SOLVED EXAMPLES

Example 1.

The electron of hydrogen atom is considered to be revolving round a proton in circular orbit of radius $\hbar^2/me^2$ with velocity $e^2/\hbar$. Find the expression for the current (the circulating charge is equivalent to current). $\left(\hbar = \frac{h}{2\pi}\right)$

(1) $\frac{4\pi^2 me^5}{h^3}$ (2) $\frac{4\pi^2 me^5}{h^2}$ (3) $\frac{4\pi^2 me^3}{h^2}$ (4) $\frac{2\pi^2 me^5}{h^3}$

Solution:

(1) We know that $i = \frac{q}{t}$ (charge per unit time) ...(1)

The time required for the electron to complete one trip around the circular orbit of radius r is equal to the circumference divided by its speed, i.e.,

$$t = \frac{2\pi r}{v} \quad ...(2) \qquad \therefore\ i = \frac{q}{\left(\frac{2\pi r}{v}\right)} = \frac{ev}{2\pi r} \quad \text{(where q = e = electronic charge)}$$

Here $v = \frac{e^2}{\hbar}$ and $r = \frac{\hbar^2}{me^2}$

Substituting these values, we have

$$i = \frac{e\left(\frac{e^2}{\hbar}\right)}{2\pi\left(\frac{\hbar^2}{me^2}\right)} = \frac{e^3.me^2}{2\pi\hbar^3} = \frac{me^5}{2\pi\hbar^3} \quad \text{or} \quad i = \frac{4\pi^2 me^5}{h^3} \qquad \left(\because \hbar = \frac{h}{2\pi}\right)$$

Example 2.

A battery of e.m.f. E and internal resistance r sends a current i_1 and i_2 when connected to an external resistance R_1 and R_2 respectively. The e.m.f. of the battery.

(1) $\frac{i_1 i_2 (R_1 + R_2)}{(i_2 - i_1)}$ (2) $\frac{i_1 i_2 (R_1 - R_2)}{(i_2 - i_1)}$ (3) $\frac{i_1 i_2 (R_1 + R_2)}{(i_2 + i_1)}$ (4) $\frac{i_1 i_2 (R_1 - R_2)}{(i_2 + i_1)}$

Solution:

(2) According to the given problem $i_1 = \frac{E}{R_1 + r}$

where E and r be the e.m.f. and internal resistance of the cell.

$\therefore \quad E = i_1(R_1 + r)$

Further, $i_2 = \frac{E}{(R_2 + r)}$ or $E = i_2(R_2 + r)$

...(ii)

From eqs. (i) and (ii), we get $i_1(R_1 + r) = i_2(R_2 + r)$

or $r = \frac{i_1 R_1 - i_2 R_2}{(i_2 - i_1)}$ ...(iii)

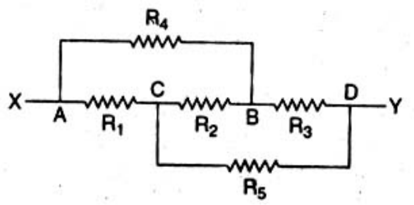
Substituting the value of r from eq. (iii) in eq. (i) we get

$$E = i_1\left[R_1 + \frac{i_1R_1 - i_2R_2}{(i_2 - i_1)}\right]$$

$$E = \frac{i_1 i_2 (R_1 - R_2)}{(i_2 - i_1)} \qquad \text{...(iv)}$$

Example 3.

What is the equivalent resistance between the points X and Y of the circuit?



Assume that the resistance of each resistor is 25 ohm.

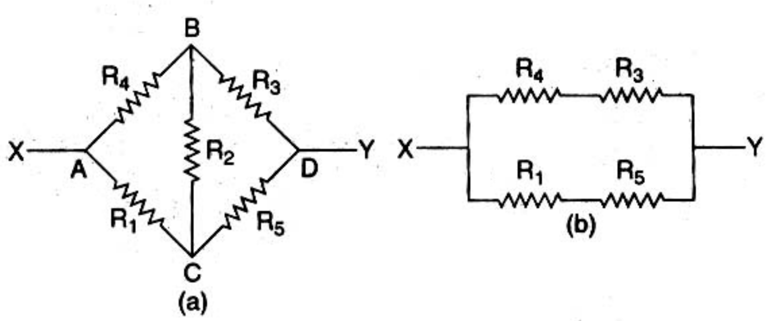
(1) 15 ohm (2) 20 ohm (3) 25 ohm (4) 30 ohm

Solution:

(3) The circuit is redrawn in fig. Since each resistance is of 25 ohm, if a potential difference is applied between X and Y, there will be no current in resistance R_2 . This is because the resistance form a balanced Wheatstone's bridge.

$$\frac{R_4}{R_1} = \frac{R_3}{R_5} = 1$$

So, R_2 can be omitted from the circuit as shown in fig.



Now R_4 and R_3 and R_1 and R_5 are in series and then the two are in parallel. Hence

R_4+R_3= 50 ohm and R_1+R_5 = 50 ohm

Effective resisatnce $= \frac{1}{R} = \frac{1}{50} + \frac{1}{50} = \frac{1}{25}$ $\therefore$ R = 25 ohm

Example 4.

Three 4 V batteries, internal resistance 0.1, 0.2 and 0.3 are connected in parallel and in series with a 2.045 ohm resistor. The terminal voltage of each cell is

(1) 3.8960 V (2) 3.955 V

(3) 3.8955 V (4) 3.9855 V

Solution:

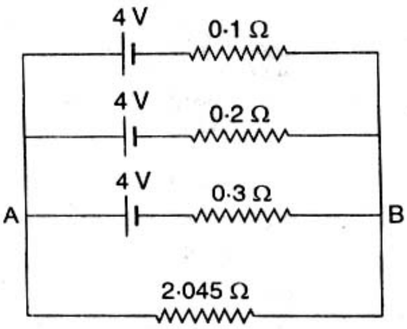
(3) The circuit arrangement is shown in fig.

As the batteries are connected in parallel, hence total e.m.f. of the circuit = 4 V

The effective resistance R_{AB} between A and B is given by

$$\frac{1}{R_{AB}} = \frac{1}{0.1} + \frac{1}{0.2} + \frac{1}{0.3} = \frac{110}{6}$$

$$R_{AB} = \frac{6}{110} = 0.055\,\text{ohm}$$



Equivalent emf = 4 volt

Current in the circuit $= \frac{4}{2.1} = 1.9\text{amp}$

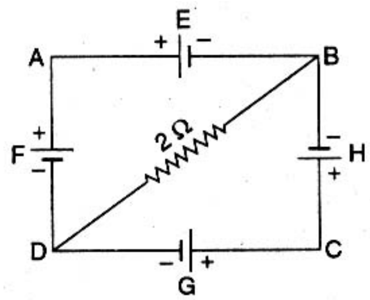
Terminal voltage of equivalent cell

$= 4 - i\,R_{AB} = 4 - 1.9 \times 0.055 = 4 - 0.1045 = 3.8955$ V

Batteries are in parallel hence terminal voltage for each cells is 3.8955 V

Example 5.

In the circuit shown in fig. E, F, G and H are cells of e.m.f. 2, 1, 3 and 1 volt and their internal resistances are 2, 1, 3 and 1 ohm respectively. Calculate the potential difference between B and D.



(1) 2/3 V (2) 2/13 V (3) 13/2 V (4) 13/3 V

Solution:

(2) Fig. shows the curent distribution.

Applying Kirchhoff's first law at point D, we have

$i = i_1 + i_2$ ...(1)

Applying Kirchhoff's second law to mesh and ABDA, we have

$2i + i + 2\,i_1 = 2 - 1 = 1$ or $3i + 2i_1 = 1$ ...(2)

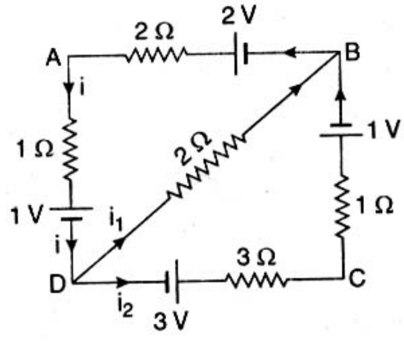
Applying Kirchhoff's second law to mesh DCBD, we get

$3i_2 - 1i_2 - 2i_1 = 3 - 1$

or $4i_2 - 2i_1 = 2$ ...(3)

Solving eqs. (1), (2) and (3), we get

$i_1 = \frac{1}{13}\text{amp}$, $i_2 = \frac{6}{13}\text{amp}$ and $i = \frac{5}{13}\text{amp}$

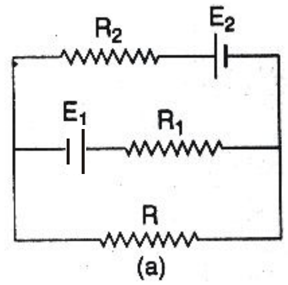


Potential difference between B and D

$$= 2i_1 = 2\left(\frac{1}{13}\right) = \frac{2}{13}\,\text{volt}$$

Example 6.

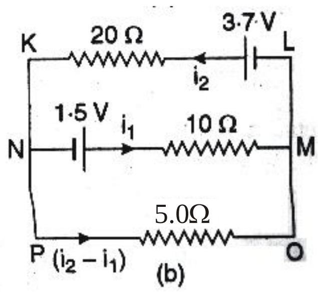
Find the magnitude of the current flowing through the resistance R in the circuit shown in fig. if the e.m.fs of the sources are equal to E_1 = 1.5 V and E_2 = 3.7 V and the resistances are equal to $R_1 = 10\Omega$, $R_2 = 20\Omega$, $R = 5.0\Omega$. The internal resistances of the sources are negligible.



(1) 0.02 amp (2) 0.03 amp (3) 0.32 amp (4) 0.12 amp

Solution:

(1) The current distribution in the circuit is shown in fig.



Applying Kirchhoff's law to mesh POLKP, we have

$20i_2 + 5(i_2 - i_1) = 3.7$ or $25i_2 - 5i_1 = 3.7$ ...(1)

For mesh NMOPN, we have

$10i_1 - 5(i_2 - i_1) = 1.5$ or $-5i_2 + 15i_1 = 1.5$ ...(2)

Multiplying eq. (1) by 3 and adding it to eq. (2), we get

we get $70i_2 = 12.6$ or $i_2 = 0.18$ amp

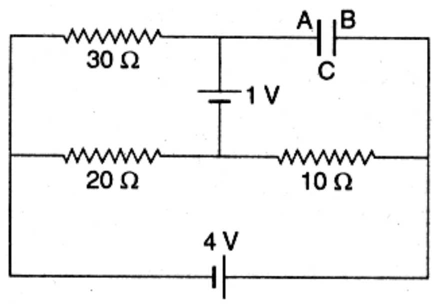
Multiplying eq. (2) by 5 and adding it to eq. (1), we get

we get $70i_i = 11.2$ or $i_1 = 0.16$ amp

Hence current flowing through R = $i_2 - i_1$ = 0.18 – 0.16 = 0.02 amp

Example 7.

Find the potential difference between the plates of the capacitor C in the circuit shown in fig. The internal resistance of the sources are negligible.



(1) 1 V (2) – 1 V

(3) 2 V (4) –2 V

Solution: (2)

The current distribution is shown in fig. When the condenser has been fully charged, there will be no current in this branch.

Applying Kirchhoff's first law at junction M, we have

$i_2 + i_3 = i_1$ ...(1)

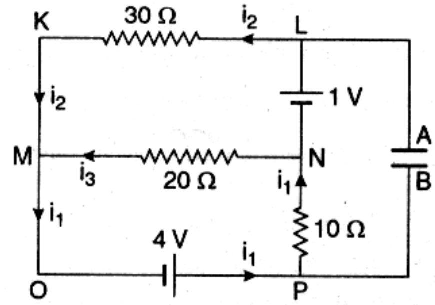
Applying Kirchhoff's second law to meshes NLKMN and PNMOP, we have

$30i_2 - 20i_3 = 1$ ...(2)

and $10i_1 + 20i_3 = 4$ ...(3)

Solving eqs. (1) , (2) and (3), we get

$i_2 = i_3 = \frac{1}{10}$ amp and $i_1 = \frac{1}{5}$ amp



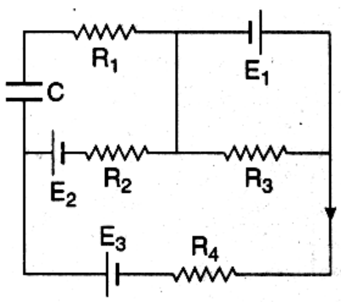
Considering the mesh PBALP, we have

$V_{AB} - 1 = -10i_1 = -10 \times \frac{1}{5} = -2$

$\therefore \quad V_{AB} = -2 + 1 = -1$ volt

Example 8.

In the given circuit. E_1 = 6V, E_2 = 2V, E_3 = 3V, R_1 = 6ohm, R_2 = 2ohm, R_3=4 ohm, R_4= 3 ohm and $C = 5\mu F$. Find the current in R_3 and energy stored in the capacitor.



(1) 1.5 amp, 14.4×10^{-6} joule

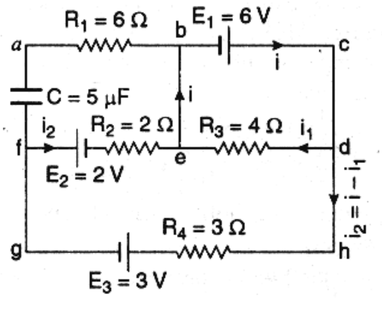
(2) 0.15 amp, 1.44×10^{-6} joule

(3) 0.015amp, 0.144×10^{-6} joule

(4) 15 amp, 144×10^{-6} joule

Solution:

(1) The distribution of current is shown in fig.



Applying Kirchhoff's second law to mesh bcdeb,we have

4i = 6 or $i_1 = \frac{6}{4} = 1.5$ amp

Current in resistor R_3 = 1.5 amp

Applying Kirchhoff's second law of mesh dhgfed, we have

$3i_2 + 2i_2 - 4i_1 = -3 - 2$ or $5i_2 - 4i_1 = -5$ or $5i_2 - 4 \times 1.5 = -5$

Solving, we get $i_2 = 0.2$ amp

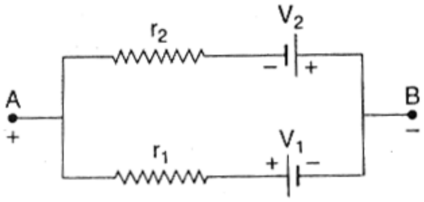
To find out the potential difference between b and f, we consider the path be f

$V_b + 2i_2 + 2 = V_f$ $\therefore$ $V_f - V_b = 2i_2 + 2 = 2 \times 0.2 + 2 = 2.4$ volt

It is obvious that there is no current in resistor R_1 hence there will be 2.4 volt potential difference across the condenser. The energy stored in capactior C is given by $U = \frac{1}{2}CV^2 = \frac{1}{2}(5 \times 10^{-6})(2.4)^2 = 14.4 \times 10^{-6}$ J

Example 9.

Find the e.m.f. (V) and internal resistance (r) of a single battery which is equivalent to a parallel combination of two batteries of e.m.fs. V_1 and V_2 and internal resistances r_1 and r_2 respectively, with polarities as shown in fig.



(1) $V = \frac{V_1r_2 + V_2r_1}{(r_1 + r_2)}$ and $r = \frac{r_1r_2}{(r_1 - r_2)}$ (2) $V = \frac{V_1r_2 - V_2r_1}{(r_1 + r_2)}$ and $r = \frac{r_1r_2}{(r_1 + r_2)}$

(3) $V = \frac{V_1r_2 + V_2r_1}{(r_1 - r_2)}$ and $r = \frac{r_1r_2}{(r_1 - r_2)}$ (4) $V = \frac{V_1r_2 + V_2r_1}{(r_1 + r_2)}$ and $r = \frac{r_1r_2}{(r_1 + r_2)}$

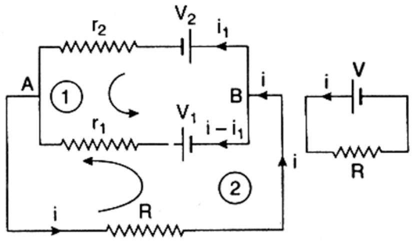
Solution:

(2) The internal resistance r of the source, equivalent to two batteries will be

$$\frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} \qquad \text{or} \quad r = \left(\frac{r_1r_2}{r_1 + r_2}\right)$$

The current distribution is shown in fig.

Applying Kirchhoff's law to mesh I, we have



$i_1 r_2 - (i - i_1) r_1 = -V_1 - V_2$

or $-i r_1 + i_1 (r_1 + r_2) = (V_1 + V_2)$ ...(1)

Further, applying Kirchhoff's law to mesh 2, we have

$(i - i_1) r_1 + iR = V_1$

or $i(r_1 + R) - i_1 r_1 = V_1$ ...(2)

Adding equations (1) and (2), we get

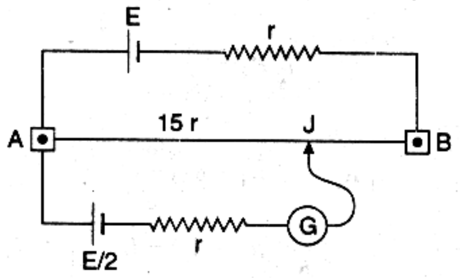
$$i = \frac{\frac{(V_1r_2 - V_2r_1)}{(r_1 + r_2)}}{\frac{r_1r_2}{(r_1 + r_2)} + R} \qquad ...(3)$$

But $i = \frac{V}{r + R}$

Hence $V = \frac{V_1r_2 - V_2r_1}{(r_1 + r_2)}$ and $r = \frac{r_1r_2}{(r_1 + r_2)}$

Example 10.

A 600 cm long potentiometer wire is connected to a circuit as shown in fig. The resistance of the potentiometer wire is 15r. If the jockey touches the wire at a distance of 560 cm from A, what will be the current in the galvanometer?



(1) 3E/22r (2) 8E/3r (3) 3E/4R (4) 4E/3r

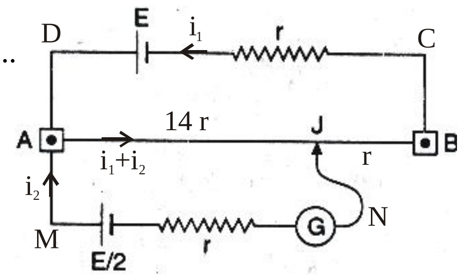
Solution:

(1) Appling Kirchhof's law in loop ABCD

$E - 16\, i_1 r - 14\, i_2\, r = 0$ ... (i)

In loop DMNJCD

$$\frac{E}{2} - 2i_1 r + i_2 r = 0$$ ...



form equation (i) and (ii)

$$i_2 = -\frac{3E}{22r}$$

Example 11.

One kilowatt electric heater is to be used with 220 V. D.C. supply.

(i) The current in the heater,

(ii) Its resistance and

(iii) The power dissipated in the heater respectively are

(1) 4.55A, 48.4Ω, 1000W (2) 2.44A, 36.8Ω, 500W

(3) 2.00A, 40Ω, 250W (4) 4.00A, 48Ω, 1000W

Solution:

(1) Here P = 1 kW = 1000 W and V = 220 Volt.

(i) Current in the heater $i = \frac{P}{V} = \frac{1000W}{220V} = 4.55A$

(ii) Resistance of heater coil $R = \frac{V^2}{P} = \frac{220 \times 220}{1000} = 48.4 ohm$

(iii) Power dissipated in heater = 1000 W

Example 12. The walls of a closed cubical box of edge 60 cm are made of material of thickness 1 mm and thermal conductivity 4×10^{-4} cal s^{-1} $cm^{-1}(°C)^{-1}$. The interior of the box is maintained 1000°C above the outside temperature by a heater placed inside the box and connected across 400 V, D.C. Calculate the resistance of the heater.

(1) 6.35 ohm (2) 63.5 ohm (3) 635 ohm (4) 0.635 ohm

Solution: (3) We know that the amount of heat transmitted per second through the walls of closed cubical box is given by

$$\frac{Q}{t} = \frac{KA(T_2 - T_1)}{d}$$

Here K = 4×10^{-4} cal s^{-1} cm^{-1} $(°C)^{-1}$. $(T_2–T_1)$=100°C, d= 1 mm = 0.1 cm, A=6×area of each face = 6×50×50 cm^2

$$\therefore \quad \frac{Q}{t} = \frac{(4\times10^{-4})(6\times50\times50)(100)}{0.1} = 6000\,\text{cal}\ s^{-1}$$

The heat lost must be produced by electric currnet in coil

$$H = \frac{V^2}{R\times4.2}\text{cal} \qquad \text{or} \qquad R = \frac{V^2}{H\times4.2}$$

Here V = 400 volt and H = 6000 cal.

$$\therefore \quad R = \frac{400\times400}{600\times4.2} \approx 635\text{ohm}.$$

MULTIPLE CHOICE QUESTIONS

LEVEL – 1

1. A current i flows through a uniform wire of diameter d when the mean drift velocity is v_d. The same current will flow through a wire of diameter d/2 made of the same material if the mean drift velocity of the electron is

(1) v/4 (2) v/2
(3) 4v (4) 2v
(5) v

2. Kirchhoff's first law, i.e. , $\sum i = 0$ at a junction deals with

(1) conservation of charge
(2) conservation of energy
(3) conservation of momentum
(4) conservation of angular momentum

3. Two wires A and B of the same material, having radii in the ratio 1:2 and carry currents in the ratio 4 : 1. The ratio of drift speed of electrons in A and B is

(1) 16 : 1 (2) 1 : 16
(3) 1 : 4 (4) 4 : 1

4. A cell of e.m.f. E is connected across a resistance r. The potential difference between the terminals of the cell is found to be V. The internal resistance of the cell must be

(1) $\frac{2(E-V)V}{r}$ (2) $\frac{2(E-V)r}{V}$
(3) $\frac{(E-V)r}{V}$ (4) $(E-V)r$

5. Two cells of the same e.m.f. e but different internal resistance r_1 and r_2 are connected in series with an external resistance R. The potential drop across the first cell is found to be zero. The external resistance will be

(1) $r_1 - r_2$ (2) r_1 / r_2
(3) $r_1 r_2$ (4) $r_1 + r_2$

6. A cell of negligible resistance and e.m.f. 2 volt is connected to series combination of 2, 3 and 5 ohm. The potential difference in volt between the terminals of 3 ohm resistance will be

(1) 0.6 V (2) 2/3 V
(3) 3 V (4) 6 V

7. Five cells each of e.m.f. E and internal resistance r are connected in series. If due to oversight, one cell is connected wrongly, then the equivalent e.m.f. and internal resistance of the combination is

(1) 5 E and 5 r (2) 3 E and 3 r
(3) 3 E and 5 r (4) 5 E and 4 r

8. A small sphere that carries charge q is whirled in a circle at the end of an insulating string. The angular frequency of rotation is 2ω. This rotating charge represents a current

(1) $\frac{q\omega}{\pi}$ (2) $\frac{q\omega}{2\pi}$
(3) $\frac{q\pi}{\omega}$ (4) $q\omega$

9. A constant voltage is applied between the two ends of a uniform metallic wire. Same heat is developed in it. The heat develped is doubled if

(1) both the length and radius of the wire are halved
(2) both the length and radius of the wire are double
(3) the radius of the wire is doubled
(4) the length of the wire is doubled

10. The masses of the three wires of copper are in the ratio 1 : 3 : 5. And their lengths are in the ratio of 5 : 3 : 1. The ratio of their electrical resistance is

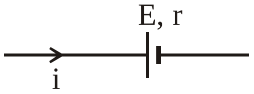
(1) 1 : 3 : 5
(2) 5 : 3 : 1
(3) 1 : 15 : 125
(4) 125 : 15 : 1

11. A cell develops the same power across two resistances R_1 and R_2 separately. The internal resistance of the cell is

(1) $R_1 + R_2$ (2) $\frac{R_1 + R_2}{2}$

(3) $\sqrt{R_1 R_2}$ (4) $\frac{\sqrt{R_1 R_2}}{2}$

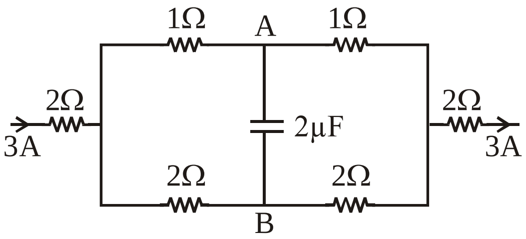
12. A current i is being driven through a cell of emf E and internal resistance r as shown. The chemical energy is stored in the cell at the rate of



(1) Ei (2) Ei–ir

(3) Ei–i^2r (4) None of these

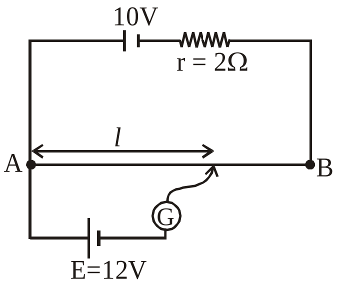
13. A part of electric circuit is shown in figure. A capacitor of 2μF is connected across A and B. At steady state the energy stored in capacitor is.



(1) Zero (2) 10 Joule

(3) 12 Joule (4) 8 Joule

14. Figure shows a potentiometer with a cell of 10 volt and internal resistance 2 Ω maintaining a potential drop across the resistor wire AB. A cell of emf 12V is connected through galvanometer. The null deflection is found at (Given $R_{AB} = 8\,\Omega$, L_{AB} = 100cm)

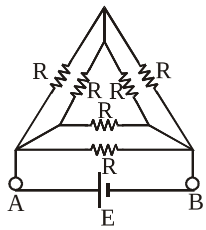


(1) l = 80 cm (2) l = 20 cm

(3) l = 60 cm

(4) Galvanometers will never show null deflection

15. Six resistances of each value (R) are connected as shown in figure. Which one of the following is correct ?



(1) Equivalent resistance between A & B is $\frac{R}{4}$

(2) Current in all the resistances will be same

(3) Current in all the resistances are different

(4) In some resistances the currents are same

16. The resistance of a metallic conductor increases with temperature due to

(1) Change in carrier density

(2) Change in the dimensions of the conductor

(3) Increase in the number of collisions among the carriers

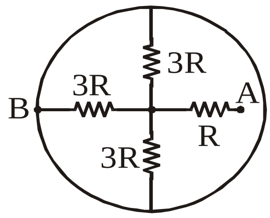
(4) Increase in the rate of collisions between the carriers and the vibrating atoms of the conductor

17. A nonconducting ring of radius R has charge Q distributed unevenly over it. If it rotates with an angular velocity ω, the equivalent current will be

(1) Zero (2) $Q\omega$

(3) $Q\frac{\omega}{2\pi}$ (4) $Q\frac{\omega}{2\pi R}$

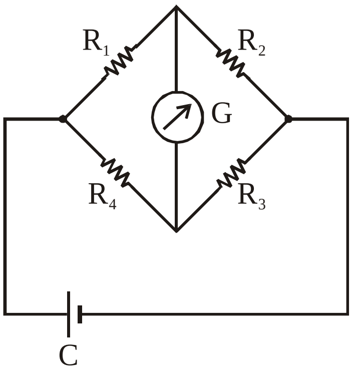
18. In the network shown below, the ring has zero resistance. The equivalent resistance between the point A and B is



(1) 2R (2) 4R

(3) 7R (4) 10R

19. The Wheatstone bridge shown in the figure is balanced. If the positions of the cell C and the galvanometer G are now interchanged, G will show zero deflection



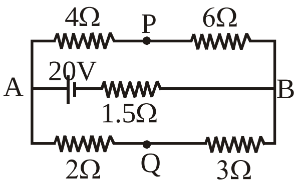
(1) In all cases

(2) Only if all the resistances are equal

(3) Only if $R_1 = R_3$ and $R_2 = R_4$

(4) Only if $R_1/R_3 = R_2/R_4$

20. In the given circuit



(1) The current through the cell is greater than 5.0 A

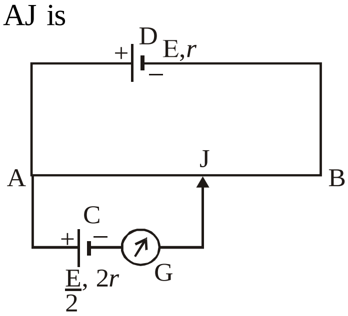
(2) P and Q are at the same potential

(3) P is at higher potential than Q

(4) Q is at higher potential than P

LEVEL - II

1. In the figure, the potentiometer wire AB of length L and resistance $9r$ is joined to the cell D of emf E and internal resistance r. The cell C's emf is E/2 and its internal resistance is $2r$. The galvanometer G will show no deflection when the length AJ is

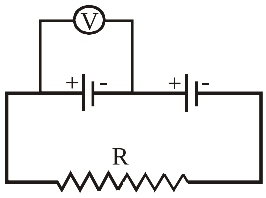


(1) $\frac{4L}{9}$

(2) $\frac{5L}{9}$

(3) $\frac{7L}{18}$ (4) $\frac{11L}{18}$

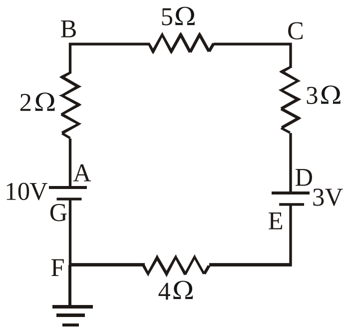
2. In the following diagram, the two cells have equal e.m.f E but internal resistances are r_1 and r_2. If the reading of the ideal voltmeter is zero, the relation between R, r_1 and r_2 is



(1) $R = r_1 - r_2$ (2) $R = r_1 + r_2$

(3) $R = 2r_1 - r_2$ (4) $R = r_1/r_2$

3. In the circuit as shown in the figure, the point F is grounded as shown. Which of the following is a wrong statement ?



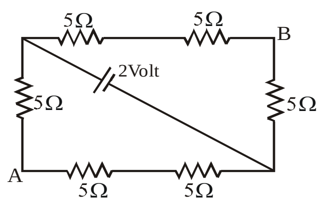
(1) Potential of E is zero

(2) Potential of D is 5 V

(3) Current in the circuit will be 0.5 A

(4) Current is same whether or not F is grounded.

4. The potential difference between the points A and B in the circuit diagram will be



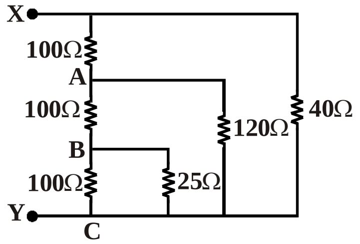
(1) $\frac{2}{3}$ volt

(2) $\frac{8}{9}$ volt

(3) $\frac{4}{3}$ volt

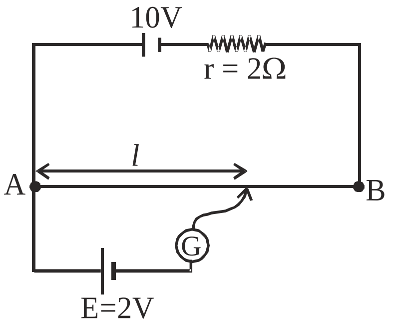
(4) 2 volts

5. The equivalent resistance of the network shown in the figure between points X and Y is



(1) 23Ω (2) 53Ω
(3) 32Ω (4) 35Ω

6. Figure shows a potentiometer with a cell of 10 volt and internal resistance 2Ω maintaining a potential drop across the resistor wire AB. A cell of emf 2V is connected through galvenometer. The null deflection is found at (Given R_{AB} = 8Ω, L_{AB} = 100cm)



(1) l = 80 cm (2) l = 70 cm
(3) l = 60 cm (4) l = 25 cm

7. The length of a potentiometer wire is l. A cell of emf E is balanced at a length l/3 from the positive end of the wire. If the length of the wire is increased by l/2. At what distance will the same cell give a balance point. (Internal resistance of driver cell is zero)

(1) $\frac{2l}{3}$ (2) $\frac{l}{2}$
(3) $\frac{l}{6}$ (4) $\frac{4l}{3}$

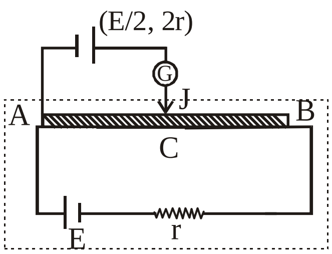
8. A voltmeter with resistance 500Ω is used to measure the emf of a cell of internal resistance 4Ω. The percentage error in the reading of the voltmeter will be

(1) 0.2% (2) 0.8%
(3) 1.4% (4) 2.2%

9. Two resistors having temperature co-efficient of resistance α_1 and α_2 have resistances R_1 and R_2 respectively at 0°C. The effective temperature co-efficients of resistance of parallel combination of both the resistor is

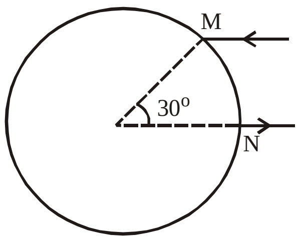
(1) $\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}$ (2) $\frac{\alpha_1 R_1+\alpha_2 R_2}{R_1+R_2}$
(3) $\frac{\alpha_1 R_2+\alpha_2 R_1}{R_1+R_2}$ (4) $\alpha_1+\alpha_2$

10. In the given circuit, the potentiometer wire AB has length L. The balancing point of the cell $\left(\frac{E}{2}, 2r\right)$ is obtained when the Jockey touches the potentiometer wire at C. Then



(1) AC = L (2) $AC=\frac{L}{2}$
(3) $AC>\frac{L}{2}$ (4) $AC<\frac{L}{2}$

11. A uniform wire of resistance 36 ohm is bent in form of a circle. The effective resistance between points M and N is



(1) 2.75 Ω (2) 3.5 Ω
(3) 33 Ω (4) 36 Ω

12. Two identical capacitors A and B are charged to the same potential and then made to discharge through resistances R_A and R_B respectively, with $R_A > R_B$.

(1) A will require greater time than B to discharge completely

(2) More heat will be produced in A than in B

(3) More heat will be produced in B than in A

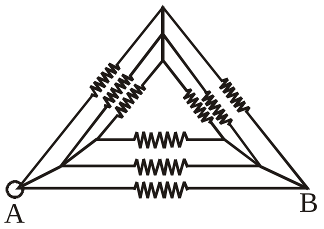
(4) None of these

13. The charge flowing through a resistance R varies with time t as $Q = at - bt^2$. The total heat produced in R in time t = 1is

(1) $\frac{a^3R}{6b}$ (2) $\frac{a^3R}{3b}$

(3) $\frac{a^3R}{2b}$ (4) $\frac{a^3R}{b}$

14. Nine resistors each of resistance R are connected in the circuit as shown in figure. The net resistance between A and B is



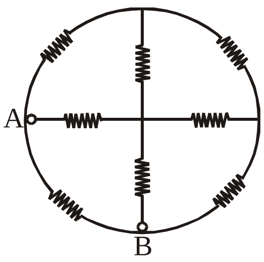
(1) R

(2) $\frac{7R}{6}$

(3) $\frac{3R}{5}$

(4) $\frac{2R}{9}$

15. Eight resistances each of resistance $5\,\Omega$ are connected in the circuit shown in figure. The equivalent resistance between A and B is



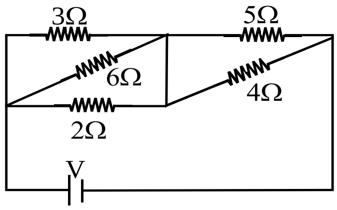
(1) $\frac{8}{3}\Omega$

(2) $\frac{16}{3}\Omega$

(3) $\frac{15}{7}\Omega$

(4) $\frac{19}{2}\Omega$

16. The resistor in which maximum heat will be produced is



(1) 6Ω (2) 2Ω

(3) 5Ω (4) 4Ω

17. A cell of internal resistance r drives a current through an external resistance R. The power delivered by the cell to the external resistance is maximum when

(1) R = r

(2) R > > r

(3) R < < r (4) R = 2 r

18. If the length of the filament of a heater is reduced by 10% , the power of the heater will

(1) Increase by about 9%

(2) Increase by about 11%

(3) Increase by about 19%

(4) Decrease by about 10%

19. An electric kettle, rated 2.1 kW contains 1 kg of water. Assuming no heat loss and neglecting the thermal capacities of the kettle, how long will it take to start to boil the water if its initial temperature is 20°C? (Specific heat of water $= 4.2 \times 10^3$ J/kg)

(1) 80 s

(2) 120 s

(3) 160 s

(4) 200 s

20. A length of potentiometer wire is l. A cell of emf E is balanced at a length l /3 from the positive end of the wire. If the width of the wire is doubled, at what distance from end A will the same cell give a balance point.

(1) $\frac{2l}{3}$ (2) $\frac{l}{3}$

(3) $\frac{l}{6}$ (4) $\frac{4l}{3}$

LEVEL - III

1. A wire of uniform cross-section and 60 Ω resistance is uniformly stretched until its new length is three times the original length. Find its new resistance. Assume that the density and resistivity of the material remain constant during the drawing process.

(1) 60 Ω

(2) 210 Ω

(3) 450 Ω

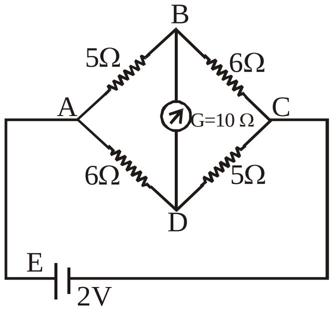
(4) 540 Ω

2. The potential difference across the terminals of a storage battery is 10 V in a closed circuit. If the external resistance is increased by 1Ω, the potential difference increases by 1 V. A further increase in the external resistance by $3\ \Omega$ produces a further increase of 2 V in the potential difference. What is the emf E the battery?

(1) 19V (2) 20V

(3) 18V (4) 17V

3. Four resistances 5 Ω, 6 Ω, 5 Ω and 6 Ω are connected along AB, BC, CD and DA the sides of a rectangle. The junctions A and C are connected to the +ve and -ve terminals of a cell of emf 2V and internal resistance 4 Ω. A galvanometer of resistance 10 Ω is connected across the junctions B and D. The effective resistance across the points A and C is



(1) 5 Ω (2) 5.52 Ω

(3) 5.8 Ω (4) 6 Ω

4. When two resistances X and Y are put in the left hand and right hand gaps in a Wheatstone meter bridge (total wire length is 1m), the null point is at 60 cm from the left end. If X is shunted by a resistance equal to half of itself find the shift in the null point.

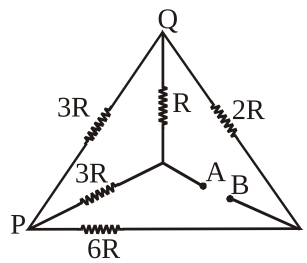
(1) 26.7 cm towards left

(2) 26.7 cm towards right

(3) 33.3 cm towards left

(4) 33.3 cm towards right

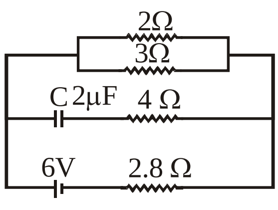
5. If each of the resistances in the network is R, what is the resistance between the terminals A and B?



(1) 2.2 R (2) 2.5 R

(3) 2.25 R (4) 2.55 R

6. The steady state current in the 2 Ω resistor in figure, when the internal resistance of the battery is negligible and the capacitance of the condenser C is 0.2 μF is



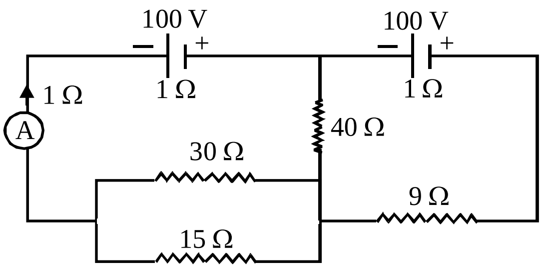
(1) 0.8 A

(2) 0.7 A

(3) 1.0 A

(4) 0.9 A

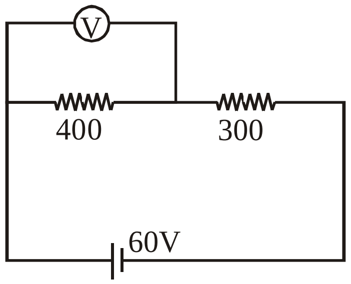
7. If the internal resistance of the ammeter and each cell are 1Ω, find the reading of the ammeter is



(1) 9 A (2) 7 A

(3) 8 A (4) 10 A

8. In the shown circuit, a voltmeter reads 30 V when it is connected across 400 Ω resistance.



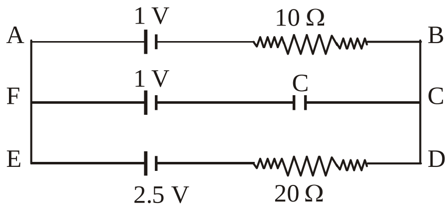
Calculate what the same voltmeter will read when it is connected across the 300 Ω resistance.

(1) 22.5 V (2) 2.25 V

(3) 225 V

(4) 0.225 V

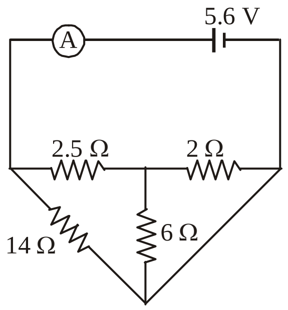
9. Find the potential difference across the capacitor in the figure



(1) 0.5 V (2) 0.05 V

(3) 10 V (4) 1 V

10. Find the reading of the ammeter in the given circuit in below figure.



(1) 1.5 A (2) 4 A

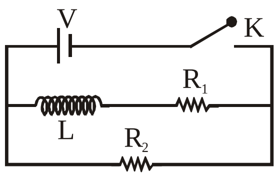
(3) 1.8 A (4) 2 A

11. In a series LCR circuit R = 200 Ω and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30º. On taking out the inductor from the circuit the current leads the voltage by 30º. The power dissipated in the LCR circuit is

(1) 242 W (2) 305 W

(3) 210 W (4) zero W.

12. In the circuit shown below, the key K is closed at t = 0. The current through the battery is



(1) $\frac{V(R_1+R_2)}{R_1R_2}$ at t = 0 and $\frac{V}{R_2}$ at t = ∞

(2) $\frac{VR_1R_2}{\sqrt{R_1^2+R_2^2}}$ at t = 0 and $\frac{V}{R_2}$ at t = ∞

(3) $\frac{V}{R_2}$ at t = 0 and $\frac{V(R_1+R_2)}{R_1R_2}$ at t = ∞

(4) $\frac{V}{R_2}$ at t = 0 and $\frac{VR_1R_2}{\sqrt{R_1^2+R_2^2}}$ at t = ∞.

ANSWERS (CURRENT ELECTRICITY)

LEVEL - I

1. (3)	5. (1)	9. (2)	13. (1)	17. (3)
2. (1)	6. (1)	10. (4)	14. (4)	18. (1)
3. (1)	7. (3)	11. (3)	15. (4)	19. (1)
4. (3)	8. (1)	12. (1)	16. (4)	20. (2)

LEVEL - II

1. (2)	5. (3)	9. (3)	13. (1)	17. (1)
2. (1)	6. (4)	10. (3)	14. (4)	18. (2)
3. (1)	7. (2)	11. (1)	15. (1)	19. (3)
4. (1)	8. (2)	12. (4)	16. (4)	20. (2)

LEVEL - III

1. (4)	3. (2)	5. (3)	7. (1)	10. (3)
2. (1)	4. (3)	6. (4)	8. (1)	11. (1)
			9. (1)	12. (3)

SOLUTIONS (LEVEL - III)

1. Let l be the initial length and A be the initial cross-sectional area. The resistance of the wire is given by R = $\rho l/A$ where ρ is resistivity of the material of the wire.

   Since the volume of the wire remains unchanged, if length becomes $3l$, area of cross-section becomes A/3.

   Hence, resistance of the stretched wire is

   $R' = \rho\frac{3l}{A/3} = 9\ \rho l/A = 9 \times 60\ \Omega$ (as $\rho l/A = 60\ \Omega$)

   It may be noted that if the length of the given wire is increased 'n' times by stretching it uniformly, the resistance becomes n^2 times the original resistance.

2. Let the original value of the external resistance be R.

   Since $\frac{E}{V} = \frac{R+r}{R} = 1 + \frac{r}{R}$

   $\Rightarrow \frac{E}{10} = 1 + \frac{r}{R}$ ..... (i)

   $\frac{E}{10+1} = 1 + \frac{r}{R+1}$ ..... (ii)

   $\frac{E}{10+1+2} = 1 + \frac{r}{R+1+3}$ ..... (iii)

   Solving (i), (ii) and (iii)

   E = 19 V

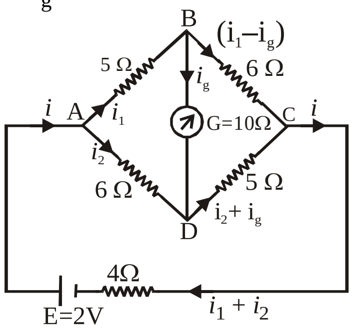
3. (i) In the closed mesh ABDCEA

   $5i_1 + 10i_g + 5(i_2 + i_g) + 4(i_1 + i_2) = 2$ ..... (i)

   In closed mesh ADBCEA

   $6i_2 - 10i_g + 6(i_1 - i_g) + 4(i_1 + i_2) = 2$ ... (ii)

   $19i - i_g = 9$



   Solving (i) & (ii) we get,

   $i_1 + i_2 = 0.21$ A and $i_g = 6.77 \times 10^{-3}$ A

   Say R is effective resistance across A and C, then

   $i = \frac{E}{4+R} \Rightarrow 0.21 = \frac{2}{4+R}$

   $\Rightarrow R = 5.52\ \Omega$

4. Initially $\frac{X}{Y}=\frac{60}{40}=\frac{3}{2}$

Now when X is shunted by $\frac{X}{2}$ the effective resistance in the left hand gap becomes,

$$X'=\frac{(X)\left(\frac{X}{2}\right)}{X+\frac{X}{2}}=\frac{X^2}{2\left(\frac{3}{2}X\right)}=\frac{X}{3}$$

Then the new ratio $\frac{X}{3}/Y = \frac{1}{3}\frac{X}{Y}$

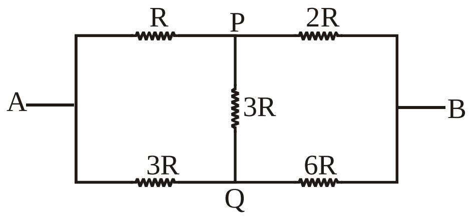
$$=\frac{1}{3}.\frac{3}{2}=\frac{1}{2}$$

Then the null point must be at the 33.3 cm mark (from left end) of the meter wire.

5. It is easy to see that the circuit reduces to the one on the right. This set up obviously forms a balanced Wheatstone bridge, hence points P and Q are at the same potential and no current flows in the resistance 3R connected them,

Resistance between A and B

$$=\frac{(R+2R)\ (3R+6R)}{(R+2R)+(3R+6R)}=2.25R$$



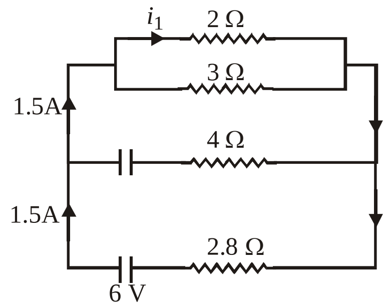
6. At steady state, the capacitor (C) branch acts as an open branch i.e. of infinite resistance, with zero current in it.

Then R = Effective resistance of the circuit =

$$\left(\frac{2\times 3}{2+3}\right)+2.8=4\Omega$$

Current from the cell = $\frac{6}{4}$ = 1.5 A

i_1 = current in 2Ω



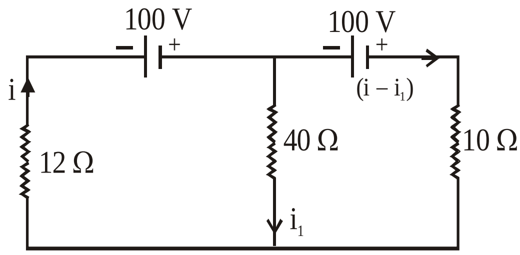
$= (1.5)\left(\frac{3}{2+3}\right)$ (by current division formula)

= 0.9 A

7. The above circuit is reducible to the circuit shown below

By Kirchhoff's Second Law, across the two loops

$$100 = 40\,i_1 + 12i$$
$$100 = 10\,(i - i_1) - 40i_1$$



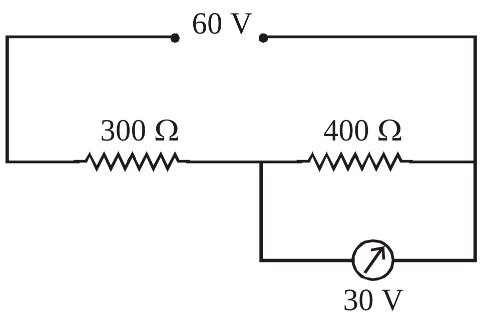
$\Rightarrow$ i = 9 A

8. pd across 400 Ω = 30 V

So pd across 300 Ω = (60 – 30) = 30 V

Since pd is equally shared, therefore

$$\frac{400R}{400+R}=300$$



where R is the resistance of the voltmeter.

Solving, R = 1200 Ω

When R is connected across $300\,\Omega$, the effective resistance of the combination =

$$\frac{300\times1200}{300+1200}=240\ \Omega$$

Then pd of 60 V is shared between $240\ \Omega$ and $400\,\Omega$ in the direct ratio of the resistance.

pd across 240 : pd across 400 = 240 : 400 = 3 : 5. Total is 60 V.

$\therefore$ pd across $240\,\Omega$ (i.e. the combination of $300\,\Omega$ and the voltmeter in parallel)

$$= 60\times\frac{3}{8}=22.5\,\text{V}$$

9. In steady state no current flows through the capacitor (so remove the branch containing capacitor to find steady state current).

Applying Kirchoff's Rule in remaining loop ABDE (figure-ii)

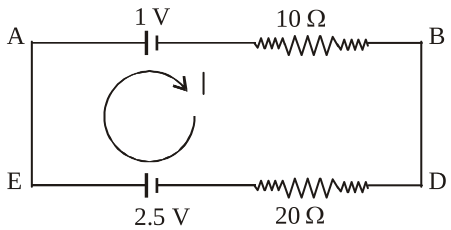


figure (ii)

1 + 10 I + 20 I – 2.5 = 0

I = 0.05 A

Connect the branch containing capacitor (figure-iii).

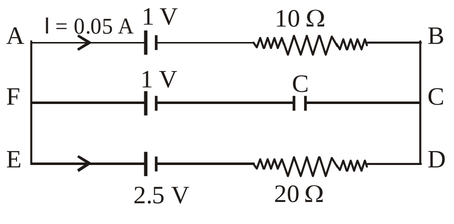
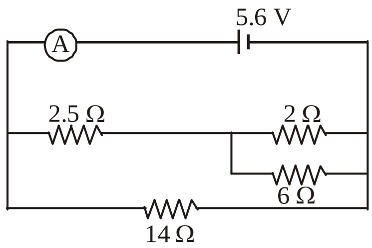


figure (iii)

Assuming a potential V developed across capacitor, apply Kirchoff's Rule in upper loop ABCF.

1 + V – 10 × 0.05 – 1 = 0, V = 0.5 volts

10. Reducing the circuit, we get the circuit as shown in below figure :



Net resistance of circuit

2W and 6W are in parallel $= \frac{2\times6}{2+6} = 1.5\text{W}$

1.5W and 2.5W are in series = 1.5 + 2.5 = 4W

4W and 14W are in parallel $= \frac{14\times4}{14+4} = \frac{28}{9}\text{W}$

Reading of ammeter (i.e. current in circuit)

$$= \frac{E}{R}=\frac{5.6}{28/9} = 1.8\text{ A}$$

11. Circuit is in resonance

$$P=(220)\left(\frac{220}{200}\right)(1)$$

$$P=\frac{22\times22}{2}=11\times22$$

P = 242 W.

12. At t = 0 inductor behaves as open circuit and t = ∞ it behaves as short circuit.