Lesson-1
ELECTRIC CIRCUITS

Current

The time rate of flow of charge through any cross-section is called current.

i.e., $I_{avg} = \frac{\Delta q}{\Delta t}$

$$I = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt}$$

Unit of current is ampere

There are two types of current

❖ If magnitude and direction of current does not vary with time, it is said to be direct current.

❖ If current is periodic (with constant magnitude) with half cycle positive and half negative, it is said to be alternating current.

Current density

Current at any cross section is defined as

$$i = \vec{J} \cdot \overrightarrow{dS}$$

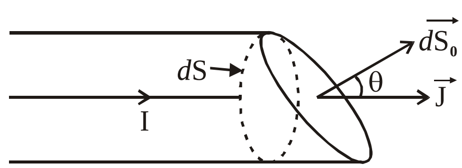
wher J is current density and $\overrightarrow{dS}$ is cross-section area.

or $\vec{J} = \lim_{\Delta S \to} \frac{\Delta I}{\Delta S} \vec{n}$ i.e., $\vec{J} = \frac{dI}{dS} \vec{n}$

where $\vec{n}$ is a unit vector in the direction of flow of current.

If cross-section is not perpendicular to the current, the cross-section area normal to current in accordance to given figure will be $dS = dS_0 \cos\theta$.

$$\Rightarrow \quad J = \frac{dI}{dS_0 \cos\theta}$$



Also, $\vec{J} = \sigma\vec{E}$

where σ is conductivity of the material and $\vec{E}$ is electric field across the ends of the conductor.

Drift velocity

It is defined as average velocity with which charge (free electron for conductor) flows when potential difference is applied across conductor.

$$v_d = \frac{eE}{m}\tau$$

Where τ is time constant, E is electric field across conductor and m is mass of electron.

Drift velocity and current are related as

$$I = neAv_d$$

where n = no. of free electron per unit volume

A = cross section area of conductor

v_d = drift velocity of electrons

Resistivity (ρ)

It is given by

$$\rho = \frac{m}{ne^2\tau}$$

- unit of resistivity is Ω-m
- for conductor ρ increases with temperature
- for semiconductor and insulator ρ decreases with temperature

Mobility of electron (μ_e) = $\frac{\text{drift velocity}}{\text{electric field}} = \frac{v_d}{E}$, where $v_d = eE\tau/m$, τ = relaxation time.

Conductivity

Inverse of resistivity is defined as conductivity of material.

Electric Circuit

An electric circuit consists of active and passive elements. An active element like a cell, battery or power supply provides current and electrical energy to an electric circuit. The passive elements like resistor (R), capacitor (C) and inductor (L) consume or store the electrical energy. A resistor opposes flow of current. A capacitor C offers a low resistance to flow of alternating current and does not allow direct current to pass through it at steady state. Energy stored in a capacitor, $U = \frac{1}{2}CV^2 = \frac{Q^2}{2C}$. An inductor L opposes the variations of current and it does not oppose steady or direct current. The energy stored in an inductor, $U = \frac{1}{2}LI^2$.

Ohm's Law

Ohm's law states that the ratio of potential difference V maintained across a conductor to the current flowing through the conductor is a constant which is equal to the resistance of the conductor provided the physical conditions remain unchanged. If V is the potential difference in volts and current I is in amperes, the electrical resistance is measured in ohms in the S.I. units.

i.e., $\frac{V}{I} = R$

Resistance

Resistance R of material is given by

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

Where l is the length and A is the area of cross-section of the conducting body of resistance R.

The resistance of most of the conductors increases with increase in temperature whereas the resistance of few of the materials decreases with temperature. In the case of some of the conductors, the resistivity changes linearly with the increase of temperature. If ρ_0 is the resistivity at lower temperature T_0 and ρ is the resistivity at higher temperature T, then

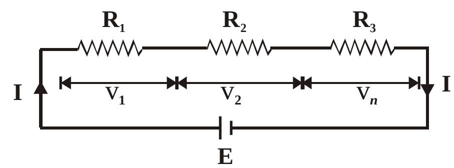
$$\rho = \rho_0[1 + \alpha(T - T_0)]$$

where α is called the temperature coefficient of resistivity.

For semi-conductors and insulators resistance decreases with increase in tempearture.

Resistances in series

If a number of resistances R_1, R_2, R_3, ..., R_n are connected in series to a battery of e.m.f. E, the same current will pass through all the resistances. The equivalent or effective resistance R_{series} for such resistance is equal to the sum of all resistances.

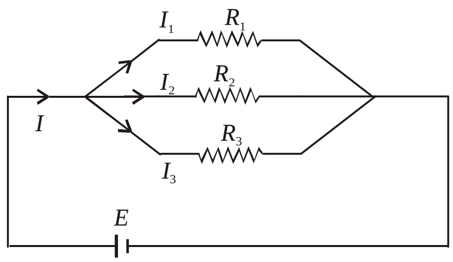


$$R_{series} = R_1 + R_2 + \cdots + R_n$$

$$v_1 = v_2 = v_n$$

Resistances in parallel

A parallel combination of resistances can be made by connecting one end of all resistances to the positive terminal of the battery and the second end of all resistances is connected to the negative terminal of the battery. The potential difference across all the resistances is the same whereas the current I in the main circuit divides itself across the respective resistances R_1, R_2, R_3, ..., R_n as I_1, I_2, I_3, ..., I_n so that



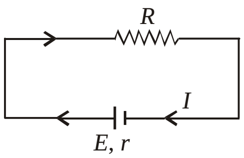
$$I = I_1 + I_2 + I_3 + \ldots + I_n$$

The equivalent or effective resistance in parallel R_{11} is given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$$

Electromotive Force and Potential Difference

If a battery of e.m.f. E volts and internal resistance r ohm is connected to an external resistance R ohm, the current I flows throughout the circuit.



$$E = IR + Ir$$

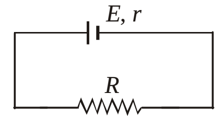
The potential difference across the external resistance R is less than the e.m.f. of the cell. This potential difference across R when the current is flowing through it is called as the closed circuit voltage. It is less than the e.m.f. of the cell when no current flows through the battery. Terminal potential difference across R = IR = E – Ir.

Maximum power transfer

If a cell of e.m.f. E and internal resistance r is connected to a load resistance R,

current $I = \dfrac{E}{R + r}$

Electric Power = $P = I^2R = \dfrac{E^2R}{(R+r)^2}$



If maximum power is transferred,

$$\frac{dP}{dR} = 0 \quad \text{or} \quad \frac{d}{dR}\left[\frac{E^2R}{(R+r)^2}\right] = E^2\left[\frac{1}{(R+r)^2} - \frac{2R}{(R+r)^3}\right] = 0 \quad \text{or} \quad R = r$$

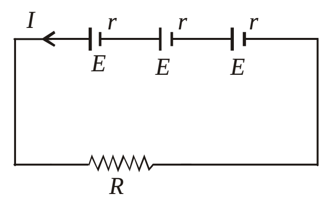
For R = r, $\dfrac{d^2p}{d\,R^2} < 0$ $\qquad\Rightarrow$ P is maximum

i.e., The power transferred is maximum when load resistance is equal to internal resistance of a cell.

Grouping of Cells

Series Combination

If n cells are connected in series, as shown in figure, then they can be replaced by a single cell of emf E and resistance r, given by



$$E = E_1 + E_2 + \cdots + E_n$$

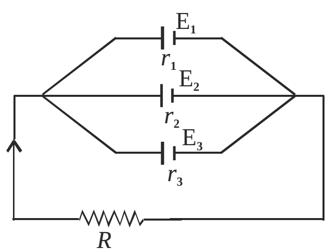
and $\quad r = r_1 + r_2 + \cdots + r_n$

Parallel Combination

If m cells are connected in parallel as shown in figure, then their equivalent cell of emf E and internal resistance r is given by

$$E = \frac{\dfrac{E_1}{r_1} + \dfrac{E_2}{r_2} + \cdots + \dfrac{E_m}{r_m}}{\dfrac{1}{r_2} + \dfrac{1}{r_2} + \cdots + \dfrac{1}{r_m}}$$

and $\dfrac{1}{r} = \dfrac{1}{r_2} + \dfrac{1}{r_2} + \cdots + \dfrac{1}{r_m}$

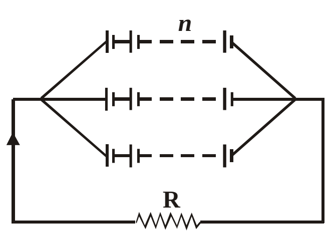


Series and Parallel Grouping of Cells

Suppose there are N identical cells each of emf E and internal resistance r. And, they are grouped together to form an arrangement as shown in figure. In each branch there are n cells in series and there are m such branches in parallel. The group of cells is joined across an external resistor R.

Since the total number of cells N, therefore

$$N = mn$$



The equivalent cell of the group has the emf

$$E_0 = nE$$

and internal resistance $r_0 = \dfrac{n}{m} r$

Thus, the total current flowing through the external resistor R is

$$I = \frac{E}{r_0 + R} = \frac{nE}{\dfrac{nr}{m} + R} \quad \text{or} \quad I = \frac{mnE}{nr + mR}$$

Condition for Maximum Current through the External Resistance R.

- For maximum current through R, we must have

$$nr = mR$$

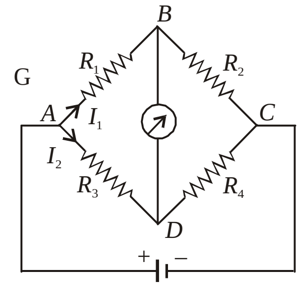
or $$\frac{m}{n} = \frac{r}{R}$$

- The maximum current is given by

$$I_{max} = \frac{nE}{2R} = \frac{mE}{2r} = \frac{E}{2}\sqrt{\frac{mn}{rR}}$$

Wheatstone's bridge

If a net work of four resistances R_1, R_2, R_3 and R_4 are connected along arms *AB*, *BC*, *AD* and *CD* and ends *A* and *C* are connected across the terminals of a battery so that the galvonometer connected across *B* and *D* does not show any deflection *i.e.* potential at point *B* and *D* is equal. Such an arrangement is called a balanced Wheatstone's Bridge for which current I_1, flows across *ABC* and I_2 flows across *ADC*.



$$\therefore \quad I_1R_1 = I_2R_3$$

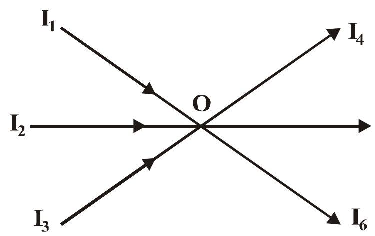
$$I_1R_2 = I_2R_4$$

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

Kirchhoff's Law

If an electrical circuit has more than one path of electrical closed circuits, it is called a network. The electric currents in different portions of such electric circuits can be found by the application of the following Kirchhoff's Laws :

Kirchhoff's First Law of Current : The algebraic sum of currents at any junction in a circuit is zero. It implies that the sum of the currents entering at any junction is equal to the sum of currents leaving that junction. At junction O,



$$I_1 + I_2 + I_3 - I_4 - I_5 - I_6 = 0.$$

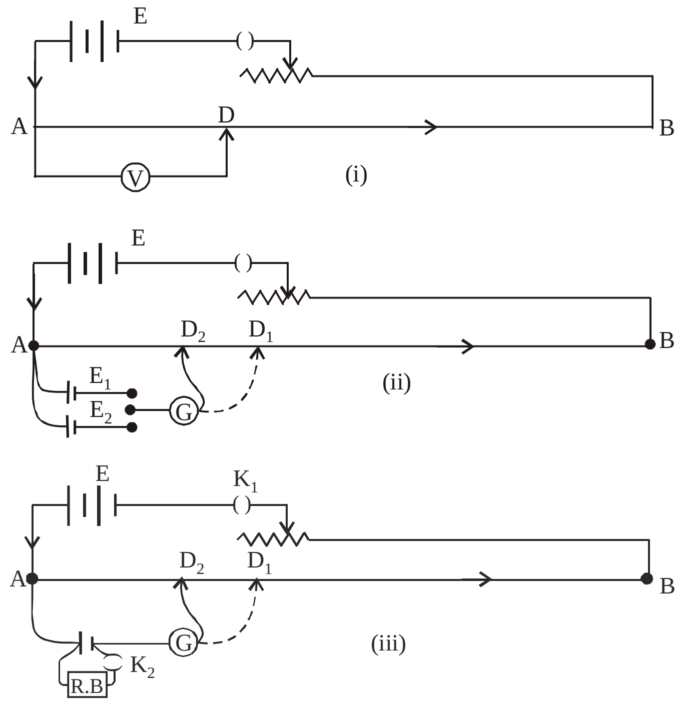
Kirchhoff's Voltage Law (KVL): Around any closed circuit loop the sum of voltage changes (drops or gains) across all the circuit elements while traversing in one direction (clockwise or anticlockwise) must be zero.

- While moving from higher potential to lower potential while crossing element to apply. Kichhoff's IInd law, P.D. is taken as negative.

Potentiometer

1. Potentiometer consists of a uniform wire of large length of 4 m, 6 m, 8 m, etc.

2. The potential drop across the potentiometer wire is directly proportional to its length (this is because the wire is of uniform area of cross-section).



3. Through the path of galvanometer, current from the battery of *e.m.f.* E can be varied i.e. if point D is closer to point A, less current flows through the path of galvanometer; and if point D is farther from point A, then more current flows through the path of galvanometer.

4. *For comparing e.m.f.s of two cells*, the positive terminals of both the cells and the positive terminal of the battery (of e.m.f. E) are connected to the same end A of the potentiometer wire. Now, we locate point D on the potentiometer wire so that no current flows through the path of galvanometer. Then [see figure (ii)]

E.M.F. of cell = P.D. across A and D on potentiometer wire ...(i)

For two cells, $\frac{E_1}{E_2} = \frac{AD_1}{AD_2} = \frac{l_1}{l_2}$ .....(*ii*)

5. *For finding internal resistance* (r) *of a cell* :

(i) We connect a cell [see figure (iii)] and locate a point D_1 on potentiometer wire so that no current flows through the path of galvanometer, when key K_2 is not used.

(ii) Now, we take out some resistance R from the resistance-box (R.B.) and use key K_2 also, and locate a point D_2 on the potentiometer wire so that no current flows through the path of galvanometer.

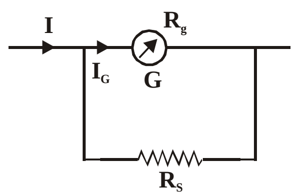
Then, $r = R\left[\frac{l_1}{l_2} - 1\right]$, where l_1 = length AD_1 of potentiometer wire

l_2 = length AD_2 of potentiometer wire

Conversion of Galvanometer into ammeter and voltmeter

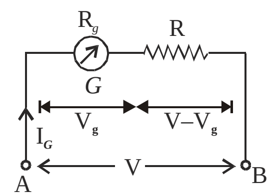
In a galvanometer, a moving coil is placed in a uniform magnetic field. When the current to be measured is passed through the coil of a galvanometer, the coil is deflected through a certain angle depending upon the current. The current I can be measured by converting a galvanometer into an ammeter by connecting a small resistance R_s in parallel to the galvanometer of resistance R_g through which the current I_g is flowing.

$$R_s = \frac{I_g}{I - I_g} \times R_g$$



The potential difference V between any two points A and B is measured by connecting a voltmeter across these points. A galvanometer is converted into a voltmeter by connecting a high resistance R in series with a galvanometer of resistance R_g.

$$\frac{V_g}{R_g} = \frac{V - V_g}{R}$$



Heating Effects of Current

If a current I ampere passes through a heating element of resistance R for time t when a potential difference V volt is applied across it, the power produced is P.

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

Electrical energy or work = VIt J

Heat produced = $H = \frac{\text{Work}}{J} = \frac{VIt}{J}$ cal

where Joule's constant, J = 4.18 Joule/calorie

$$H = \frac{VIt}{4.2} = 0.24\ VIt = \frac{0.24V^2t}{R} \text{ calorie}$$

1 kilowatt hour = $1000 \times 60 \times 60 = 3.6 \times 10^6$ Joule.

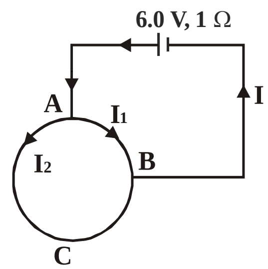
Fuse Wire

It is used in series with electrical installations to protect from high electric current, this fuse melts causing breakage in the circuit when high electric current flows. Fuse wire has high resistance and low melting point, it is gernerally prepared from tin lead alloy (63% tin + 37 lead).

SOLVED EXAMPLES

Ex.1 A wire of uniform area of cross-section has a resistance of 10 Ω. It is bent into a circle and points *A* and *B* situated at a distance of a quarter of the circumference apart are connected to a battery of e.m.f. 6.0 V and of internal resistance 1 Ω. Find the current in two parts *AB* and *ACB* of the circuit.

Sol.: Total resistance of the wire = 10 Ω



Resistance of wire *AB* = $r_1 = \frac{10}{4} = 2.5\ \Omega$ (∵ resistance α length)

Resistance of wire *ACB* = $r_2 = \frac{10 \times 3}{4} = 7.5\ \Omega$

Let equivalent resistanceof r_1 & r_2 is R

$$\Rightarrow \frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{2.5} + \frac{1}{7.5} = \frac{2}{5} + \frac{2}{15} = \frac{8}{15}$$

$$R = \frac{15}{8}\Omega$$

$$I = \frac{E}{r + R} = \frac{6.0}{1 + \frac{15}{8}} = \frac{48}{23} A$$

By current division

$$I_1 = I \frac{r_2}{r_1 + r_2} = \frac{48}{23} \times \frac{7.5}{2.5 + 7.5} = \frac{36}{23} A$$

$$I_2 = I - I_1 = \frac{48}{23} - \frac{36}{23} = \frac{12}{23} A$$

Ex.2 A uniform copper wire of mass 2.23 gm carries a current of 1 A when an e.m.f. of 1.7 volt is applied across it. Find the length and area of cross-section. If the wire is uniformly stretched to double its length, find the new resistance. Density of copper = 8.92×10^3 kg/m^3 and its resistivity is 1.7×10^{-8} Ω m.

Sol.: If *A* is area of cross-section and *L* is length of wire,

$$\text{Volume} = L \times A = \frac{\text{mass}}{\text{density}} = \frac{2.23 \times 10^{-3}}{8.92 \times 10^3} = \frac{10^{-6}}{4} \qquad \text{..... } (i)$$

Resistance of wire, $R = \frac{V}{I} = \frac{1.7}{1} = 1.7\ \Omega$

$$R = \frac{\rho L}{A} \quad \text{or} \quad \frac{L}{A} = \frac{R}{\rho} = \frac{1.7}{1.7 \times 10^{-8}} = 10^8 \qquad \text{.....}(ii)$$

Multiplying (*i*) and (*ii*) $L \times A \times \frac{L}{A} = \frac{10^{-6}}{4} \times 10^8 = \frac{10^2}{4} = 25$

$\Rightarrow L = 5$m

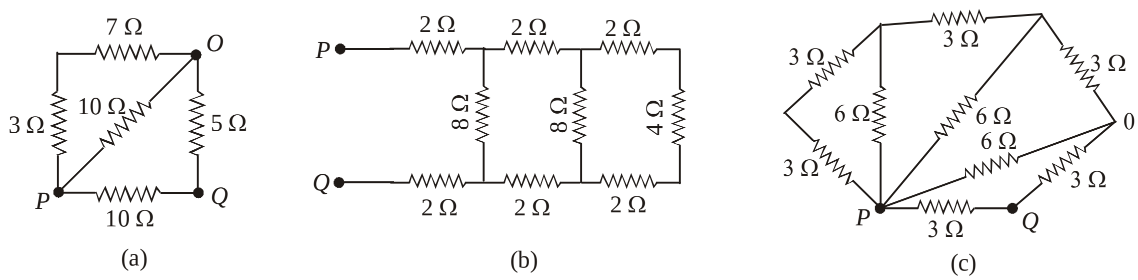
$$A = \frac{10^{-6}}{4 \times 5} = 5 \times 10^{-8}\ \text{m}^2$$

When the wire is stretched to double its length, its volume remains constant. Its new area A' is given as

$$A' \times 2L = A \times L \quad \text{or} \quad A' = \frac{A}{2} = 2.5 \times 10^{-8}\ \text{m}^2$$

$$\text{New resistance} = \frac{\rho \times 2L}{\left(\frac{A}{2}\right)} = \frac{4\rho L}{A} = 4 \times 1.7 = 6.8\ \Omega$$

Ex.3 Calculate the equivalent resistance between points P and Q of the network of resistances shown in figures (a), (b) and (c).



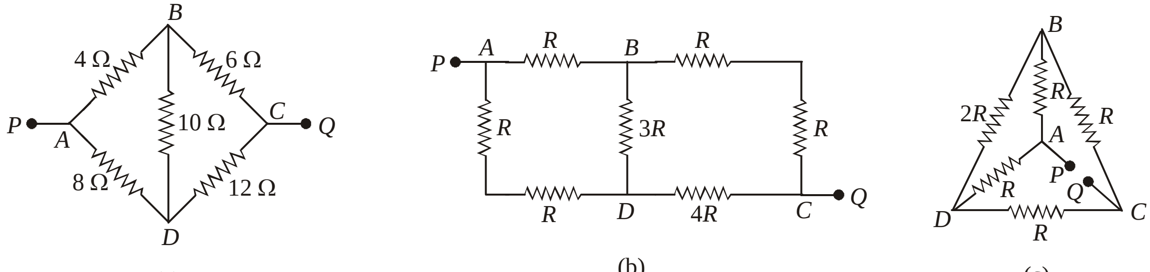
Sol.: The network of resistances in these circuits are arranged in various branches such that these can be grouped into series or parallel combinations of resistances. The resistances should be grouped from the sides farthest from points P and Q.

(a) Resistors 3Ω and 7Ω in series have a total resistance of 10Ω which is parallel to 10Ω resistance. This resistance of 10Ω is in parallel to a resistance of 10Ω along OP which gives an equivalent resistance of $\frac{10 \times 10}{10 + 10}$ = 5Ω. This resistance of 5Ω along OP is in series with 5Ω resistance along OQ yielding a total resistance of 10Ω. This resistance of 10Ω is parallel to 10Ω along PQ which gives an equivalent resistance of 5Ω between the points P and Q.

(b) Resistances 2, 4 and 2Ω on extreme right side are in series and gives a total resistance of 8Ω which in parallel with 8Ω resistance and gives $\frac{8 \times 8}{8 + 8}$ = 4Ω. Again 2, 4 and 2Ω in series combine to give a resistance of 8Ω which is parallel to 8Ω resistance and it gives total resistance of 4Ω. The resistances of 2 and 2Ω are in series with this 4Ω resistance on extreme left combine to yield an equivalent resistance of 8Ω between points P and Q.

(c) Consider the 3Ω resistance in series with 3Ω along extreme left side of the network which combines to give 6Ω which inturn is parallel to 6Ω and yields a total resistance 3Ω and so on. At last, there will be a resistance of 3Ω along PO in series with 3Ω along OQ which is equal to 6Ω. The resistance of 3Ω along PQ alongwith 6Ω in parallel will yield an equivalent of $\frac{6 \times 3}{6 + 3}$ = 2Ω resistance between points P and Q.

Ex.4 Calculate the equivalent resistances between points P and Q of the network of resistances shown in figures (a), (b) and (c).



Sol.: All these network of resistances represent balanced Wheatstone's Bridge in which no current flows through the side *BD*.

(a) The resistance 10Ω through *BD* is ineffective in balanced Wheatstone's Bridge. The resistance across *P* and *Q* is equivalent to 4 and 6Ω in series which is parallel to 8 and 12Ω in series. Equivalent resistance R_{eq} is

$$\frac{1}{R_{eq}} = \frac{1}{4+6}+\frac{1}{8+12} = \frac{1}{10}+\frac{1}{20} = \frac{2+1}{20} = \frac{3}{20}$$

$$R_{eq} = \frac{20}{3} = 6.67\ \Omega.$$

(b) In balanced Wheatstone's Bridge *ABCD*, 3*R* across *BD* is ineffective. Arm *AD* and *BC* have respective resistances 2*R* and 2*R*. R_{eq} across *PQ* is sum of resistances *R* and 2*R* in seires which is parallel to resistance, 2*R* on side *AD* in series with 4*R* along *CD*.

$$\frac{1}{R_{eq}} = \frac{1}{R+2R}+\frac{1}{2R+4R} = \frac{1}{3R}+\frac{1}{6R} = \frac{2+1}{6R}$$

$$R_{eq} = 2R$$

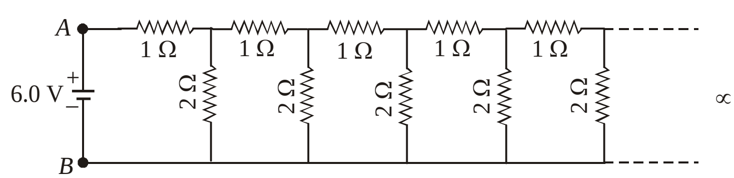
(c) The circuit *ABCD* is equivalent to balanced Wheatstone's Bridge with each arm having equal resistance *R* and resistance 2*R* along *BD* is ineffective. The equivalent resistance R_{eq} is given by:

$$\frac{1}{R_{eq}} = \frac{1}{R+R}+\frac{1}{R+R} \quad \text{or} \quad R_{eq} = \frac{2R\times 2R}{2R+2R} = R$$

Ex.5 A battery of 6.0 V is connected to an infinite network of resistances of 1Ω connected in series and 2Ω in parallel as shown in the circuit. Find

(a) effective resistance between *A* and *B*

(b) the current through 2Ω resistance nearest to the battery.

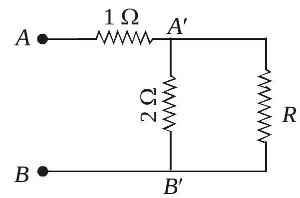


Sol.: (a) Let *R* be equivalent resistance between *A* and *B*. Assume that one more set of resistances 1Ω and 2Ω is connected between them. As there are infinite resistances having a total resistance *R* between *A* and *B*, the addition of resistances 1Ω and 2Ω will not affect the resistance *R*. Let *R′*

be total resistance between A and B. As addition of one resistance does not make any difference for infinite resistances.

$R' = R$

If R_1 is resistance between A' and B'.



$$\frac{1}{R_1} = \frac{1}{R} + \frac{1}{2} = \frac{2+R}{2R} \quad \text{or} \quad R_1 = \frac{2R}{2+R}$$

Resistance between $AB = R' = 1 + \frac{2R}{2+R} = \frac{2+3R}{2+R} = R$

$\Rightarrow$ $2R + R^2 - 3R - 2 = 0$ or $R^2 - R - 2 = 0$

$(R + 1)(R - 2) = 0$ or $R = +2, -1$

$R = -1\Omega$ is not possible

$\therefore$ $R = 2$ ohm.

(b) Resistance between A' and B' = $\frac{2 \times 2}{2+2} = 1\Omega$

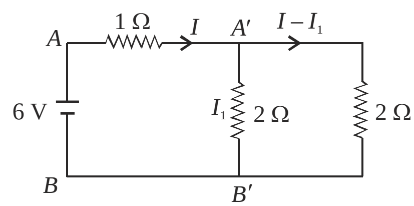
Resistance across $AB = 1\Omega + 1\Omega = 2\Omega$

Let a current I flows through 1Ω and current I_1 flows from A' to B'.

Current $I = \frac{6}{2} = 3$ ampere

P.D. across $A'B' = R_{AB} \times \text{I} = 1 \times 3 = 3\text{V}$

current across $AB = \frac{3}{2} = 1.5$ ampere.



Ex.6: Twelve wires, each of resistance 6Ω are connected to form a network of skelton cube. A current enters at one corner and leaves from the diagonally opposite corner. Find the effective resistance between the opposite corners.

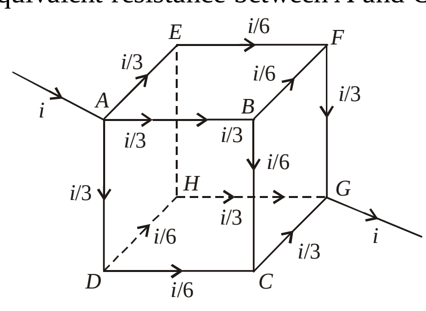
Sol.: Let i be the current flowing towards junction A which will divide itself across different 12 wires as shown. This is due to symmetry. AB, AE and AD are symmetrically placed so that current equal to $i/3$ flows through each of them, similarly $i/3$ current flows through each of the resistance CG, FG & HG such that the current i flows out of junction G. Let R be equivalent resistance between A and G.

Consider path $ABCG$,

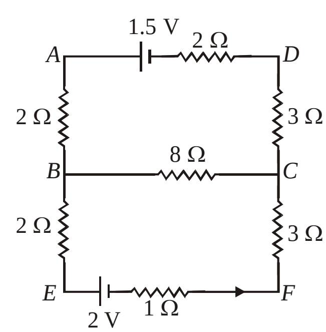
$$V_{AG} = V_{AB} + V_{BC} + V_{CG}$$

$$iR_{eq} = \left(\frac{i}{3}\right)r + \left(\frac{i}{6}\right)r + \left(\frac{i}{3}\right)r = \left(\frac{5i}{6}\right)r$$

$$R_{eq} = \left(\frac{5}{6}\right)r = \frac{5}{6} \times 6 = 5 \text{ ohm.}$$

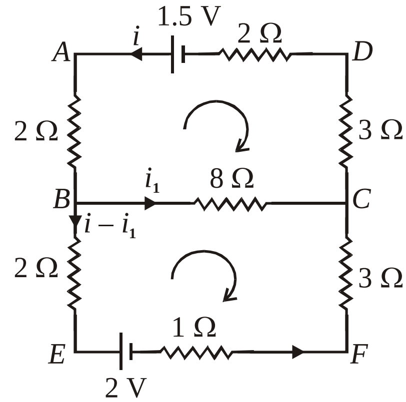


Ex.7. Find the potential difference between points B and C in the circuit shown in the figure where the battery of 1.5 V has an internal resistance of 2Ω and the battery of 2V has an internal resistance of 1Ω.



Sol.: Figure between show current distribution according to Kirchhoff's Ist Law

Applying Kirchhoff's second law for loops *ADCBA* and *BCFEB*.



$$-1.5 + 2i + 3i + 8i_1 + 2i = 0$$

or $\quad 7i + 8i_1 = 1.5 \quad$ ...(i)

and $-8i_1 + 3(i - i_1) + 1(i - i_1) + 2 + 2(i - i_1) = 0$

or $\quad 3i - 7i_1 = -1 \quad$ ...(ii)

Solving (i) and (ii)

$$i_1 = \frac{23}{146} \text{ and } i = \frac{3}{146}$$

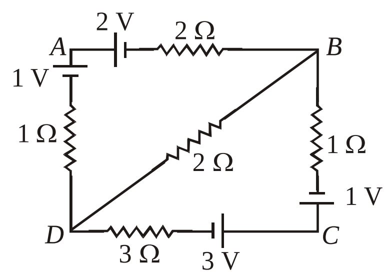
Potential difference between *B* and *C*,

$$V_B - V_C = 8 \times \frac{23}{146} = \frac{92}{73} \text{ V}$$

Ex.8 In the circuit shown, find :

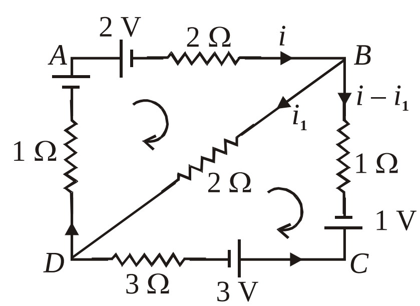
(a) potential difference between *B* and *D*

(b) potential difference across cell of 1V between *B* and *C* and cell of 3V between *C* and *D*



Sol.: Figure shows distribution of current according to Kischoff's first law

Applying Kirchhoff's second law to loop *ABDA* and *BCDB*



$$-2 - 2i - 2i_1 - 1 \times i + 1 = 0$$

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

and $-1(i - i_1) + 1 - 3 - 3(i - i_1) + 2i_1 = 0$

or $\quad 4i - 6i_1 = -2 = 0 \quad$ ...(ii)

Solving i and i_1

$$i = -\frac{5}{13} \text{ A}, \; i_1 = \frac{1}{13} \text{ A}$$

(a) P.D across *B* and = $V_B - V_D = -\dfrac{2}{13}$ V

(b) $\because \quad i - i_1 = -\dfrac{5}{13} - \dfrac{1}{13} = -\dfrac{6}{13}$

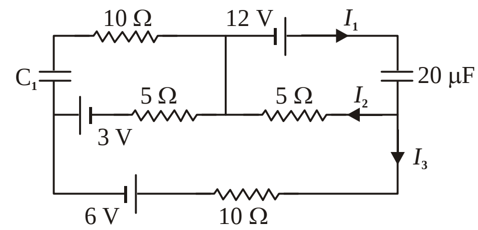
$$V_{BC} = 1 + 1 \times \frac{6}{13} = \frac{19}{13} \text{ V}$$

$$V_{DC} = 3 - \frac{6}{13} \times 3 = \frac{21}{13} \text{ V}$$

Ex.9: Two capacitors $C_1 = 10\ \mu F$ and $C_2 = 20\ \mu F$ are connected in the circuit diagram showing three cells of E.M.F. 12V, 6V and 3V connected alongwith various resistors. In the steady state, find :

(a) the currents I_1, I_2 and I_3

(b) the energy stored in capacitors C_1 and C_2



Sol.: (a) In steady state, capacitor C_2 acts as an open circuit.

$\therefore \quad I_1 = 0.$

Applying Kirchhoff's First Law at junction *D*,

$I_1 - I_2 - I_3 = 0.$

or $\quad I_3 = -I_2$ ...(i)

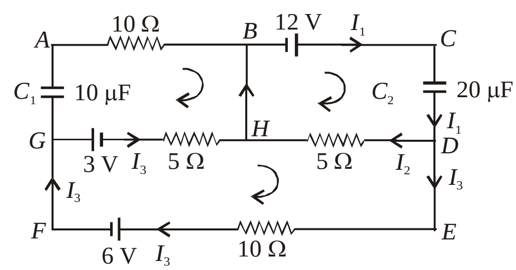
Applying Kirchhoff's Second Law to mesh *GHDEFG*, $\sum IR = \sum E$.

$-3 - 5I_3 + 5I_2 - 10I_3 - 6 = 0$

or $\quad 15I_3 - 5(-I_3) = -9$

$\Rightarrow \quad I_3 = -\dfrac{9}{20}, I_2 = \dfrac{9}{20}$

$\therefore \quad I_1 = 0, I_2 = \dfrac{9}{20}A, I_3 = -\dfrac{9}{20}A.$



It shows that the direction of current I_3 is clockwise and is opposite to what is shown in the figure.

(b) Applying Kirchhoff's Second Law to mesh *ABHGA*, where the potential difference across condenser C_1 is V_1,

$5I_3 + 3 + V_1 = 0 \quad \Rightarrow \quad V_1 = -5I_3 - 3$

or $\quad V_1 = \dfrac{5 \times 9}{20} - 3 = -\dfrac{3}{4} V$ (Negative sign shows that polarity of charge on capacitor plates are opposite to what shown in figure)

Energy stored in capacitor $C_1 = \dfrac{1}{2} C_1 V_1^2 = \dfrac{1}{2} \times 10 \times 10^{-6} \times \left(\dfrac{-3}{4}\right)^2 = 2.8 \times 10^{-6}$ J

Applying Kirchhoff's Second Law to mesh *BCDHB*, where the potential difference across C_2 is V_2,

$12 + V_2 - I_2 \times 5 = 0 \quad \Rightarrow \quad V_2 = 5I_2 - 12$

or $\quad V_2 = 5 \times \dfrac{9}{20} - 12$

$\Rightarrow \quad V_2 = \dfrac{9}{4} - 12 = \dfrac{-39}{4} V$ *i.e.* *C* is at a higher potential than *D*.

Energy stored in capacitor C_2

$= \dfrac{1}{2} C_2 V_2^2 = \dfrac{1}{2} \times 20 \times 10^{-6} \times \left(\dfrac{-39}{4}\right)^2$

$= 9.506 \times 10^{-4}$ J.

Ex.10. An electric tea kettle has two heating coils. When one of the coils is switched on, the water in the kettle begins to boil in 6 minutes. When only the other coil is switched on, the boiling starts in 8 minutes. Find the time it will take so that boiling begins when both the coils are switched on simultaneously if these are connected (a) in series (b) in parallel.

Sol.: If R_1 and R_2 are the respective resistances of both coils and a potential difference V is applied for time t, let H be heat required so that boiling begins,

$$H = \frac{V^2 t}{R}$$

$\Rightarrow$ For constant H, $t \propto R$

$$\Rightarrow \quad \frac{R_1}{R_2} = \frac{t_1}{t_2} = \frac{3}{4}$$

$$R_2 = \frac{4R_1}{3}$$

(a) For series connection, $R' = R_1 + R_2 = R_1 + \frac{4R_1}{3} = \frac{7R_1}{3}$

Let t_1' be time taken for boiling,

Then $\frac{t_1'}{t_1} = \frac{R_1'}{R_1} = \frac{7}{3}$ or $t_1' = 6 \times \frac{7}{3} = 14$ min.

(b) For parallel connection,

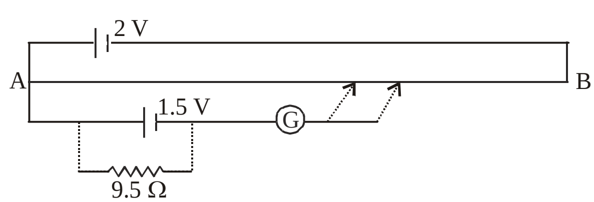
$$\frac{1}{R_2'} = \frac{1}{R_1} + \frac{3}{4R_1} = \frac{7}{4R_1}, \quad R_2' = \frac{4R_1}{7}$$

Let t_2' be time taken,

Then $\frac{t_2'}{t_2} = \frac{R_2'}{R_1} = \frac{4}{7}$

or $t_2' = 6 \times \frac{4}{7} = 3.43$ min.

Ex.11: A cell of steady emf. 2.0 V is put across a potentiometer wire. For finding internal resistance of a cell of emf 1.5 V, it is connected as shown under. The balance point for this cell in open circuit is 76.3 cm. When a resistance of 9.5 Ω is put across this cell, the balance point shifts to 64.8 cm. Find the internal resistance of the cell.



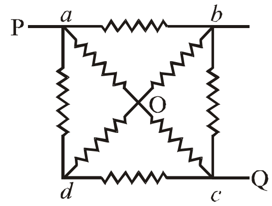
Sol.: $R = 9.5\ \Omega$ $\quad l_1 = 76.3\ \Omega$ $\quad l_2 = 64.8\ \Omega$ $\quad r = ?$

$$r = R\left[\frac{l_1}{l_2} - 1\right] = 9.5 \times \left[\frac{76.3}{64.8} - 1\right]$$

$$= 9.5 \times [1.1775 - 1] = 9.5 \times 0.1775 = 1.686\ \Omega$$

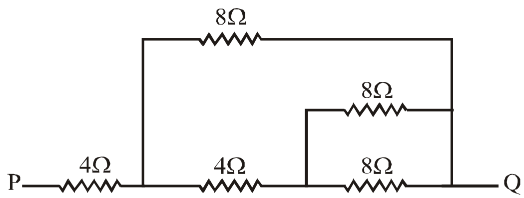
OBJECTIVE QUESTIONS

1. Calculate the resistance between P and Q in the following network. Each element has resistance 3Ω.



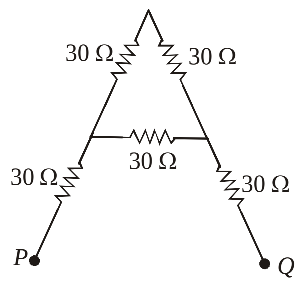
(a) 6 Ω (b) 4 Ω (c) 3 Ω (d) 2 Ω

2. The resistance between P and Q in the following combination of resistances is



(a) 8 Ω (b) 6 Ω (c) 5 Ω (d) 4 Ω

3. The effective resistance between points P and Q is

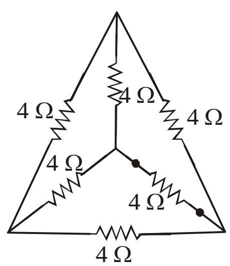


(a) 150 Ω (b) 120 Ω (c) 90 Ω (d) 80 Ω

4. Six resistances, each equal to 4 Ω are connected as shown in the figure. The effective resistance between any two vertices is

(a) 2 Ω (b) 8 Ω

(c) 12 Ω (d) 16 Ω



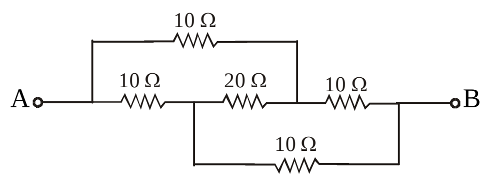
5. The equivalent resistance between the points A and B of the following circuit is

(a) 5 Ω

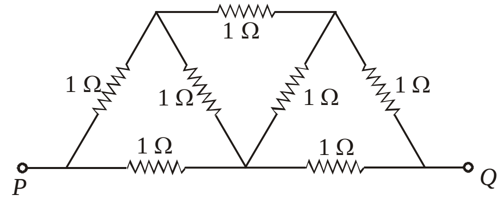
(b) 10 Ω

(c) 15 Ω

(d) 20 Ω



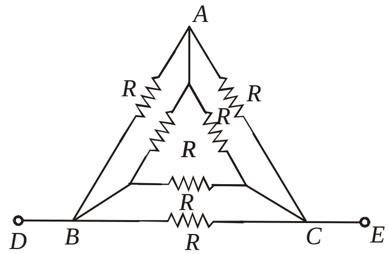
6. Seven resistors, each of 1 Ω, are connected as shown in the figure. The effective resistance between P and Q is



(a) $\frac{4}{3}\Omega$ (b) $\frac{8}{7}\Omega$

(c) $\frac{3}{2}\Omega$ (d) 7Ω

7. The resistance across points D and E of the circuit is

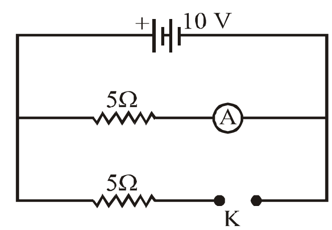


(a) $R/2$ (b) $R/3$ (c) $R/4$ (d) $2R$

8. Five cells each of internal resistance 0.2 and e.m.f. 2V are connected in series with a resistance of 4Ω. The current through the external resistance is

(a) 0.2 A (b) 0.5 A (c) 1 A (d) 2 A

9. Assume that the internal resistance of battery is zero and the key is closed in the following circuit, the reading of the ammeter is



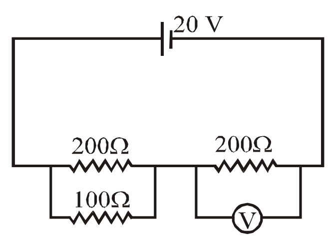
(a) 0.25 A

(b) 0.5 A

(c) 1.0 A

(d) 2.0 A

10. In the following circuit, the reading of the voltmeter is

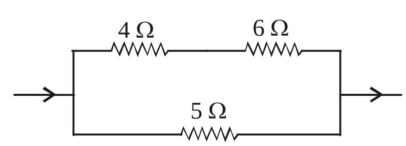


(a) 5 V (b) 10 V (c) 15 V (d) 16.5 V

11. A cell of *e.m.f.* E is connected across a resistance R. The potential difference between the terminals of a cell is measured equal to V. The internal resistance of the cell is

(a) (E – V)R (b) $\frac{2(E-V)R}{V}$ (c) $\frac{2(E-V)R}{E}$ (d) $\frac{(E-V)R}{V}$

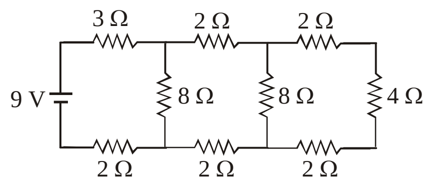
12. In the circuit shown in the figure, the heat produced in the 5 Ω resistor, due to the current flowing through it, is 10 calories per second. The heat generated in the 4 ohm resistor is



(a) 1 cal/s (b) 2 cal/s

(c) 3 cal/s (d) 4 cal/s

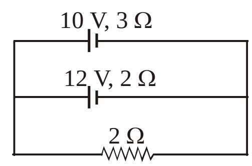
13. In the circuit shown in the figure, the current through _______



(a) 3 Ω resistor is 0.5 A (b) 3 Ω resistor is 0.25 A

(c) 4 Ω resistor is 0.5 A (d) 4 Ω resistor is 0.25 A

14. The current through the resistor in the given circuit is



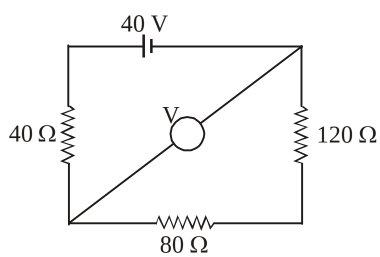
(a) 1.5 A

(b) 2.5 A

(c) 3.5 A

(d) 5.0 A

15. The resistance of votlmeter in the given circuit is 800 Ω. The voltmeter will read



(a) 8 V (b) 16 V (c) 32 V (d) 40 V

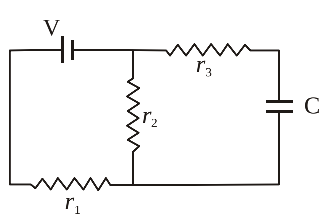
16. The temperature coefficient of resistance of a wire is 0.00125 per°C. At 300 K, its resistance is 1 Ω. The resistance of the wire will be 2 Ω at

(a) 1100 K (b) 1127 K (c) 1154 K (d) 1400 K

17. Two electric lamps A and B having power 200 watt and 100 watt respectively are rated on the same voltage. The ratio of resistance of lamp A to that of B is

(a) 1 : 2 (b) 2 : 1 (c) 1 : 4 (d) 4 : 1

18. In the circuit shown in the figure, the final voltage drop across the capacitor C in steady state is

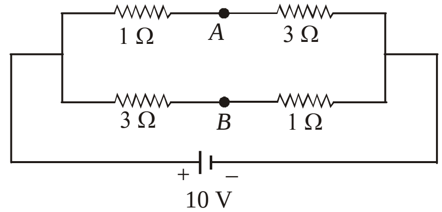


(a) $\dfrac{Vr_1}{r_1 + r_2}$ (b) $\dfrac{Vr_2}{r_1 + r_2}$ (c) $\dfrac{V(r_1 + r_2)}{r_2}$ (d) $\dfrac{V(r_1 + r_2)}{r_1 + r_2 + r_3}$

19. Three capacitors of capacitance 3 μF each are connected in series. The energy stored in the capacitances, when a potential of 1 kilo volt is applied to these for charging, is

(a) 5 J (b) 0.5 J (c) 0.005 J (d) 50 J

20. A battery of *e.m.f.* 10 V is connected to resistances as shown in the figure. The potential difference between A and B is



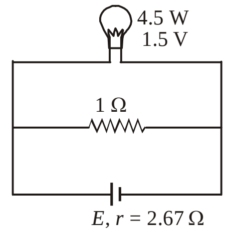
(a) –2 V

(b) +2 V

(c) –5 V

(d) 5 V

21. A torch bulb rated as 4.5 W, 1.5 V is connected as shown in the figure. The e.m.f. of the cell of internal resistance 2.67 Ω, needed to make the bulb glow at full intensity is



(a) 4.5 V (b) 6.75 V

(c) 13.5 V (d) 27 V

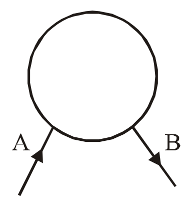
22. Four equal resistors, when connected in series, dissipate a power of 5 watts. If these resistors are connected in parallel, the power dissipated will be

(a) 20 watts (b) 40 watts (c) 50 watts (d) 80 watts

23. If a wire is stretched so that its length increases by 0.1 %, the percentage change in its resistance will be

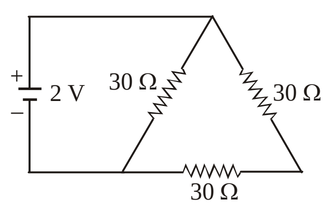
(a) 0.1 % (b) 0.2 % (c) 0.3 % (d) 0.4 %

24. A uniform wire of resistance 20 Ω having resistance 1 Ω/m is bent in the form of a circle as shown in the figure. If the equivalent resistance between A and B is 1.8 Ω, the length of the shorter section is



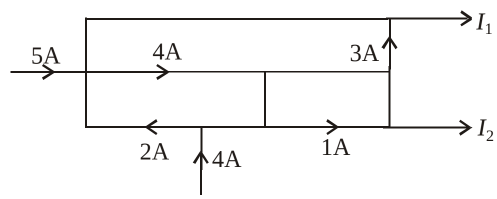
(a) 1.8 m (b) 2.0 m (c) 2.5 m (d) 4 m

25. The current in the circuit in the figure is



(a) $\frac{1}{5}$ amp. (b) $\frac{1}{10}$ amp. (c) $\frac{1}{15}$ amp. (d) $\frac{1}{30}$ amp.

26. In the given circuit currents I_1 and I_2 are



(a) 5A, 4A

(b) 6A, 3A

(c) 7A, 2A

(d) 6A, 2A

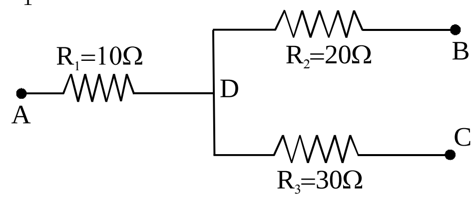
27. In the circuit shown, R_1 = 10 ohm, R_2 = 20 ohm and R_3 = 30 ohm. The potentials of points *A*, *B* and *C* are 10V, 6V and 5V respectively. The current through resistance R_1 is

(a) 0.1 A

(b) 0.2 A

(c) 0.3 A

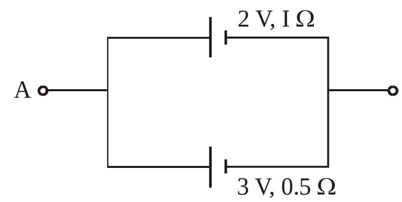
(d) 0.4 A



28. In the given circuit, the potential difference between the points A and B is

(a) 2.5 V (b) 3.0 V

(c) 2.67 V (d) 2.33 V



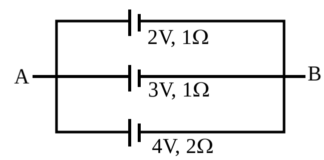
29. In the following circuit, emf across *A* and *B* is

(a) 3.0 V

(b) 3.2 V

(c) 2.5 V

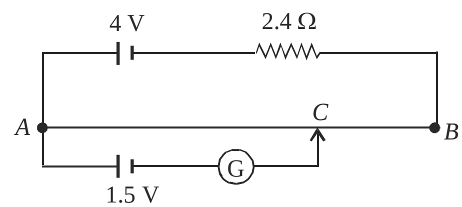
(d) 2.8 V



30. A simple potentiometer circuit is shown in the figure. The internal resistance of the 4V battery is negligible. *AB* is a uniform wire of length 100 cm and resistance 2Ω. For what length *AC*, the galvanometer shows no deflection?

(a) 78.5 cm (b) 84.5 cm

(c) 82.5 cm (d) 80.5 cm



MORE THAN ONE CORRECT CHOICE

31. The charge flowing in a conductor varies with line as $Q = at - bt^2$. Then, the current

(a) decreases linearly with time (b) reaches a maximum and then decreases

(c) fall to zero after time $t = a/2b$ (d) changes at a rate – 2b

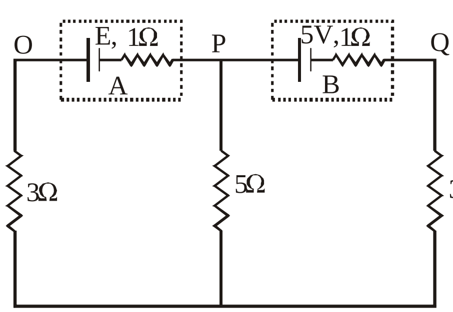
32. Two batteries A and B and three resistors are connected. Internal resistance of both batteries is 1Ω each as shown. EMF of battery B is 5V, the potential difference between P and Q is zero. Which of the following is/are true –

(a) the current through 5Ω is 3A

(b) the current through the battery A is 8A

(c) the emf of the source A is 47A

(d) the p.d. between O and P is 8V



33. In a potentiometer arrangement, E_1 is the cell establishing current in primary circuit, E_2 is the cell to be measured. AB is the potentiometer wire and G is a galvanometer. Which of the following are the essential condition for balance to be obtained.

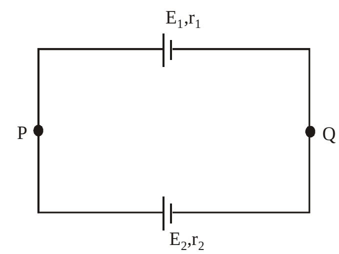
(a) The emf of E_1 must be greater than the emf of E_2.

(b) Either the positive terminals of both E_1 and E_2 or the negative terminals of both E_1 and E_2 must be joined to one end of potentiometer wire.

(c) The positive terminals of E_1 and E_2 must be joined to one end of potentiometer wire.

(d) The resistance of G must be less than the resistance of AB

34. Two cells of unequal emfs E_1 and E_2 and internal resistances r_1 and r_2 are joined as shown in figure. V_p and V_Q are the potential at P and Q respectively.



(a) The potential difference across both the cells will be equal

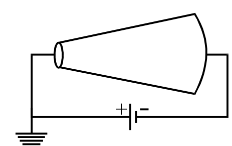
(b) One of the cell, will supply energy to the other cell.

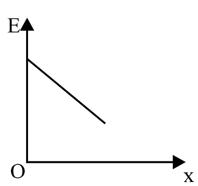
(c) The potential difference across one of the cells will be greater than its emf.

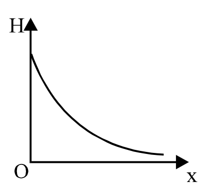
(d) $V_P - V_Q = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

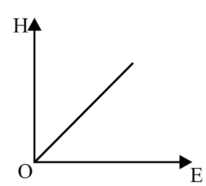
35. A conductor is made of an isotropic material and has shape of a truncated cone.

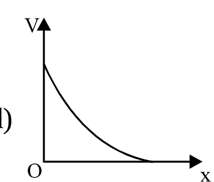
A battery of constant emf is connected across it and its left end is earthed as shown in figure. If at a section distance x from left end, electric field intensity, potential and the rate of generation of heat per unit length are E, V and H respectively, which of the following graphs is/are correct?



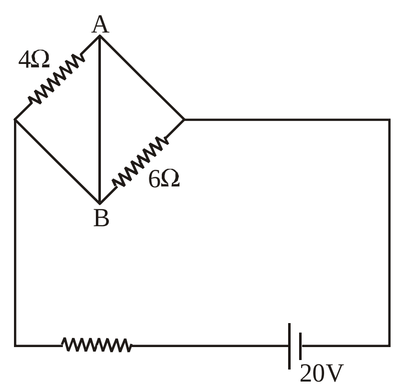
(a) 

(b) 

(c) 

(d) 

36. In the circuit shown in figure –



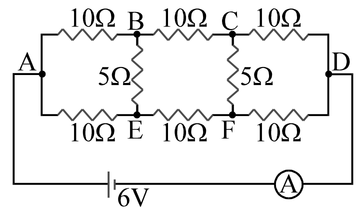
(a) power supplied by the battery is 200 watt

(b) current flowing in the circuit is 5A

(c) potential difference across 4Ω resistance is equal to the potential difference across 6Ω resistance

(d) current in wire AB is zero

37. In the given circuit.



(a) Current measured by ammeter is 0.4 amp

(b) Potential of point C and F are equal

(c) Potential of point B and E are equal

(d) If 5 ohm resistances are replaced by 10 ohm resistance each, then current in all the 10 ohm resistance will be same.

38. Two heaters designed for the same voltage V have different power ratings. When connected individually across a source of voltage V, they produce H amount of heat each in times t_1 and t_2 respectively. When used together across the same source, they produce H amount of heat in time t

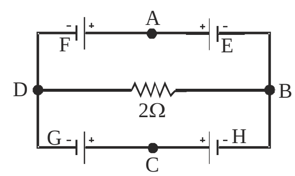
(a) if they are in series, $t = t_1 + t_2$

(b) if they are in series, $t = 2(t_1 + t_2)$

(c) if they are in parallel, $t = \frac{t_1 t_2}{(t_1 + t_2)}$

(d) if they are in parallel, $t = \frac{t_1 t_2}{2(t_1 + t_2)}$

39. In the circuit shown E, F, G and H are cells of e.m.f. 2V, 1V, 3V and 1V respectively and their internal resistance are 2Ω, 1Ω, 3Ω and 1Ω respectively.



(a) $V_D - V_B = -\frac{2}{13} V$

(b) $V_D - V_B = \frac{2}{13} V$

(c) $V_G = \frac{13}{21} V$ = Potential difference across G

(d) $V_H = \frac{19}{13} V =$ Potential difference across H.

40. Which of the following statements is/are correct ?

(a) Potential difference between terminals of a non-ideal battery can never be greater than its emf.

(b) If a non-ideal battery is short circuited by a wire, heat generated in the wire is less than electric energy developed in the battery

(c) EMF of an ideal battery is, first, measured by a potentiometer and than by a voltmeter. Both the measurements are equally correct.

(d) The terminal potential difference of a battery can never be zero in any closed circuit containing other batteries.

MISCELLANEOUS ASSIGNMENT

Comprehension-1

Two persons are pulling a square of side *a* along one of the diameters horizontally to make it rhombus. Plane of rhombus is always vertical and uniform magnetic field B exist perpendicular to plane. They start pulling at $t = 0$ and with constant velocity v.

1. The induced emf in the frame when angle at corner being pulled is 60°

(a) Bav (b) 2B*a*v (c) $\frac{Bav}{2}$ (d) $\frac{Bav}{4}$

2. If the resistance of the frame is R the current induced is

(a) $\frac{Bav}{2R}$ (b) $\frac{2Bav}{R}$ (c) $\frac{Bav}{R}$ (d) $\frac{Bav}{4R}$

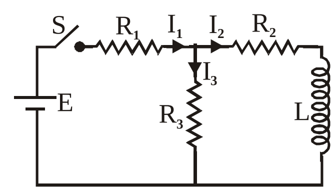
3. Finally square frame reduces to straight wire. The total charge flown is

(a) $\frac{a^2 B}{R}$ (b) $\frac{a^2 B}{2R}$ (c) $\frac{2a^2 B}{R}$ (d) $\frac{4a^2 B}{R}$

Comprehension-2

In case of analysis of circuits, containing cells, resistences and inductances two things are very important one is conservation of charge which leads to the fact that at any junction of circuit incoming current is equal to out going current. The other thing is that sum of voltage drop in a closed loop is equal to zero. Inductors have a unique property by which they oppose the change in magnetic flux linked to them. The voltage drop across resistor is

V_R = IR and across inductor is $L\frac{dI}{dt}$. In the steady state current through inductor becomes constant which leads to zero voltage drop across inductor. *ie.* it behaves like short circuit. Refer to circuit given in the figure. E = 10 V, R_1 = 2Ω, R_2 = 3Ω, R_3 = 6Ω and L = 5H.



Now answer the following questions

4. The current I_1 just after pressing the switch S is

(a) $\frac{10}{8}$ A (b) $\frac{10}{5}$ A (c) $\frac{10}{12}$ A (d) $\frac{10}{6}$ A

5. The current I_1 long after pressing the switch S is

(a) $\frac{10}{4}$ A (b) $\frac{10}{5}$ A (c) $\frac{10}{12}$ A (d) $\frac{10}{6}$ A

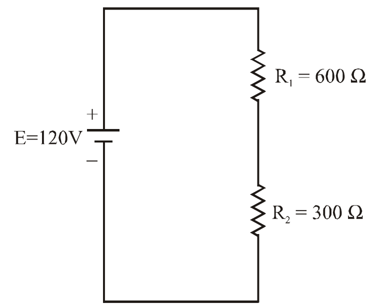
6. The current I_2 long after pressing the switch S is

(a) $\frac{10}{4}$ A (b) $\frac{10}{5}$ A (c) $\frac{10}{12}$ A (d) $\frac{10}{6}$ A

7. The current through R_2 just after releasing the switch S is

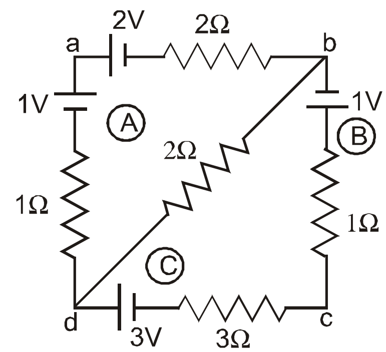
(a) $\frac{10}{4}$ A (b) $\frac{10}{5}$ A (c) $\frac{10}{6}$ A (d) $\frac{10}{12}$ A

8. In the circuit, the battery is ideal. A voltmeter of resistance 600 Ω is connected in turn across R_1 and R_2, giving readings V_1 and V_2 respectively.



	Column I		**Column II**
A.	V_1	(p)	30 volt
B.	V_2	(q)	60 volt
C.	Error in V_1 reading	(r)	– 20 volt
D.	Error in V_2 reading	(s)	– 10 volt

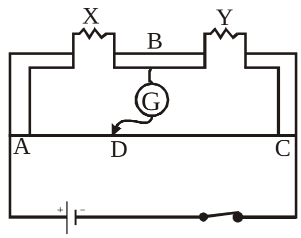
9. For the circuit shown in figure, match the columns



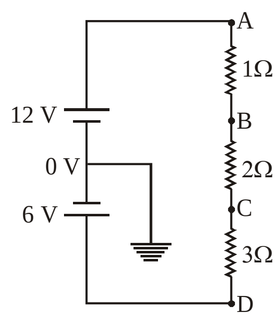
	Column I		**Column II**
A.	The current in db	(p)	1/13 amp
B.	The PD across db	(q)	2/13 volt
C.	The PD across the cell (C)	(r)	21/13 volt
D.	The PD across the cell (B)	(s)	19/13 volt

INTEGER TYPES OF QUESTIONS

10. In a metre bridge, (Figure) the balance point is found to be at 39.5 cm from the end A, when the resistor Y is of 12.5Ω. The resistance of X is 4.1nΩ. Find the value of n.



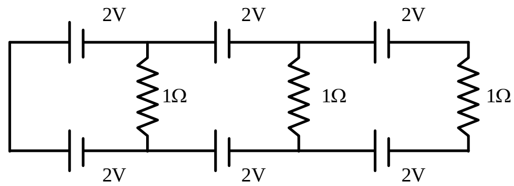
11. In the circuit shown the potential at D is 3n volt. Find the value of n



12. A battery of emf 10V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5A ? The terminal voltage of the battery (when the circuit is closed) is 1.7n volt. Find the value of n

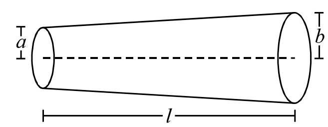
13. A fuse made of lead wire has an area of cross-section 0.2 mm^2. On short circuiting, the current in the fuse wire reaches 30 amp. After $0.0945n$ second, short circuiting the fuse begins to melt. Find the value of n. Specific heat capacity of lead = 134.3 J/kg-K. Melting point of lead = 327°C. Density of lead = 11340 kg/m^3. Resistivity of lead = 22×10^{-8} ohm-h. Initial temperature of the wire = 20°C. Neglect heat loss.

14. Find the current in the three resistors shown in figure.

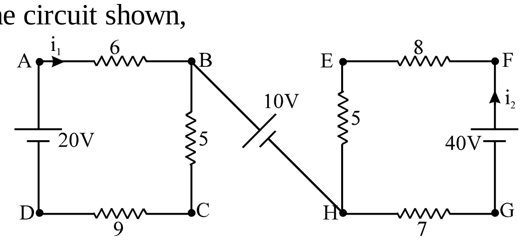


15. Flow of charge through a surface is given as : $Q = 4t^2 + 2t$ (for 0 to 10 sec.) the average current for (0 – 10 sec) is 7n ampere. Find the value of n

16. Figure shows a conductor of length l having a circular cross-section . The radius of cross-section varies linearly from a to b . The resistivity of the material is ρ . Assuming that $(b - a) << l$, the resistance of the conductor is $\rho l n / \pi ab$. Find the value of *n*.

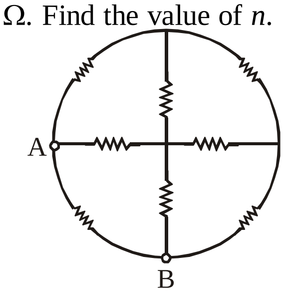


17. In the circuit shown,

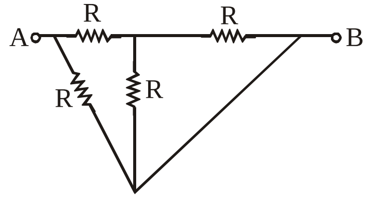


Find current i_1 in ampere.

18. Eight resistances each of resistance 5Ω are connected in the circuit shown in figure. The equivalent resistance between A and B is *n*/3 Ω. Find the value of *n*.



19. The equivalent resistance between points A and B is (3/n)R. Find the value of n

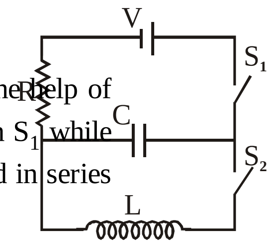


PREVIOUS YEAR QUESTIONS

IIT-JEE/JEE-ADVANCE QUESTIONS

Comprehension

The capacitor of capacitance C can be charged (with the help of a resistance R) by a voltage source V, by closing switch S_1 while keeping switch S_2 open. The capacitor can be connected in series with an inductor L by closing switch S_2 and opening S_1.



1. Initially, the capacitor was uncharged. Now, switch S_1 is closed and S_2 is kept open. If time constant of this circuit is τ, then

(a) after time interval τ, charge on the capacitor is CV/2

(b) after time interval 2τ, charge on the capacitor is $CV(1 - e^{-2})$

(c) the work done by the voltage source will be half of the heat dissipated when the capacitor is fully charged

(d) after time interval 2τ, charge on the capacitor is $CV(1 - e^{-1})$

2. After the capacitor gets fully charged, S_1 is opened and S_2 is closed so that the inductor is connected in series with the capacitor. Then,

(a) at $t = 0$, energy stored in the circuit is purely in the form of magnetic energy

(b) at any time $t > 0$, current in the circuit is in the same direction

(c) at $t > 0$, there is no exchange of energy between the inductor and capacitor

(d) at any time $t > 0$, instantaneous current in the circuit may $V\sqrt{\frac{C}{L}}$

3. If S_1 is opened and S_2 is closed at $t = 0$ and total charge stored in the LC circuit is Q_0, then for $t \geq 0$

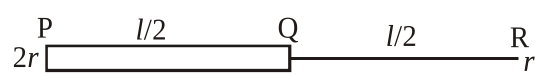
(a) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} + \frac{t}{\sqrt{LC}}\right)$

(b) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} - \frac{t}{\sqrt{LC}}\right)$

(c) the charge on the capacitor is $Q = -LC\frac{d^2Q}{dt^2}$

(d) the charge on the capacitor is $Q = -\frac{1}{\sqrt{LC}}\frac{d^2Q}{dt^2}$

4. Two wires PQ and QR of radius $2r$ and r respectively having equal length $l/2$ and equal resistivity ρ are joined as shown. Current I is flowing through the wires.

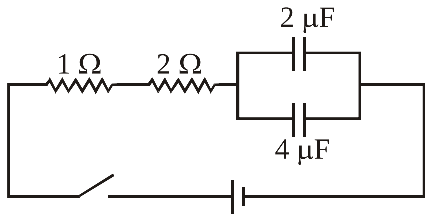


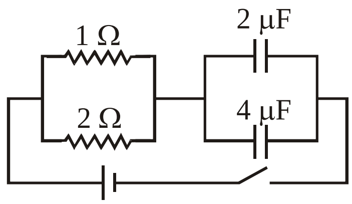
(a) Power loss in PQ is four times power loss in QR

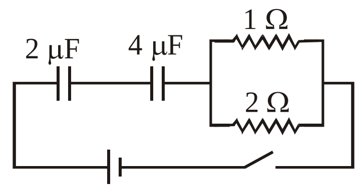
(b) Current density will be equal in both wire

(c) P.D. across wire PQ is four time compare to wire QR

(d) Electricfield is equal in both wires

5. (a) 

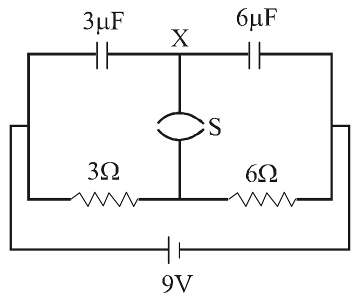
(b) 

(c) 

Time constant (in micro seconds) of circuits in order are

(a) 18, 4, 8/9 (b) 18, 8/9, 4 (c) 4, 8, 8/9 (d) 4, 8/9. 18

6. A circuit is connected as shown in the figure with the switch S open. When the switch is closed, the total amount of charge that flows from Y to X is



(a) 0 (b) 54 μC

(c) 27 μC (d) 81 μC

7. A resistance of 2 Ω is connected across one gap of a metre-bridge (the length of the wire is 100 cm) and an unknown resistance, greater than 2 Ω, is connected across the other gap. When these resistances are interchanged, the balance point shifts by 20 cm. Neglecting any corrections, the unknown resistance is

(a) 3 Ω (b) 4 Ω (c) 5 Ω (d) 6 Ω

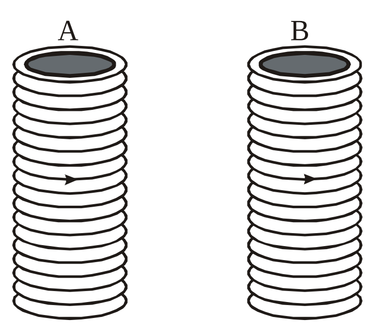
8. For the circuit shown in the figure

(b) the potential difference across R_L is 18V

(c) ratio of powers dissipated in R_1 and R_2 is 3

(d) if R_1 and R_2 are interchanged, magnitude of the power dissipated in R_L will decrease by a factor of 9

9. Two metallic rings A and B, identical in shape and size but having different resistivities ρ_A and ρ_B, are kept on top of two identical solenoids as shown in the figure. When current I is switched on in both the solenoids in identical manner, the rings A and B jump to heights h_A and h_B, respectively, with $h_A > h_B$. The possible relation (s) between their resistivities and their masses m_A and m_B is (are)



(A) $\rho_A > \rho_B$ and $m_A = m_B$ (B) $\rho_A < \rho_B$ and $m_A = m_B$

(C) $\rho_A > \rho_B$ and $m_A > m_B$ (D) $\rho_A < \rho_B$ and $m_A < m_B$

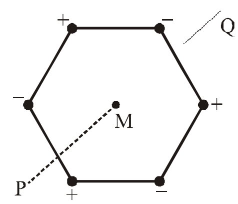
10. Match the following

A	Dielectric ring uniformly charged	(p)	Time independent electrostatic field out of system
B	Dielectric ring uniformly charged rotating with angular velocity ω	(q)	Magnetic field
C	Constant current in ring i_0	(r)	Induced electric field
D	$i = i_0 \cos \omega t$	(s)	Magnetic moment

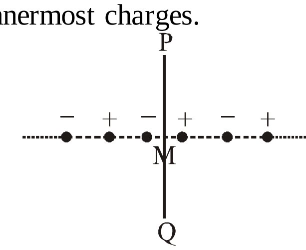
11. Six point charges, each of the same magnitude q, are arranged in different manners as shown in column-II. In each case, a point M and a line PQ passing through M are shown. Let E be the electric field and V be the electric potential at M (potential at infinity is zero) due to the given charge distribution when it is at rest. Now, the whole system is set into rotation with a constant angular velocity about the line PQ. Let b be the magnetic field at M and μ be the magnetic moment of the system in this condition. Assume each rotating charge to be equivalent to a steady current.

Column -I **Column-II**

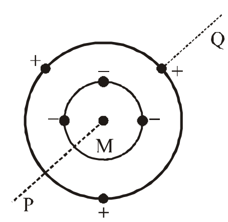
A. E = 0 (p) Charges are at the corners of a regular hexagon. M is at the centre of the hexagon. PQ is perpendicular to the plane of the hexagon.



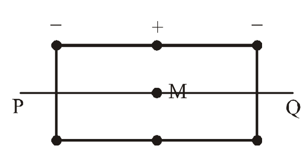
B. V ≠ 0 (q) Charges are on a line perpendicular two PQ at equal intervals. M is the mid-point between the two innermost charges.



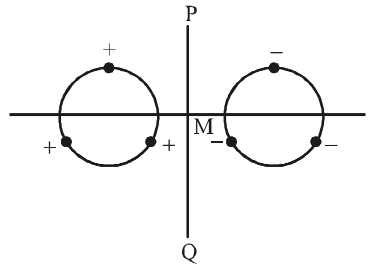
C. B = 0 (r) Charges are placed on two coplanar insulating rings at equal intervals M is the common centre of the rings. PQ is perpendicular to the plane of the rings.



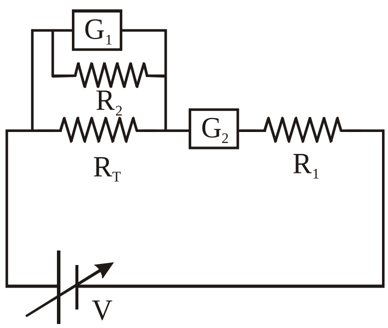
D. μ ≠ 0 (s) Charges are placed at the corners of a rest angle of sides a and $2a$ and at the mid points of the longer sides. M is at the centre of the rectangle. PQ is parallel to the longer sides.

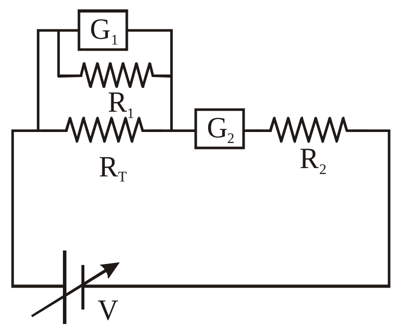


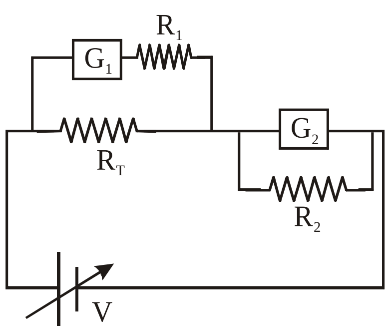
(t) Charges are placed on two coplanar, identical insulating rings at equal intervals. M is the mid point between the centres of the rings. PQ is perpendicular to the line joining the centres and coplanar to the rings.

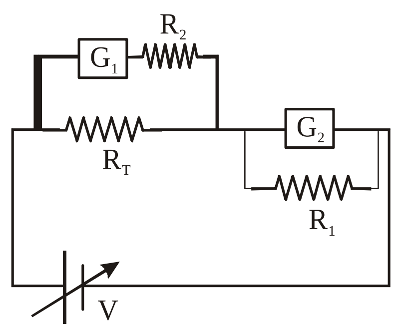


12. To verify Ohm's law, a student is provided with a test resistor R_T, a high resistance R_1, a small resistance R_2, two identical galvanometers G_1 and G_2, and a variable voltage source V. The correct circuit to carry out the experiment is

(a) 

(b) 

(c) 

(d) 

13. Incandescent bulbs are designed by keeping in mind that the resistance of their filament increases with the increase in temperature. If at room temperature, 100 W, 60 W and 40 W bulbs have filament resistances R_{100}, R_{60} and R_{40}, respectively, the relation between these resistances is

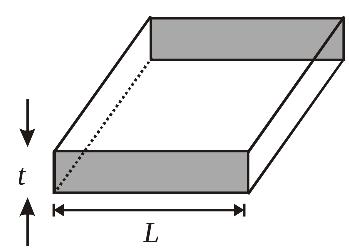
(a) $\frac{1}{R_{100}} = \frac{1}{R_{40}} + \frac{1}{R_{60}}$

(b) $R_{100} = R_{40} + R_{60}$

(c) $R_{100} > R_{60} > R_{40}$

(d) $\frac{1}{R_{100}} > \frac{1}{R_{60}} > \frac{1}{R_{40}}$

14. Consider a thin square sheet of side L and thickness t, made of a material of resistivity ρ. The resistance between two opposite faces, shown by the shaded areas in the figure is



(a) directly proportional to L

(b) directly proportional to t

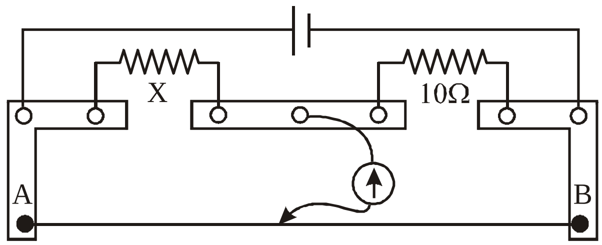
(c) independent of L

(d) independent of t

15. When two identical batteries of internal resistance 1 Ω each are connected in series across a resistor

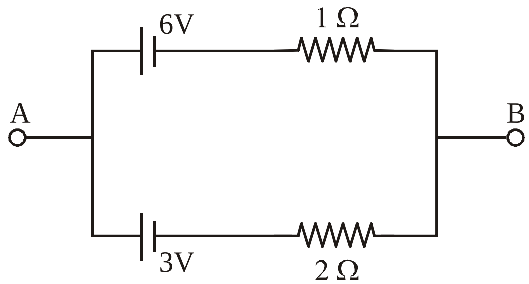
R, the rate of heat produced in R is J_1. When the same batteries are connected in parallel across R, the rate is J_2. If $J_1 = 2.25\ J_2$ then the value of R in Ω is

16. A meter bridge is set-up as shown, to determine an unknown resistance 'X' using a standard 10 ohm resistor. The galvanometer shows null point when tapping key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of 'X' is

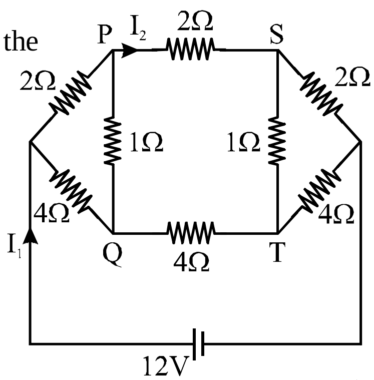


(a) 10.2 ohm (b) 10.6 ohm (c) 10.8 ohm (d) 11.1 ohm

17. Two batteries of different emfs and different internal resistances are connected as shown. The voltage across AB in volts is



18. For the resistance network shown in the figure, choose the correct option (s)



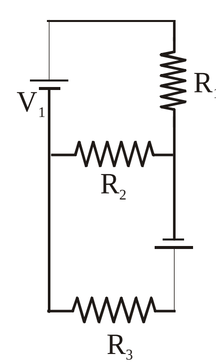
(a) The current through PQ is zero

(b) $I_1 = 3A$

(c) The potential as S is less than the at Q

(d) $I_2 = 2A$

19. Two ideal batteries of emf V_1 and V_2 and three resistances R_1, R_2 and R_3 are connected as shown in the figure. The current in resistance R_2 would be zero if



(a) $V_1 = V_2$ and $R_1 = R_2 = R_3$

(b) $V_1 = V_2$ and $R_1 = 2R_2 = R_3$

(c) $V_1 = 2V_2$ and $2R_1 = 2R_2 = R_3$

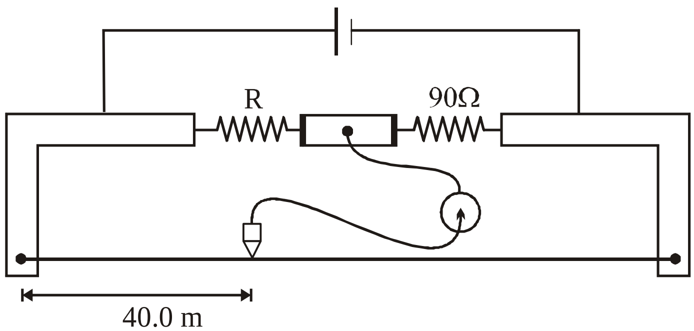
(d) $2V_1 = V_2$ and $2R_1 = R_2 = R_3$

20. Heater of an electric kettle is made of a wire of length L and diameter *d*. It takes 4 minutes to raise the temperature of 0.5 kg water by 40 K. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter 2*d*. The way these wires are connected is given in the options. How much time in minutes will it take to rise the temperature of the same amount of water by 40 K?

(a) 4 if wires are in parallel
(b) 2 if wires are in series
(c) 1 if wires are in series
(d) 0.5 if wires are in parallel

21. A galvanometer gives full scale deflection with 0.006 A current. By connecting it to a 4990 Ω resistance, it can be converted into a voltmeter of range 0 – 30V. If connected to a $\frac{2n}{249}\Omega$ resistance, it becomes an ammeter of range 0 – 1.5 A. The value of n is

22. During an experiments with a metre bridge, the galvanometer shows a null point when the jockey is pressed at 40.0 cm using a standard resistance of 90 Ω, as shown in the figure. The least count of the scale used in the metre bridge is 1 mm. The unknown resistance is



(A) 60 ± 0.15 Ω
(B) 135 ± 0.56 Ω
(C) 60 ± 0.25 Ω
(D) 135 ± 0.23 Ω

DCE QUESTIONS

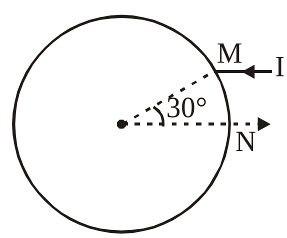
1. A potentiometer is used to determine the emf of a cell. No current flows through the galvanometer. If the cell is shunted by a 2Ω resistance, the balancing length becomes half. What is the internal resistance of the cell?

(a) 2 Ω
(b) 4 Ω
(c) 1 Ω
(d) none of these

2. If the colours are blue, blue, red, silver, then the resistance is

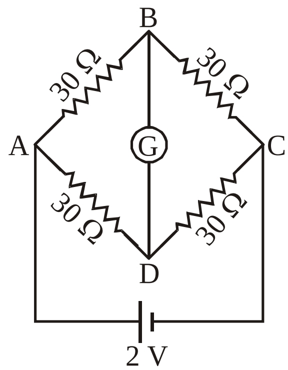
(a) $66 \times 10^6 \pm 10\%\ \Omega$
(b) $22 \times 10^6 \pm 10\%\ \Omega$
(c) $66 \times 10^6 \pm 5\%\ \Omega$
(d) $66 \times 10^2 \pm 10\%\ \Omega$

3. A uniform wire of resistance 36 Ω is bent in form of a circle. The effective resistance across the points M and N is **[DCE-2002]**



(a) 2.75 Ω
(b) 3 Ω
(c) 33 Ω
(d) 36 Ω

4. What is the current in BD?

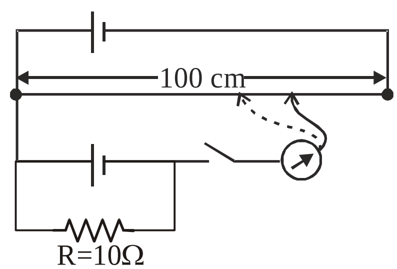


(a) 0 (b) 0.033 A (c) 0.066 A (d) none of these

5. Two wires having resistances R and 3 R are connected in parallel, the ratio of heat generated in 3 R and R is

(a) 1 : 2 (b) 3 : 1 (c) 1 : 4 (d) 4 : 1

6. Null point with 1 V cell comes out to be 55 cm and with R = 10 Ω, it is 50 cm. What is the internal resistance of the cell?



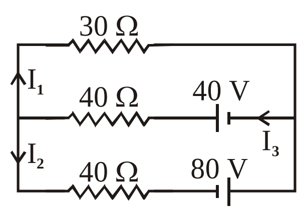
(a) 5 Ω

(b) 4 Ω

(c) 1 Ω

(d) 2 Ω

7. In the given circuit I_1 is



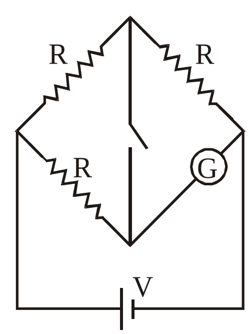
(a) 0.4 A

(b) –0.4 A

(c) 0.8 A

(d) –0.8 A

8. In the balanced Wheatstone bridge circuit as shown in the figure, when the key is pressed, what will be the change in the reading of the galvanometer



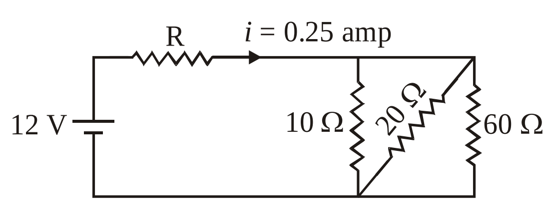
(a) remains same

(b) increased

(c) decreased

(d) zero

9. What is R?



(a) 42 Ω

(b) 62 Ω

(c) 84 Ω

(d) none of these

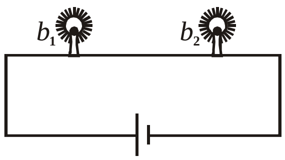
10. An electric bulb illuminates a plane surface. The intensity of illumination on the surface at a point 2 m away from the bulb is 5×10^{-4} phot (lumens/cm^2). The line joining the bulb to the point makes an angle of 60° with the normal to the surface. The intensity of the bulb in candela (candle power) is

(a) $40\sqrt{3}$ (b) 40 (c) 20 (d) 40×10^{-4}

11. Resistance of rod is 1Ω. It is bent in form of square. What is resistance across adjoint corner

(a) 1Ω (b) 3Ω (c) (3/16)Ω (d) $\frac{3}{4}\Omega$

12. Bulb B_1 is 100 W – 250 V and bulb B_2 is 100 W – 200 V are connected across 250 V. What is potential drop across B_2 ?

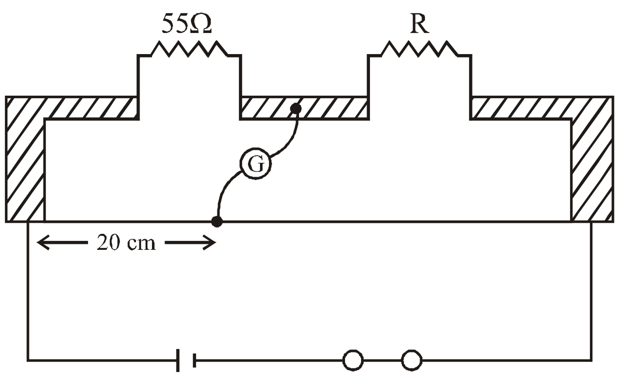


(a) 200 V (b) 250 V

(c) 98 V (d) 48 V

MAINS QUESTIONS

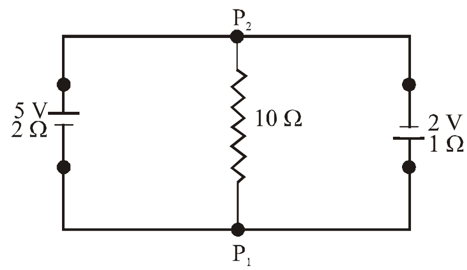
1. Shown in the figure below is a meter-bridge set up with null deflection in the galvanometer.



The value of the unknown resistor *R* is

(a) 220 Ω (b) 110 Ω (c) 55 Ω (d) 13.75 Ω

2. A 5 V battery with internal resistance 2Ω and 2 V battery with internal resistance 1Ω and is connected to a 10Ω resistor as shown in the figure



(a) 0.03 A P_1 to P_2 (b) 0.03 A P_2 to P_1

(c) 0.27 A P_1 to P_2 (d) 0.27 A P_2 to P_1

Passage

Directions : Question No. 3 and 4 are based on the following paragraph.

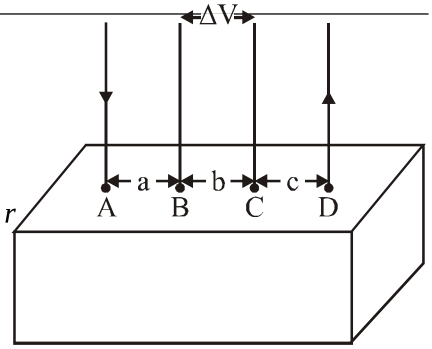
Consider a block of conducting material of resistivity ρ shown in the figure. Current *I* enters at *A* and leaves from *D*. We apply superposition principle to find voltage Δ*V* developed between *B* and *C*. The calculation is done in the following steps :

(i) Take current *I* entering from *A* and assume it to spread over a hemispherical surface in the block.

(ii) Calculate field $E(r)$ at distance r from A by using Ohm's law $E = \rho J$, where J is the current per unit area at r.

(iii) From the r dependence of $E(r)$, obtain the potential $V(r)$ at r.

(iv) Repeat (i), (ii) and (iii) for current I leaving D and superpose results for A and D.



3. For current entering at A, the electric field at a distance r from A is

(a) $\frac{\rho I}{r^2}$ (b) $\frac{\rho I}{2\pi r^2}$ (c) $\frac{\rho I}{4\pi r^2}$ (d) $\frac{\rho I}{8\pi r^2}$

4. ΔV measured between B and C is

(a) $\frac{\rho I}{a} - \frac{\rho I}{(a+b)}$ (b) $\frac{\rho I}{2\pi a} - \frac{\rho I}{2\pi(a+b)}$ (c) $\frac{\rho I}{2\pi(a-b)}$ (d) $\frac{\rho I}{\pi a} - \frac{\rho I}{\pi(a+b)}$

5. **Statement-1:** The temperature dependence of resistance is usually given as $R = R_0 (1 + \alpha \Delta t)$. The resistance of a wire change from 100Ω to 150Ω when its temperature is increased from 27°C to 227°C. This implies that $\alpha = 2.5 \times 10^{-3}$/°C.

Statement-2: $R = R_0 (1 + \alpha\Delta t)$ is valid only when the change in the temperature ΔT is small and $\Delta R = (R - R_0) << R_0$.

(a) Statement-1 is true, Statement-2 is true, Statement-2 is the correct explanation of Statement-1

(b) Statement-1 is true, Statement-2 is true, Statement-2 is not the correct explanation of Statement-1

(c) Statement-1 is false, Statement-2 is true

(d) Statement-1 is true, Statement-2 is false

6. An electric current is passed through a circuit containing two wires of the same material, connected in parallel. If the lengths and radii of the wires are in the ratio of (4/3) and (2/3), then the ratio of the currents passing through the wires will be

(a) 8/9 (b) 1/3 (c) 3 (d) 2

7. In a metre bridge experiment null point is obtained at 20 cm. from one end of the wire when resistance X is balanced against another resistance Y. If X < Y, then where will be the new position of the null point from the same end, if one decides to balance a resistance of 4 X against Y?

(a) 40 cm (b) 80 cm (c) 50 cm (d) 70 cm

8. The thermistors are usually made of

(a) metal oxides with high temperature coefficient of resistivity

(b) metals with high temperature coefficient of resistivity

(c) metals with low temperature coefficient of resistivity

(d) semiconducting materials having low temperature coefficient of resistivity

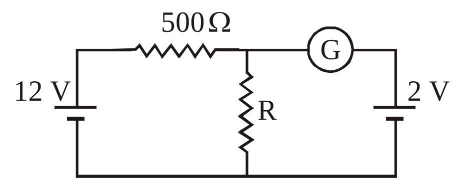
9. Time taken by a 836 W heater to heat one litre of water from 10°C to 40°C is

(a) 150 s (b) 100 s (c) 50 s (d) 200 s

10. A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be

(a) one fourth (b) halved (c) doubled (d) four times

11. In the circuit, the galvanometer G shows zero deflection. If the batteries A and B have negligible internal resistance, the value of the resistor R will be



(a) 500 Ω (b) 1000 Ω

(c) 200 Ω (d) 100 Ω

12. Two sources of equal emf are connected to an external resistance R. The internal resistances of the two sources are R_1 and R_2 ($R_2 > R_1$). If the potential difference across the source having internal resistance R_2 is zero, then

(a) $R = \frac{R_1 R_2}{(R_1 + R_2)}$ (b) $R = \frac{R_1 R_2}{(R_2 - R_1)}$

(c) $R = R_2 \times \frac{(R_1 + R_2)}{(R_2 - R_1)}$ (d) $R = R_2 - R_1$

13. In a potentiometer experiment the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 cm. The internal resistance of the cell is

(a) 4 Ω (b) 2 Ω (c) 1 Ω (d) 0.5 Ω

14. The resistance of hot tungsten filament is about 10 times the cold resistance. What will be the resistance of 100 W and 200 V lamp when not in use?

(a) 400 Ω (b) 200 Ω

(c) 40 Ω (d) 20 Ω

15. An energy source will supply a constant current into the load if its internal resistance is

(b) non-zero but less than the resistance of the load

(c) equal to the resistance of the load

(d) very large as compared to the load resistance

16. The Kirchhoff's firs law ($\Sigma i = 0$) and second law ($\Sigma iR = \Sigma E$), where the symbols have their usual meanings, are respectively based on

(a) conservation of charge, conservation of momentum

(b) conservation of energy, conservation of charge

(c) conservation of momentum, conservation of charge

(d) conservation of charge, conservation of energy

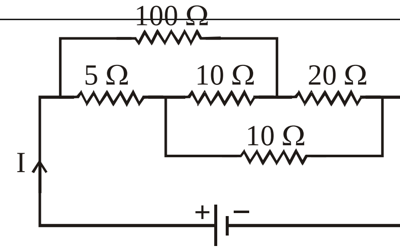
17. The current I drawn from the 5 volt source will be

(a) 0.33 A

(b) 0.5 A

(c) 0.67 A

(d) 0.17 A



18. In a Wheatstone's bridge, three resistances P, Q and R are connected in the three arms and the fourth arm is formed by two resistances S_1 and S_2 connected in parallel. The condition for the bridge to be balanced will be

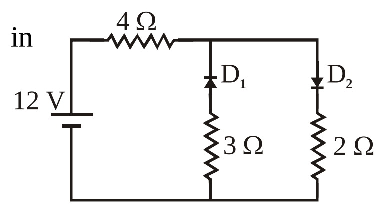
(a) $\frac{P}{Q} = \frac{2R}{S_1 + S_2}$

(b) $\frac{P}{Q} = \frac{R(S_1 + S_2)}{S_1 S_2}$

(c) $\frac{P}{Q} = \frac{R(S_1 + S_2)}{2 S_1 S_2}$

(d) $\frac{P}{Q} = \frac{R}{S_1 + S_2}$

19. The circuit has two oppositely connected ideal diodes in parallel. What is the current flowing in the circuit?



(a) 1.71 A (b) 2.00 A

(c) 2.31 A (d) 1.33 A

20. An electric bulb is rated 220 volt – 100 watt. The power consumed by it when operated on 110 volt will be

(a) 75 watt (b) 40 watt (c) 25 watt (d) 50 watt

21. Two electric bulbs marked 25 W-220 V and 100 W - 220 V are connected in series to a 440 V supply. Which of the bulbs will fuse?

(a) Both (b) 100 W (c) 25 W (d) Neither

22. The supply voltage to a room is 120 V. The resistance of the lead wires if 6Ω. A 60W bulb is already switched on. What is the decrease of voltage across the bulb, when a 240 W heater is switched on in parallel to the bulb?

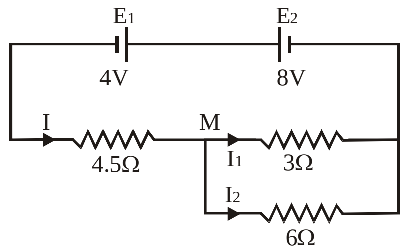
(a) 13.3 Volt (b) 10.04 Volt (c) zero Volt (d) 2.9 Volt

23. The current voltage relation of diode is given by $I = (e^{1000V/T} - 1)$ mA, where the applied voltage V is in volts and the temperature T is in degree Kelvin. If a student makes an error mesuring ±0.01 V while measuring the current of 5 mA at 300 K, what will be the error in the value of current in mA?

(a) 0.5 mA (b) 0.05 mA (c) 0.2 mA (d) 0.02 mA

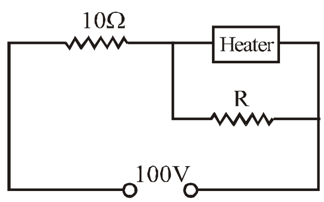
BASIC PROBLEMS

1. Two cells E_1 and E_2, having e.m.f. 4 V and 8 V and internal resistance 0.5 Ω and 1 Ω respectively are connected as shown. Find the current in each resistor and potential difference across each cell.

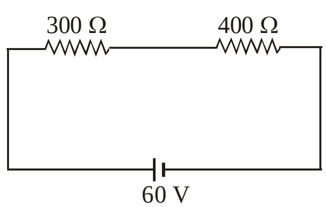


2. A galvanometer having 30 divisions has a current sensitivity of 20 μA per division and a resistance of 25 ohm. Find the shunt required to convert it into an ammeter of 1 ampere range. Find the resistance which should be connected in series to convert this ammeter into a voltmeter of range 1 V.

3. A heater is designed to operate with a power of 1000 watts in a 100-volts line. It is connected, in combination with a resistance of 10 ohms and a resistance R, to a 100-volts mains as shown in the figure. What should be the value of R so that the heater operates with a power of 62.5 watts?

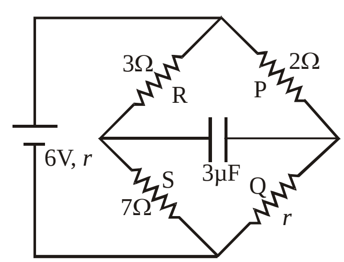


4. In the circuit shown a voltmeter reads 30 volts when it is connected across the 400 ohms resistance. Calculate what the same voltmeter will read when it is connected across the 300 ohm resistance ?

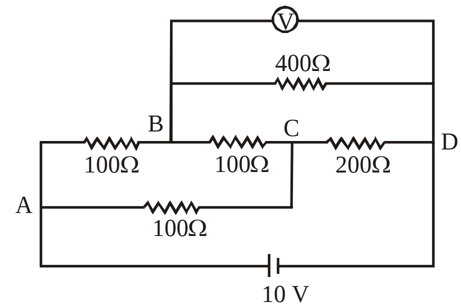


5. A galvanometer of unknown resistance in series is connected across two identical cells each of 1.5 volt. When the cells are connected in series, the galvanometer records a current of 1 A and when the cells are in parallel, the current is 0.6 A. Find the internal resistance of the cell.

6. Determine the charge and energy stored in the capacitor in the figure for the circuit in which internal resistance of battery, $r = 4\Omega$. Also, find the value of r for which the charge on the capacitor is zero.



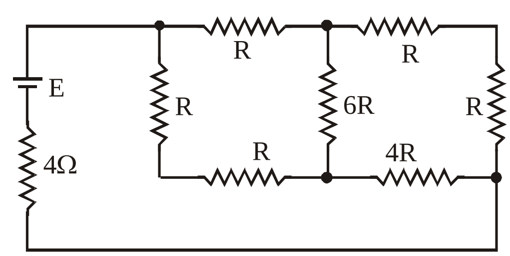
7. A battery of e.m.f. 10 V is connected to a network of resistors as shown in the figure. The potential difference across a resistor of 400 Ω is measured by a voltmeter of resistance 400 Ω. Find the reading of the volt meter.



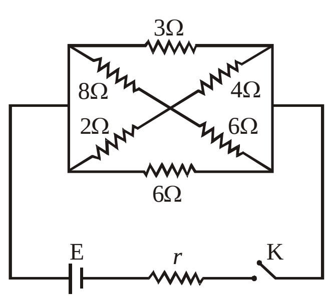
8. A battery of internal resistance 4 Ω is connected to the one single network of resistances as shown in the figure.

(a) Find the value of *R* so that maximum power is delivered to the network.

(b) Find the maximum power.



9. In the circuit shown in the figure, the e.m.f. of the cell is 1.8 V and its internal resistance *r* is $\frac{2}{3}$ Ω. Find the current in 3Ω resistance and power consumed by the circuit from the battery when K is closed.

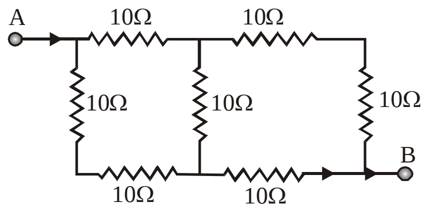


10. Two resistors, 400 ohms and 800 ohms, are connected in series with a 6-volt battery. It is desired to measure current in the circuit. An ammeter of 10 ohms resistance is used for this purpose. What will be the reading in the ammeter ? Similarly, if a voltmeter of 10,000 ohms resistance is used to measure the potential difference across the 400-ohm resistor, what will be the reading in the voltmeter ?

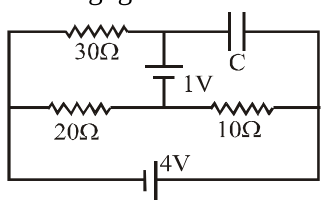
11. A carbon and an aluminium wire are connected in series. If the combination has resistance of 30 ohm at 0°C, what is the resistance of each wire at 0°C so that the resistance of the combination does not change with temperature? [$\alpha_C = -0.5 \times 10^{-3}$ (C°)$^{-1}$ and $\alpha_A = 4 \times 10^{-3}$ (C°)$^{-1}$]

ADVANCED PROBLEMS

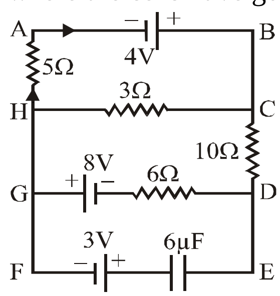
1. Find the equivalent resistance between the terminal points A and B in the network shown in the figure.



2. Find the potential difference between the plates of the capacitance *C* in the circuit shown in the figure. The internal resistances of batteries are negligible.



3. An electric circuit is shown in figure where the cells have got negligible internal resistance.

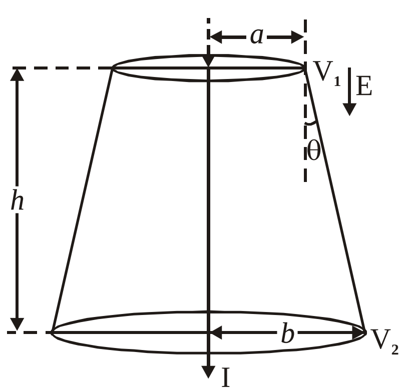


Find :

(a) the current in 3 Ω resistance and in the cell of 8 volt.

(b) the charge on the capacitor.

4. A material of resistivity σ is formed in the shape of a truncated cone of altitude *h* as shown in figure. The top end has a radius a while bottom *b*. Assuming a uniform current density through any circular cross-section of the cone, show that the resistance between the two ends is: $R = \frac{\rho}{\pi}\left[\frac{h}{ab}\right]$.



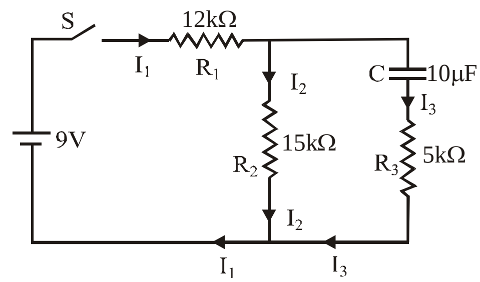
5. A battery of 9.0 V is connected to three resistances of 12 kΩ, 15 kΩ and 5 kΩ and a condenser of 10 μF through a switch S as shown in the circuit diagram. If the switch is closed for a sufficiently long time so that the capacitor becomes fully charged, find :1

(a) the steady state current I_1, I_2 and I_3.

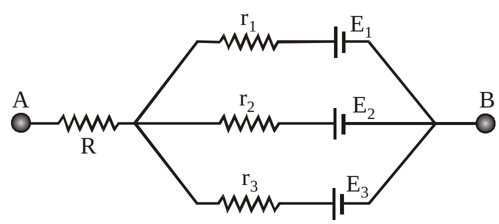
(b) the charge on the capacitor.

(c) the time it takes for the charge on the capacitor to fall to half its value if the switch S is opened at $t = 0$.

(d) the variation of the current through the resistance of 15 kΩ as a function of time after opening the switch.



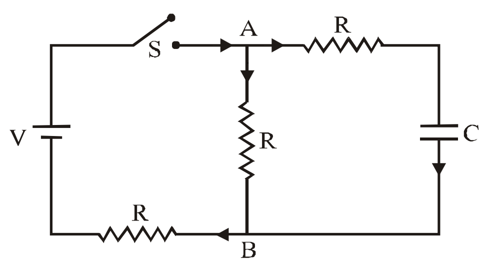
6. In the circuit shown in the figure, $E_1 = 3$ volts, $E_2 = 2$ volts, $E_3 = 1$ volt, and $R = r_1 = r_2 = r_3 = 1$ ohm.



(a) Find the potential difference between the points A and B, and the currents through each branch.

(b) If r_2 is short-circuited and the point A is connected to point B, find the currents through E_1, E_2, E_3 and the resistor R.

7. In the circuit shown in the figure, the battery is an ideal one, with e.m.f. V. The capacitor is initially uncharged. The switch S is closed at time $t = 0$.



(a) Find the charge Q on the capacitor at time t.

(b) Find the current in AB at time t. What is its limiting value as $t \rightarrow \infty$?

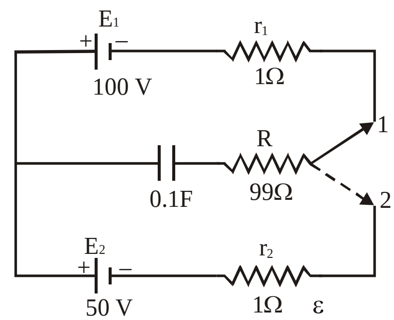
8. A fuse wire of lead has an area of cross-section 0.2 mm^2. The current in the fuse wire reaches 30 A when there is a short circuit. Find the time after the short circuit when the fuse will begin to melt. The specific heat and melting point for lead is 0.032 cal g^{-1} $(^{o}C)^{-1}$ and 327ºC respectively. The density and resistivity of fuse wire is 11.34 $g.cm^{-3}$ and 2.2×10^{-5} ohm-cm. Neglect heat losses. The initial temperature of wire of 20ºC.

9. A capacitor of capacitance C = 0.1 F is charged by a battery of e.m.f. E_1 = 100 V and internal resistance r_1 = 1 Ω by putting switch S in position 1 as shown in figure.

(a) Calculate heat generated across R resistor during charging of the capacitor.

(b) Now the switch is thrown to position 2 at instant t = 0, calculate current I(t) through the circuit, consisting of capacitor and battery of e.m.f. E_2 and internal resistance r_2.

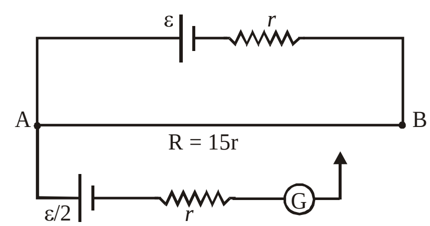
(c) Calculate heat generated in E_2 during flow of current through this battery.



10. Consider the potentiometer circuit arranged as in figure. The potentiometer wire is 600 cm long

(a) At what distance from the point A should the jockey touch the wire to get zero deflection in the galvanometer?

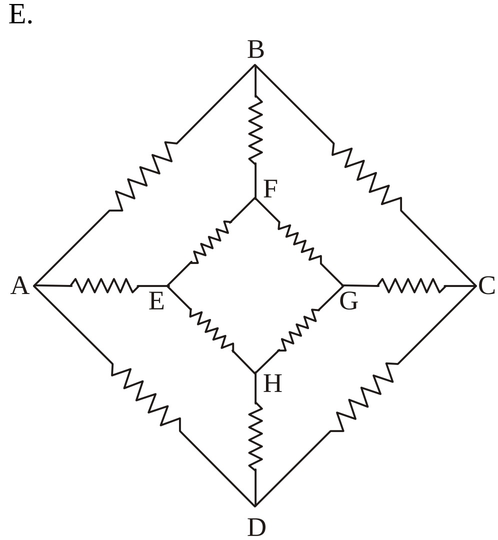
(b) If the jockey touches the wire at a distance of 560 cm from A, what will be the current in the galvanometer?



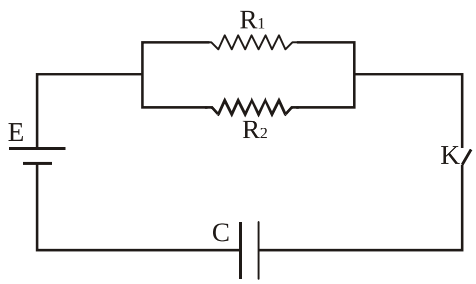
11. Three equal resistors connected in series across a source of emf together dissipate 10 watt of power. What would be the power dissipated if the same resistance are connected in parallel across the same source of emf?

12. Find the resistance of a wire in which the resistivity varies linearly from ρ_1 to ρ_2. The length and the radius of the wire are l and r respectively.

13. The network of resistors each of value R is shown in the figure, calculate the equivalent resistance between the junction A and E.



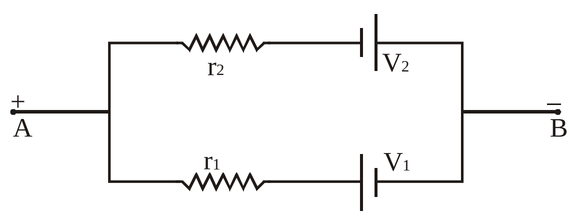
14. In the circuit shown in figure, the Capacitor having capacitance C is uncharged when the key is open. The key K is closed. Over the time during which the capacitor becomes charged to a voltage V, calculate the amount of heat liberated in the resistor R_2 if the e.m.f. of the source is E, and its internal resistance is negligible.



15. A wire of length 1.0 *m* and radius 10^{-3} *m* is carrying a heavy current is assumed to radiate as a block body. At equilibrium its tempterature is 900 K while that of the surroundings is 300 K. The resistivity of the material of the wire at 300 K is $\pi^2 \times 10^{-8}$ Ωm and its temperature coefficient of resistance is 7.8×10^{-3} per °C. Find the current in the wire.

(Given: Stefan Constant = 5.68×10^{-8} $Wm^{-2}K^{-4}$)

16. Find the emf (E) and internal resistance (*r*) of a single battery which is equivalent to a parallel combination of two batteries of emfs E_1 and E_2 and internal resistances r_1 and r_2 respectively, with polarities as shown in figure.



ANSWERS

Objectives

1.	(d)	2.	(a)	3.	(d)	4.	(a)	5.	(b)
6.	(b)	7.	(b)	8.	(d)	9.	(d)	10.	(c)
11.	(d)	12.	(b)	13.	(d)	14.	(c)	15.	(c)
16.	(b)	17.	(a)	18.	(b)	19.	(b)	20.	(d)
21.	(c)	22.	(d)	23.	(b)	24.	(b)	25.	(b)
26.	(b)	27.	(b)	28.	(c)	29.	(d)	30.	(c)
31.	(a,c,d)	32.	(a,b,c)	33.	(a,b)	34.	(a,b,c,d)	35.	(b,c)
36.	(a,c)	37.	(a,b,c)	38.	(a,c)	39.	(a,d)	40.	(b,c)

Miscellaneous Assignment

1.	(b)	2.	(b)	3.	(a)	4.	(a)	5.	(a)
6.	(d)	7.	(c)	8.	A-(q); B-(p); C-(r); D-(s)				
9.	A-(p); B-(p); C-(r); D-(s)			10.	(2)	11.	(2)	12.	(5)
13.	(1)	14.	(0) Amp	15.	(6)	16.	(1)	17.	(1)
18.	(8)	19.	(5)						

Previous Year Questions

IIT-JEE/JEE-ADVANCE QUESTIONS

1.	(b)	2.	(d)	3.	(c)	4.	(c)	5.	(b)
6.	(c)	7.	(a)	8.	(a, d)	9.	(b,d)		
10.	A-(p); B-(q),(s); C-(q),(s); D-(q),(r),(s)								
11.	A-(p), (r), (s), B-(r), (s); C-(p), (q), (t); D-(r), (s)								
12.	(c)	13.	(d)	14.	(c)	15.	[4Ω]	16.	(b)
17.	(5)	18.	(a,b,c,d)	19.	(a,b,d)	20.	(b,d)	21.	(5)
22.	(c)								

DCE QUESTIONS

1.	(a)	2.	(d)	3.	(a)	4.	(a)	5.	(b)
6.	(c)	7.	(b)	8.	(b)	9.	(a)	10.	(b)
11.	(c)	12.	(c)						

MAINS QUESTIONS

1.	(a)	2.	(b)	3.	(b)	4.	(d)	5.	(c)
6.	(b)	7.	(c)	8.	(a)	9.	(a)	10.	(c)
11.	(d)	12.	(d)	13.	(b)	14.	(c)	15.	(d)

16.	(d)	17.	(b)	18.	(b)	19.	(b)	20.	(c)
21.	(c)	22.	(d)	23.	(c)				

Basic Problems

1. $I_1 = \frac{1}{3}$ A, $I_2 = \frac{1}{6}$ A, $V_1 =$ 4.25 V, $V_2 = 7.5$ V
2. 0.015 Ω, 0.985 Ω
3. $R = 5\ \Omega$
4. 21.4 volts.
5. 0.33 Ω
6. 0.6 μC, 6×10^{-8} J, $r = 4.67\ \Omega$
7. $\frac{20}{3}$ V
8. 2 ohm, $\frac{E^2}{16}$ watt.
9. 0.4 A, 1.62 W
10. 4.96×10^{-3} ampere, 1.95 volts.
11. $R_{0A} = \frac{10}{3}\Omega$, $R_{0C} = \frac{80}{3}\Omega$
12. 1050 J/s, 5 A
13. 25 V, 75 V
14. 72 μC
15. 1A, 1 V
16. (a) 5.5×10^{-7} Ω-m; (b) 20 m

Advanced Problems

1. 14 ohms
2. –1.0 volt
3. (a) 0.168 amp., 0.5 amp. (b) 4.69×10^{-5} C
4. $\frac{\rho}{\pi}\left[\frac{h}{ab}\right]$
5. (a) $I_1 = I_2 = \frac{1}{3}$ mA (b) 50 μC (c) 0.1386 S (d) $0.25\, e^{-5t}$ mA
6. (a) 2 volts, $i_1 = -i_3 = 1$ ampere, $i_2 = 0$

   (b) current through $R = 2$ ampere, current through E_1 and E_3 remains the same.

   current through $E_2 = 2$ ampere.
7. (a) $Q = \frac{VC}{2}(1 - C^{-2t/3RC})$ (b) $\frac{V}{2R}\left(1 - \frac{1}{3}e^{-2t/3RC}\right)$, Limiting Value = $\frac{V}{2R}$
8. 0.095 sec.
9. (a) 495 J (b) $I = 0.5\, e^{-0.1t}$ (c) 1.25 J
10. (a) 320 cm (b) 3ε/22r
11. 90 W
12. $\frac{(\rho_1 + \rho_2)l}{2\pi r^2}$
13. $\frac{7R}{12}$
14. $\frac{VCR_1}{2(R_1 + R_2)}(2E - V)$
15. I = 35.5 A
16. $\frac{E_1 r_2 - E_2 r_1}{r_1 + r_2}, \frac{r_1 r_2}{r_1 + r_2}$