \times 10^{+19}$$

$$= 1.125 \times 10^{+20}\text{ electrons}$$

Result

Number of electrons $= N = 1.125 \times 10^{20}$

PROBLEM 13.2

A charge of 90 C passes through a wire in 1 hour and 15 minutes. What is the current in the wire?

Data

Charge $= Q = 90\text{ C}$

Time $= t = 1\text{ hour } 15\text{ min.}$

$= 75\text{ min.}$

$= 75 \times 60$

$= 4500\text{ sec.}$

To Find

Current in the wire $= I = ?$

SOLUTION

By formula

$$\boxed{I = \frac{Q}{t}}$$

$$I = \frac{90}{4500}$$

$$I = 0.02\text{ amp}$$

$$= \frac{20}{1000} = 20 \times 10^{-3}$$

$$= 20\text{ m A}$$

Result

Current in the wire $= I = 20\text{ mA}$

PROBLEM 13.3

Find the equivalent resistance of the circuit (Fig. P 13.3), total current drawn from the source and the current through each resistor.

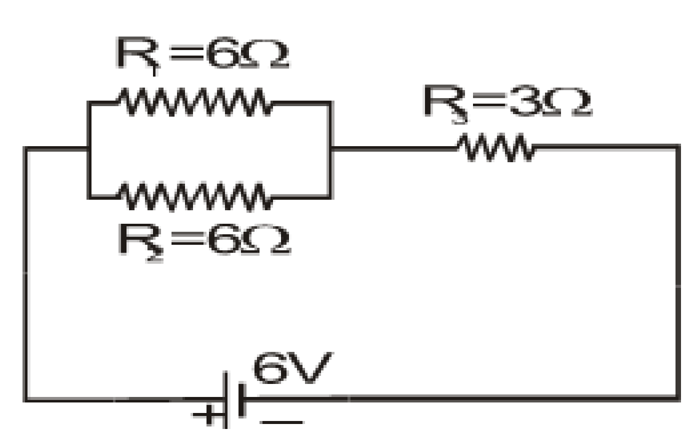


Fig. P 13.3

Data

Resistance $= R_1 = 6\Omega$

Resistance $= R_2 = 6\Omega$

Resistance $= R_3 = 3\Omega$

Voltage of battery $= V = 6\text{ volts}$

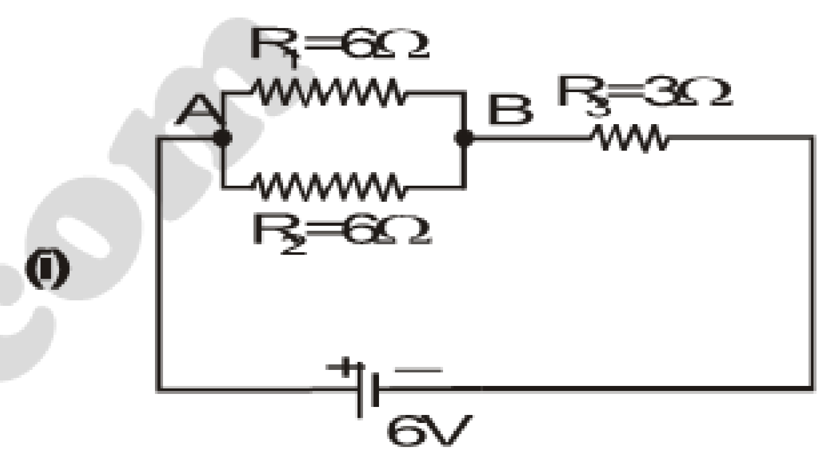
To Find

(i)	Equivalent resistance	$= R_e = ?$
(ii)	Total current through its circuit	$= I = ?$
(iii)	Current through resistance R_1	$= I_1 = ?$
	Current through resistance R_2	$= I_2 = ?$
	Current through resistance R_3	$= I_3 = ?$

SOLUTION

(i) For equivalent resistance

Since the resistance R_1 and R_2 are connected in parallel so in parallel combination



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R} = \frac{1}{6} + \frac{1}{6}$$

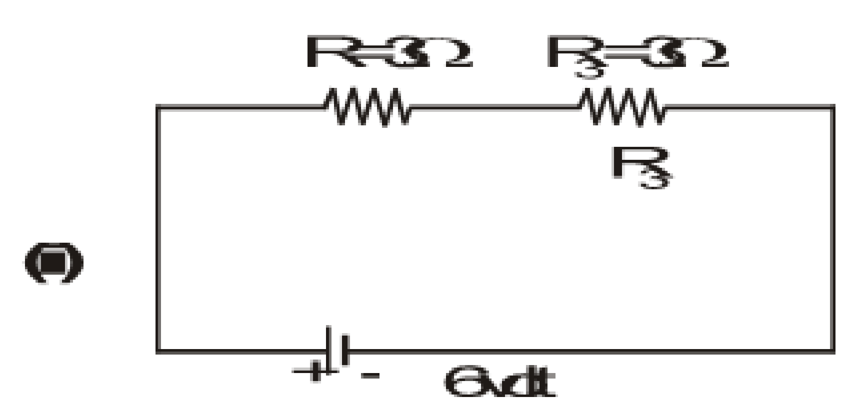
$$= \frac{1+1}{6}$$

$$\frac{1}{R} = \frac{2}{6}$$

$$\frac{1}{R} = \frac{1}{3}$$

$$R = 3\Omega$$

Since the resistance R and R_3 are connected in series as shown so in series combination



$$R_e = R + R_3$$

$$= 3 + 3$$

$$R_e = 6\,\Omega$$

So the equivalent resistance = R_e = 6Ω

(ii) For total current drawn from the circuit is

$$V = IR_e$$

$$\boxed{I = \frac{V}{R_e}}$$

$$I = \frac{6}{6}$$

$$I = 1 \text{ amp}$$

(iii) Current from each resistance

Now from the circuit (i), the potential between A and B is

$$\boxed{V_{AB} = IR}$$

$$= 1 \times 3$$

$$V_{AB} = 3 \text{ volt}$$

So the current from resistance R_1 is

$$I_1 = \frac{V_{AB}}{R_1} = \frac{3}{6}$$

$$= 0.5 \text{ A}$$

The current from resistance R_2 is

$$I_2 = \frac{V_{AB}}{R_2} = \frac{3}{6}$$

$$I_2 = 0.5\text{A}$$

The current from resistance R_3 is

$$I_3 = \frac{V}{R_e} = \frac{6}{6}$$

$$I_3 = 1\text{A}$$

Result

(i) Equivalent resistance $= R_e = 6\Omega$

(ii) Total current from the circuit $= I = 1.0$ Amp

(iii) Current from resistance R_1 $= I_2 = 0.5$ Amp

Current from resistance R_2 $= I_2 = 0.5$ Amp

Current from resistance R_3 $= I_3 = 1.0$ Amp

PROBLEM 13.4

A rectangular bar of iron is 2.0 cm by 2.0 cm in cross-section and 40 cm long. Calculate its resistance if the resitivity of iron is 11×10^{-8} Ωm.

Data

Area of cross-section $= A = 2 \times 2$

$= 4 \text{ cm}^2$

$= 4 \times 10^{-4} \text{ m}^2$

Length of iron bar $= L = 40$ cm

$= 0.4$m

Resistivity of iron $= 11 \times 10^{-8}$ Ωm

To Find

Resistance of iron bar $= R = ?$

SOLUTION

By formula

$$\boxed{R = \rho \frac{L}{A}}$$

$$R = \frac{11 \times 10^{-8} \times 0.4}{4 \times 10^{-4}}$$

$$= 1.1 \times 10^{-8+4}$$

$$R = 1.1 \times 10^{-4}\,\Omega$$

Result

Resistance of iron bar = $R = 1.1 \times 10^{-4}\,\Omega$

PROBLEM 13.5

The resistance of an iron wire at 0°C is $1 \times 10^4\ \Omega$. What is the resistance at 500°C if the temperature coefficient of resistance of iron is $5.2 \times 10^{-3}\ K^{-1}$?

Data

Temperature of iron wire = t_1 = 0°C + 273

= 273 K

Resistance at 0°C = R_0 = $1 \times 10^4\ \Omega$

Temperature = t_2 = 500°C + 273

= 773 K

Change in temperature = t = $t_2 - t_1$

= 773 – 273

= 500 K

Temperature coefficient of resistance = α = $5.2 \times 10^{-3}\ K^{-1}$

To Find

Resistance at 500°C = R_t = ?

SOLUTION

As we know that

$$\boxed{\alpha = \frac{R_t - R_o}{R_o\, t}}$$

$$R_t - R_o = \alpha R_o t$$

$$R_t = R_o + \alpha\, R_o\, t$$

$$\boxed{R_t = R_o(1 + \alpha\, t)}$$

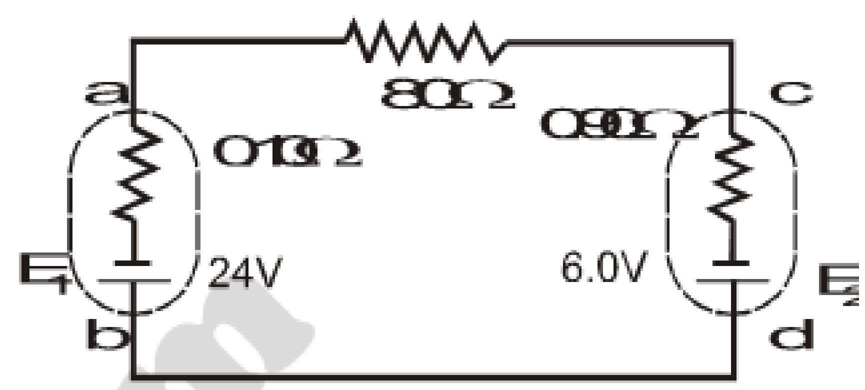
Putting the values

$$R_t = 1 \times 10^4 (1 + 5.2 \times 10^{-3} \times 500)$$
$$= 1 \times 10^4 (1 + 2.6)$$
$$= 1 \times 10^4 \times 3.6$$
$$R_t = 3.6 \times 10^4\ \Omega$$

Result

Resistance at 500°C $= R_t = 3.6 \times 10^4\ \Omega$

PROBLEM 13.6



Calculate terminal potential difference of each of cells in circuit of as shown.

Data

Potential of cell E_1 $= V_1$ $= 24$ volt

Resistance of cell E_1 $= r_1$ $= 0.10\ \Omega$

Potential of cell E_2 $= V_2$ $= 6.0$ volt

Resistance of cell E_2 $= r_2$ $= 0.9\ \Omega$

Resistance in circuit $= R$ $= 8.0\ \Omega$

To Find

(i) Potential difference of cell E_1 $= V_t = ?$

(ii) Potential difference of cell E_2 $= V_t' = ?$

SOLUTION

According to circuit, all the three resistances r_1, R and r_2 are connected in series so in series combination

$$R_e = r_1 + R + r_2$$
$$= 0.10 + 8.0 + 0.90$$
$$R_e = 9\Omega$$

As the two cells opposes each other so the net effective voltage is

$$V = 24 - 6$$
$$= 18 \text{ volt}$$

So the current flowing through the circuit is

$$V = IR_e$$
$$I = \frac{V}{R_e}$$
$$= \frac{18}{9}$$
$$I = 2 \text{ Amp}$$

So using the relation

$$E = V_t - Ir$$

(i) For 1st cell E_1

$$V_t = E_1 - Ir_1$$
$$= 24 - 2 \times 0.10$$
$$V_t = 23.8 \text{ volt}$$

(ii) For the cell E_2

$$V_1' = E_2 + Ir_2$$

Since the same current flowing through E_2 from –ve to +ve

$$V_1' = 6 + 2 \times 0.9$$
$$= 7.8 \text{ volt}$$

Result

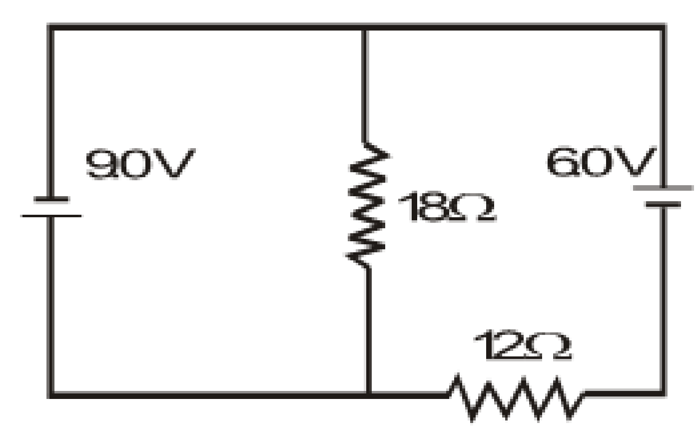
(i) Potential difference of cell E_1 = V_t = 23.8 volt

(ii) Potential difference of cell E_2 = V_t' = 7.8 volt

PROBLEM 13.7

Find the current which flows in all the resistances of the circuit of figure.

Data



Voltage of cell = E_1 = 9 volt

Resistance = R_1 = 18 Ω

Voltage of cell = E_2 = 6 volt

Resistance = R_2 = 12 Ω

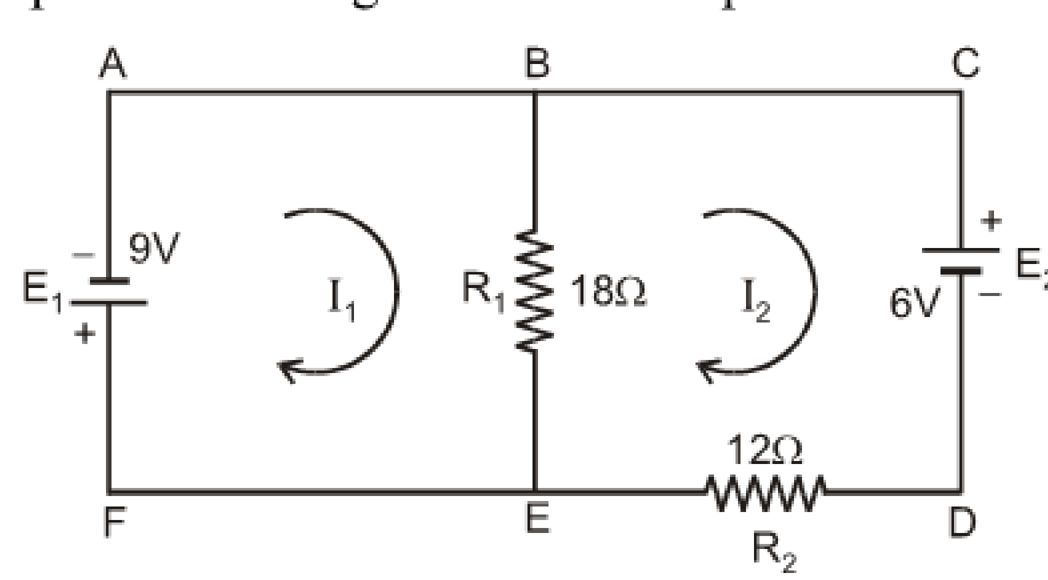
To Find

(i) Current from resistance R_1 = I_1 = ?

(ii) Current from resistance R_2 = I_2 = ?

SOLUTION

Let I_1 and I_2 are the currents flowing through the loops ABEFA and BCDEB respectively in clockwise direction. Applying Kirchhoff's second rule, the potential changes from the loop ABEFA are



$$-(I_1 - I_2)R_1 - E_1 = 0$$
$$-(I_1 - I_2)18 - 9 = 0$$

Divide by 9

$$-2(I_1 - I_2) - 1 = 0$$
$$-2I_1 + 2I_2 - 1 = 0$$
$$-2I_1 + 2I_2 = 1 \quad \text{...... (i)}$$

Applying Kirchhoff's 2nd rule on loop BCDEB

$$-E_2 - I_2R_2 - (I_2 - I_1)R_1 = 0$$

$$-6 - 12I_2 - (I_2 - I_1)18 = 0$$

Divide by 6

$$-1 - 2I_2 - 3(I_2 - I_1) = 0$$

$$-1 - 2I_2 - 3I_2 + 3I_1 = 0$$

$$3I_1 - 5I_2 = 1 \qquad \ldots\ldots \text{(ii)}$$

Multiply eq (i) by 3 and eq (ii) by 2 and add

$$-6I_1 + 6I_2 = 3$$

$$\underline{6I_1 - 10I_2 = 2}$$

$$-4I_2 = 5$$

$$I_2 = \frac{-5}{4}$$

$$I_2 = -1.25\text{A}$$

Putting in eq. (i)

$$-2I_1 + 2(-1.25) = 1$$

$$-2I_1 - 2.50 = 1$$

$$-2I_1 = 1 + 2.50$$

$$-2I_1 = 3.50$$

$$I_1 = \frac{-3.50}{2}$$

$$I_1 = -1.75\text{A}$$

Current through R_1 $= I_2 - I_1$

$= -1.25 - (-1.75)$

$= -1.25 + 1.75$

$= 0.50\text{A}$

Current through R_2 $= I_2 = -1.25\text{A}$

Result

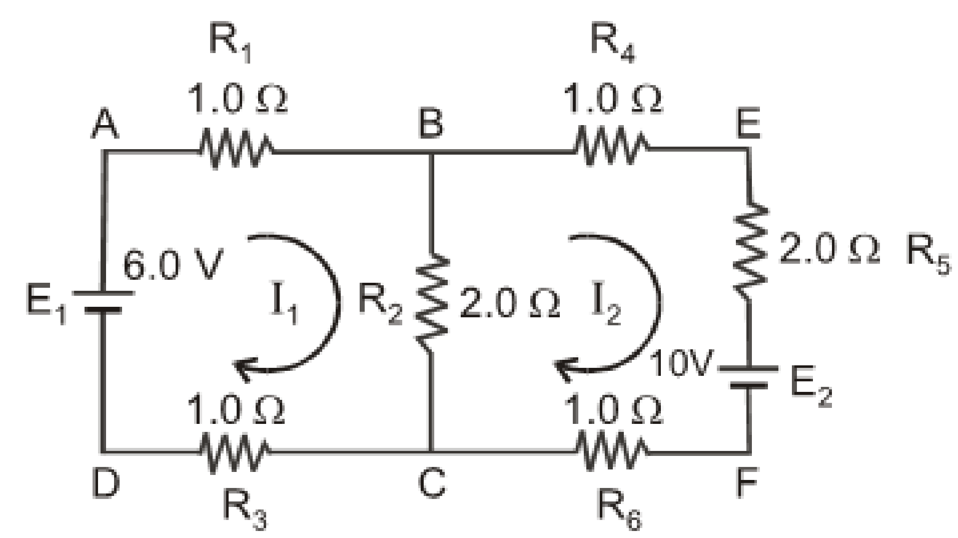
Current through R_1 $= I_1 = 0.50\text{A}$

Current through R_2 $= I_2 = -1.25\text{A}$

PROBLEM 13.8

Find the current and power dissipated in each resistance of the circuit, shown in figure.

Data



emf of the first cell = E_1 = 6 V

emf of second cell = E_2 = 10 V

Resistance = R_1 = 1.0 Ω

Resistance = R_2 = 2.0 Ω

Resistance = R_3 = 1.0 Ω

Resistance = R_4 = 1.0 Ω

Resistance = R_5 = 2.0 Ω

Resistance = R_6 = 1.0 Ω

To Find

(i) Current through resistance R_1 = I_1 = ?

Current through resistance R_2 = I_2 = ?

Current through resistance R_3 = I_3 = ?

Current through resistance R_4 = I_4 = ?

Current through resistance R_5 = I_5 = ?

Current through resistance R_6 = I_6 = ?

(ii) Power dissipation in each resistance = P = ?

SOLUTION

(i) Let I_1 and I_2 are the currents flowing from the loop ABCDA and BEFCB respectively in clockwise direction. Applying Kirchhoff's second rule on the loop ABCDA therefore the potential changes are

$$-I_1R_1 - (I_1 - I_2)R_2 - I_1R_3 + E_1 = 0$$

$$-I_1 - (I_1 - I_2)2 - I_1(1.0) + 6 = 0$$

$$-I_1 - 2I_1 + 2I_2 - I_1 + 6 = 0$$

$$-4I_1 + 2I_2 + 6 = 0 \qquad \ldots\ldots \text{(i)}$$

Applying Kirchhoff's 2nd rule on loop BEFCD

$$-I_2R_4 - I_2R_5 - E_2 - I_2R_6 - (I_2 - I_1)R_2 = 0$$

$$-I_2(1.0) - I_2(2.0) - 10 - I_2(1.0) - (I_2 - I_1)2.0 = 0$$

$$-I_2 - 2I_2 - 10 - I_2 - 2I_2 + 2I_1 = 0$$

$$-6I_2 + 2I_1 = 10 \qquad \ldots\ldots \text{(ii)}$$

Multiply eq (ii) by 2 and Add in eq (i)

$$
\begin{aligned}
-12I_2 + 4I_1 &= 20 \\
2I_2 - 4I_1 + 6 &= 0 \\
\hline
-10I_2 + 6 &= 20 \\
-10I_2 &= 20 - 6 \\
-10I_2 &= 14 \\
I_2 &= \frac{-14}{10} \\
I_2 &= -1.4A
\end{aligned}
$$

Putting in eq (i)

$$
\begin{aligned}
-4I_1 + 2(-1.4) + 6 &= 0 \\
-4I_1 - 2.8 + 6 &= 0 \\
-4I_1 + 3.2 &= 0 \\
-4I_1 &= -3.2 \\
I_1 &= \frac{3.2}{4} \\
I_1 &= 0.8\ A
\end{aligned}
$$

Now current through R_1 and $R_3 = I_1 = 0.8$ A

$$
\begin{aligned}
R_2 &= I_1 - I_2 \\
&= 0.8 - (-1.4) \\
&= 0.8 + 1.4 \\
&= 2.2\ A
\end{aligned}
$$

(ii) For power dissipation

As we know that

$$P = I^2R$$

The power dissipation from resistances R_1 and R_3 is

$$
\begin{aligned}
P &= I_1^2R_1 = I_1^2R_3 \\
&= (0.8)^2 \times 1.0 \\
&= 0.64 \text{ watt}
\end{aligned}
$$

The power dissipation from resistance R_2 is

$$
\begin{aligned}
P &= (I_1 - I_2)^2 R_2 \\
&= (2.2)^2 \times 2.0 \\
&= 9.68 \text{ watt}
\end{aligned}
$$

and similarly the power dissipation from resistances R_4 and R_6 is

$$P = I_2^2 R_4 = I_2^2 R_6$$

$$P = (1.4)^2 \times 1$$

$$= 1.96 \times 1$$

$$P = 1.96 \text{ watt}$$

The power dissipation from resistance R_5 is

$$P = I^2 R_5$$

$$= (1.4)^2 \times 2.0$$

$$= 3.92 \text{ watt}$$

Result

(i)	Current from resistance R_1 and R_3	$= I_1$	=	0.8 Amp
	Current from resistance R_2	$= I$	=	2.2 Amp
	Current from resistance R_4, R_5 and R_6	$= I_2$	=	1.4 Amp
(ii)	Power dissipation from R_1 and R_3	$= P$	=	0.64 watt
	Power dissipation from R_2	$= P$	=	9.68 watt
	Power dissipation from R_4 and R_6	$= P$	=	1.96 watt
	Power dissipation from R_5	$= P$	=	3.92 watt