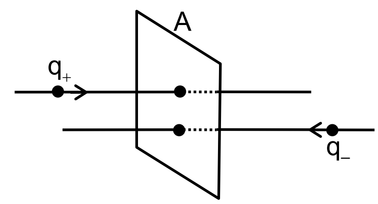
Current Electricity

1. Electric Current

Consider a small area A kept perpendicular to the direction of flow of charges as shown in figure.



Positive charges q_+ are flowing from left to right and negative charge q_- are flowing from right to left across the area. Net charge flowing through the area in the interval t from left to right $q = q_+ - q_-$.

The quotient $\frac{q}{t} = i$, is defined as the current across the area in the direction left to right. If the quotient is negative then the current is in the direction right to left. The electric current in measured by 'rate of flow of charge'.

Current $i = \frac{\text{Charge}}{\text{Time}} = \frac{dq}{dt}$,

if flow is uniform $\quad i = \frac{q}{t}$

Unit : Ampere (A)

1 ampere = 1 coulomb/second

Dimension : $(M^0L^0T^0A^1)$

If n electrons pass through any cross section in every t seconds then $i = \frac{ne}{t}$

where $e = 1.6 \times 10^{-19}$ coulomb.

1.1 Average & Instantaneous Current

1. **Average current**

   If ΔQ charge flows through any cross section of conductor in the interval t to $t + \Delta t$, then average current in that interval is defined as the ratio of ΔQ to Δt; $I_{av} = \frac{\Delta Q}{\Delta t} = \frac{Q_2 - Q_1}{t_2 - t_1}$

2. **Instantaneous current**

   If the limit of Δt is tending to zero, then the current is defined to be instantaneous current at time t.

   $$I = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

Key Points

Instantaneous current through a cross-section

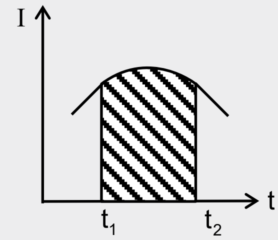
$$I = \frac{dQ}{dt}$$

Charge passed through the cross section in the interval t to t + dt

$$dQ = Idt$$

Total charge in the interval t_1 to t_2

$Q = \int_{t_1}^{t_2} Idt$ = Area below I versus t graph in the interval t_1 to t_2 as shown in figure.



Average current in the interval t_1 to t_2

$$I_{av} = \frac{\Delta Q}{\Delta t} = \frac{\int_{t_1}^{t_2} Idt}{\int_{t_1}^{t_2} dt} = \frac{\text{Area below I versus t graph}}{\text{Time interval}}$$

1.2 1 Ampere

If 1 coulomb of charge flows per second then 1 ampere of current is said to be flowing.

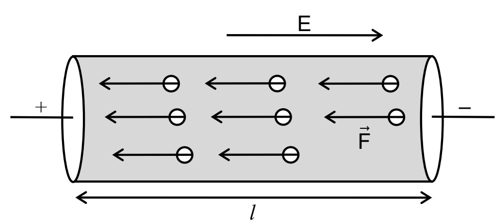
1 ampere of current means the flow of 6.25×10^{18} electrons per second through any cross section of conductor

1.3 Direction of current flow

By convention, direction of current is taken as direction of motion of positively charged particles and opposite to the direction of negatively charged particles.
Order of currents in domestic appliances is 1A.
Order of current in our nerves is 1 μA.
Order of current in lightening is 10^4 A.
Electric current is a scalar quality Although in diagrams, we represent current in a wire by an arrow but the arrow simply indicate the direction of flow of positive charges in the wire.
Current is a scalar quantity because it does not obey vector law of addition.

1.4 Flow of charge in conductors

Value of the current is same throughout the conductor, irrespective of the cross section of conductor at different points.
Net charge in a current carrying conductor is zero at any instant of time.
A current carrying conductor cannot said to be charged, because in conductor the current is caused by electron (free electron). The no. of electron (negative charge) and proton (positive charge) in a conductor is same. Hence the net charge in a current carrying conductor is zero.



- Electric field outside a current carrying conductor is zero, but it is non zero inside the conductor.
- The electric field inside charged conductor is zero in electrostatic condition, but it is non zero inside a current carrying conductor.

Key Points

- In liquids, the charge carriers are positive and negative ions.
- In gases, the charge carriers are positive ions and free electrons.
- In semiconductors, the charge carriers are holes and free electrons. The conventional direction of flow of current is opposite to the direction of flow of electrons.

Example 1:

If a charge of 1.6×10^{-19} coulomb flows per second through any cross section of any conductor, the current constituted will be :

(1) 2.56×10^{-19} A (2) 6.25×10^{-19} A (3) 1.6×10^{-19} A (4) 3.2×10^{-19} A

Solution:

From definition of current $i = \frac{q}{t}$

Here $q = 1.6 \times 10^{-19}$ C and $t = 1$ sec

$\therefore\ i = \frac{1.6 \times 10^{-19}}{1} = 1.6 \times 10^{-19}$ ampere

Example 2:

The no. of electrons flowing per second through any cross section of wire, if it carries a current of one ampere, will be :

(1) 2.5×10^{18} (2) 6.25×10^{18} (3) 12.5×10^{18} (4) 5×10^{18}

Solution:

$I = \frac{q}{t} = \frac{ne}{t}$ [$\because$ q = ne, from quantization of charge]

$\Rightarrow n = \frac{I \times t}{e} = \frac{1 \times 1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}$

Example 3:

The no. of electron passing through a heater wire in one minute, if it carries a current of 8 ampere, will be:

(1) 2×10^{20} (2) 2×10^{21} (3) 3×10^{20} (4) 3×10^{21}

Solution:

$n = \frac{It}{e} = \frac{8 \times 60}{1.6 \times 10^{-19}} = 3 \times 10^{21}$

Example 4:

In hydrogen atom, the electron moves in an orbit of radius 5×10^{-11} m with a speed of 2.2×10^{6} m/sec. the equivalent current will be :

(1) 1.12 mA (2) 4.32 mA (3) 3.32 mA (4) 7.12 mA

Solution:

Time taken by the electron in 1 revolution is

$T = \frac{2\pi r}{v}$; current $I = \frac{Q}{T} = \frac{Qv}{2\pi r}$

where R is the radius of orbit and v is the speed.

$$I = \frac{2.2 \times 10^{6} \times 1.6 \times 10^{-19}}{2 \times \left(\frac{22}{7}\right) \times (5 \times 10^{-11})} = 1.12 \text{ mA}$$

Example 5:

If charge flowing through a conductor is given by $q = 1.5\, t^2 + t$. The current flow at t = 2 second will be –

(1) 4A (2) 5A (3) 6A (4) 7A

Solution:

We know $i = \dfrac{dq}{dt}$

Here $q = 1.5\,t^2 + t \quad \therefore \dfrac{dq}{dt} = 3t + 1$

Now $I = \left(\dfrac{dq}{dt}\right)_{\text{at } t=2s} = 3 \times 2 + 1 = 7$ Amp.

Example 6:

A conductor of non–uniform cross–sectional area, has cross–sectional area at three points as $A_1 = 2\ cm^2$, $A_2 = 4\ cm^2$ and $A_3 = 6\ cm^2$. If a current of 5 ampere is passed through A_1. Value of current, when passed through A_2 and A_3 respectively as–

(1) 10 A, 15 A (2) 20 A, 30 A (3) 2.5 A, 1.66 A (4) 5A, 5A

Solution:

(4) Current will remain same. (Independent of cross sectional area)

Example 7:

A steady current is flowing in a cylindrical conductor. Is there any electric field within the conductor?

Solution:

Yes, The current in a conductor flows only when the electric field established in the conductor applies a force on each free electron.

2. Current Density

The current density at a point in a conductor is the ratio of the current at that point to the area of cross–section of the conductor at that point.

It is denoted by J i.e. $J = \dfrac{I}{A}$

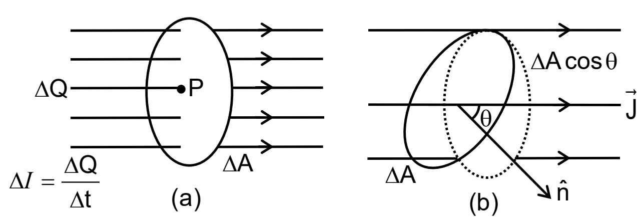
I = Electric current and A = Area of cross section. And area A is normal to current I.

If A is not normal to I, but makes an angle θ with the normal to current, then

$$J = \frac{I}{A_{normal}} = \frac{I}{A\cos\theta}$$

$$\Rightarrow \quad I = J\,A\cos\theta = \vec{J}.\vec{A}$$

$$dI = \vec{J}.d\vec{A} \Rightarrow I = \int \vec{J}.d\vec{A}$$



Electric current is the flux of current density.

It is a vector quantity. It's direction is the direction of motion of the positive charges at that point.

Unit : ampere / meter^2 (A/m^2)

Dimension : $[M^0L^{-2}T^0A]$

Example 8:

An electron beam has an aperture 1.0 mm^2. A total of 6.0×10^{16} electrons go through any perpendicular cross section per second. Find (a) the current and (b) the current density in the beam.

Solution:

(a) The total charge crossing a perpendicular cross section in one second is

$q = ne \quad = 6.0 \times 10^{16} \times 1.6 \times 10^{-19}$ C $\quad = 9.6 \times 10^{-3}$ C

The current is

$$i = \frac{q}{t} = \frac{9.6 \times 10^{-3} C}{1 s} = 9.6 \times 10^{-3} \text{ A}$$

As the charge is negative the current is opposite to the direction of motion of the beam.

(b) The current density is

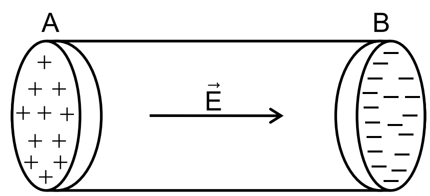
$$J = \frac{i}{A} = \frac{9.6 \times 10^{-3} A}{1.0 mm^2} = 9.6 \times 10^3 Am^{-2}$$

3. Mechanism of Current Flow in Conductors

If an electric field is applied to an electric charge, it will experience a force. If it is free to move then it will contribute to a current.

In atoms and molecules, negatively charged electrons and positively charged nuclei are bound to each other and thus are not free to move in electric field.

In some materials, the electrons will still be bound so when electric field is applied, they will not accelerate to develop current. These materials are generally called **insulators**. In electric solutions both positive and negative ions move to develop current.



In **bulk matter,** these molecules are so closely packed that electrons no longer are attached to individual nuclei. If an electric field is applied some of the electrons are practically free to move within the bulk material to develop currents in them. These materials are generally called **conductors** and these electrons are known as free electrons.

In the absence of electric field, the electrons move with their thermal motion. During their random motion they collide with fixed ions such that their speed before collision is equal to speed after collision but the direction of velocity after collision is completely random. Therefore, number of electrons in any direction will be equal to the number of electrons travelling in opposite direction, so there is no net electric current.

When electric field $\vec{E}$ is applied, the electrons will be accelerated due to the field $\vec{E}$ from end B to A. The motion constitute an electric current.

4. Factors Responsible for Current Flow

4.1 Thermal Speed (order of $v_T = 10^5$ m/s)

Conductor contain a large number of free electrons, which are in continuous random motion. Due to random motion, the free electrons collide with positive metal ions with high frequency and undergo change in direction at each collision. So, the thermal velocities are randomly distributed in all possible directions are, individual thermal velocities of the free electrons at any given time. the total number of free electrons in the conductor = N

$$\text{average velocity} \quad \vec{u}_{avg.} = \left[\frac{\vec{u}_1 + \vec{u}_2 + \ldots.. + \vec{u}_N}{N}\right] = 0$$

4.2 Drift Velocity

Drift velocity is defined as the velocity with which the free electrons get drifted towards the positive terminal under the effect of the applied electric field.

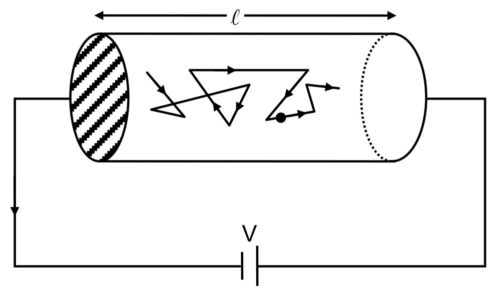
4.3 Relaxation Time

Average time elapsed between two successive collisions. It is of the order of 10^{-14} s. It is a temperature dependent characteristic of the material of the conductor. It decreases with increases in temperature.

4.4 Relation Between Drift Velocity & Relaxation Time

When the ends of a conductor are connected to a source of emf, an electric field E is established in the conductor, such that $E = \frac{V}{\ell}$

where V = the potential difference across the conductor and ℓ = the length of the conductor.



Under the action of electric field random motion of an electron with superimposed drift

The electric field $\vec{E}$ exerts an electrostatic force $-e\vec{E}$ on each electron in the conductor.

The acceleration of each electron $\vec{a} = \frac{-e\vec{E}}{m}$

m = mass of electron, e = charge of electron

so velocity of each electron $\vec{v} = \vec{u} + \vec{a}t$

So

$$\vec{v}_{av} = \vec{v}_d = <\vec{u} + \vec{a}t>$$

$$\Rightarrow \quad \vec{v}_d = <\vec{u}> + \vec{a} <t>$$

since the average thermal velocity of free electrons is zero.

$$\vec{v}_d = \vec{a}\tau \qquad \Rightarrow \qquad \vec{v}_d = -\frac{e\vec{E}}{m}\tau$$

order of drift velocity is 10^{-4} m/s

4.5 Mean free path (λ)

The mean distance travelled by a conduction electron during relaxation time is known as mean free path λ. Mean free path of conduction electron

λ = Thermal velocity × Relaxation time

(order of λ = 10Å)

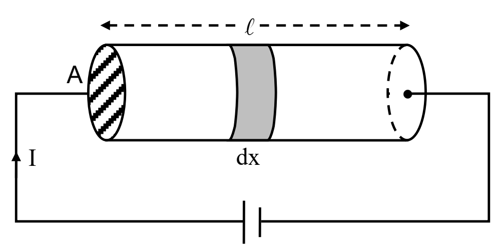
4.6 Relation between current density, conductivity and electric field

Let the number of free electrons per unit volume in a conductor = n

Total number of electrons in dx distance = n(Adx)

Total charge ΔQ = n(Adx)e

Cross sectional area = A



Current = $\frac{\Delta Q}{\Delta t}$ = nAe $\frac{\Delta x}{\Delta t}$ $\Rightarrow I = neAv_d$

Current density $J = \frac{I}{A} = nev_d \Rightarrow J = ne\left(\frac{eE}{m}\right)\tau$

$J = \left(\frac{ne^2\tau}{m}\right)E \qquad \because v_d = \left(\frac{eE}{m}\right)\tau$

again, for ohmic conductor $\vec{J} = \sigma\vec{E} \Rightarrow \sigma = \frac{ne^2\tau}{m} = \frac{1}{\rho}$

In vector form where σ is conductivity & ρ is resistivity.

σ and ρ depends only on the material of the conductor and its temperature.

4.7 Mobility (μ)

It is defined as the magnitude of the drift velocity per unit electric field

$$\mu = \frac{|\vec{v}_d|}{|E|}$$

Its SI unit is $m^2V^{-1}s^{-1}$

Its practical unit is $cm^2V^{-1}s^{-1}$

We have $V_d = \frac{e\tau E}{m} \quad \Rightarrow \quad \mu = \frac{v_d}{E} = \frac{e\tau}{m}$

Mobility of free electrons is independent of electric field and dimension of conductor.

Example 9:

A silver wire having 1mm diameter carries a charge of 90 C in 1 hour and 15 minutes. Silver contains 5.8×10^{28} free electrons per m^3. The current (in amp.) in wire and drift velocity of the electron will be respectively–

(1) 0.02, 2.69×10^{-6} (2) 0.03, 3.69×10^{-7} (3) 3.2, 2.69×10^{-7} (4) 2.3, 3.69×10^{-6}

Solution:

$$\because i = \frac{q}{t} = \frac{90}{4500} = 0.02 \text{ A}$$

$$J = \frac{i}{A} = \frac{i}{\pi r^2} = \frac{0.02}{\pi\left(5\times10^{-4}\right)^2} = 2.55 \times 10^4 \text{ A/m}^2, \qquad v_d = \frac{J}{ne} = \frac{2.55\times10^4}{(5.8\times10^{28})(1.6\times10^{-19})} = 2.69 \times 10^6 \text{m/s}$$

Example 10:

The total momentum of electrons in a straight wire of length ℓ = 1000 m carrying a current I = 70A, will be – (in Ns)

(1) 0.40×10^{-6} (2) 0.20×10^{-6} (3) 0.80×10^{-6} (4) 0.16×10^{-6}

Solution:

We know $I = neAv_d$ where $v_d \rightarrow$ drift velocity

$n \rightarrow$ no. density of electron.

Total no. of electron $N = nA\ell$

Total momentum (P) of electron $= Nmv_d$

or $P = (nA\ell m) \times \frac{I}{neA} = \frac{I\ell m}{e} \quad \Rightarrow \quad P = \frac{70\times1000\times9.3\times10^{-31}}{1.6\times10^{-19}} = 0.40\mu$ Ns

Example 11:

Find the resistivity of a metal carrying an electric field E = 10 V/m causing a current density $J = 3 \times 10^5$ A/m^2.

Solution:

$$\rho = \frac{E}{J} = \frac{10}{3\times10^5} = 3.33 \times 10^{-5} \text{ ohm-m}$$

Example 12:

An electric field $E = 5 \times 10^{-3}$ V/m sets a current i = 1 amp along a wire of radius = 10^{-3} m. Find τ. (no. density of $e^- = 3\times10^{28}/m^3$)

Solution:

$$\sigma = \frac{J}{E} = \frac{[1/\pi(10^{-3})^2]}{5\times10^{-3}} = 0.064 \times 10^9\ (\Omega\text{-m})^{-1}$$

$$\text{Then } \tau = \frac{m\sigma}{ne^2} = \frac{(9.1\times10^{-31})(0.064\times10^9)}{(3\times10^{28})(1.6\times10^{-19})^2} = 7.5 \times 10^{-14} \text{ s}$$

Example 13:

What are the possible paths of free electrons inside a conductor ?

Solution:

In the absence of electric field inside conductor, Free electrons are unaccelerated, so their path between consecutive collisions is straight line.

In the presence of electric field inside conductor, free electrons are accelerated so their path is generally curved. (zigzag path)

Example 14:

The number density of electrons in copper is $8.5 \times 10^{28}\ m^{-3}$. Find the current flowing through a copper wire of length 0.2 m, area of cross section $1mm^2$, when connected to a battery of 3V. Given that electron mobility = $4.5 \times 10^{-6} m^2\ V^{-1}s^{-1}$ and charge on electron = 1.6×10^{-19} C.

Solution:

Here, V = 3 volt; ℓ = 0.2 m; A = 1 mm^2 = $10^{-6}\ m^2$; n = $8.5 \times 10^{28}\ m^{-3}$; μ = $4.5 \times 10^{-6}\ m^2V^{-1}s^{-1}$ and e = 1.6×10^{-19}C

The electric field set up across the conductor, $E = \frac{V}{\ell} = \frac{3}{0.2} = 15\ Vm^{-1}$

Now, the current through the wire,

$I = n\ A\ \mu\ E\ e \quad = 8.5 \times 10^{28} \times 10^{-6} \times 4.5 \times 10^{-6} \times 15 \times 1.6 \times 10^{-19} \qquad = 0.92\ A$

Concept Builder-1

Q.1 10^6 positrons are flowing normally through an area in forward direction and same amount of electrons are flowing in backward direction in the interval of 10 ms. find the current through the area.

Q.2 An electron moves in a circle of radius 10 cm with a constant speed of 4×10^6 m/s find the electric current at a point on the circle.

Q.3 A current of 1.8 A flows through a wire of area of cross-section 0.5 mm^2. Find the current density in the wire.

Q.4 The diameter of a copper wire is 2mm. If a steady current of 6.25 A is caused by $8.5 \times 10^{28}\ /m^3$ electrons flowing through it. The drift velocity of conduction electrons will be –

Q.5 The total momentum of electrons in a straight wire of length ℓ = 500 m carrying a current I = 90A, will be – (in Ns)

Q.6 Mobility of free electrons in a current carrying conductor is proportional to ?

(1) V_d (2) $\frac{1}{V_d}$ (3) J (4) ρ

5. Electrical Resistance

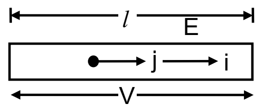
It is the property of any conductor by the virtue of which each electron requires an external electric field to move with a drift speed (corresponding to the applied electric field) against the electron cloud and metallic kernels (lattice atoms and ions). It means that some work must be done by an external agent in pushing an electron with a constant drift speed v_d along the wire (conductor). In other words, a potential is dropped along the conductor in the direction of the electric current.

In short, the resistance is the property of conductor which produces hinderance to the current flow, causing the potential drop across the conductor.

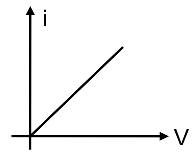
5.1 Ohm's law

It is experimentally verified that the potential drop (voltage) V is directly proportional to the current i flowing through the conductor

$V \propto i$



The potential drop along the wire is $V = iR$



For Ohmic resistance the slope of i – V graph, di / dV, is constant

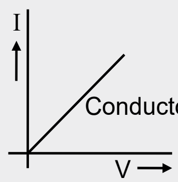
Hence, $\frac{V}{i}$ = constant which is defined as the resistance of a conductor denoted by R.

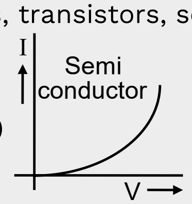
or $\frac{V}{i} = R$

The above relation holds good upon certain temperature for some conductors.

Key Points

- Unit of resistance R: ohm(Ω)
  1 ohm = 1 volt /1 ampere
- Dimension of resistance R: $[M^1L^2T^{-3}A^{-2}]$
- This is true for metallic conductors only which have free electrons
- The law is not applicable for ionized gases, transistors, semi–conductors etc.

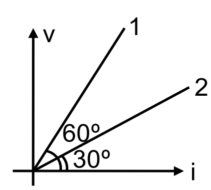
(i) 

(ii) 

Example 15:

Find the ratio of the resistances of the conductors 1 and 2.

Solution:



$R_1 = \left(\frac{V}{i}\right)_1$ = tan 60°

$R_2 = \left(\frac{V}{i}\right)_2$ = tan 30°

Hence, $\frac{R_1}{R_2} = \frac{\tan 60º}{\tan 30º} = \frac{\sqrt{3}}{1/\sqrt{3}} = 3$

Example 16:

In a wire of length 4m and diameter 6mm, a current of 120 ampere is passed. The potential difference across the wire is found to be 80 volt. The resistance of wire will be –

(1) 0.15 ohm (2) 0.25 ohm (3) 0.667 ohm (4) none

Solution:

From the definition of resistance

$R = \frac{V}{I} = \frac{80}{120} = 0.667\ \Omega$

Example 17:

Is the formula V = iR true for non–ohmic resistance also ?

Solution:

Yes, this formula defines resistance and not ohm's law.

6. Dependence of Resistance

Resistance of conductor does not depend upon the current i flowing through it and the potential difference (P.D.) along the conductor. However, it depends upon

(a) length i.e. $R \propto \ell$ (b) area i.e. $R \propto \frac{1}{A}$

(c) resistivity i.e. $R \propto \rho$

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

where ρ = resistivity of the conductor

R is in Ohm(Ω)

- Unit of ρ is Ω–m
- Dimension of ρ is $[M^1 L^3 T^{-3} A^2]$
- Inverse of resistivity is called conductivity (σ) of the material $\sigma = \frac{1}{\rho}$ (unit : mho m^{-1})
- Inverse of resistance is called conductance (G) $G = \frac{1}{R}$ (unit : mho)
- Resistivity is also defined as the ratio of the intensity of the electric field E at any point within the conductor and the current density J at that point

$$\rho = \frac{E}{J} \quad \text{or} \quad J \propto E$$

Key Points

- Resistivity is characteristic property of the material of the conductor. It does not depend upon length, area etc. of the conductor. Although it depends on temperature. It increases with increase in temperature.
- Value of resistivity is least for conductors and high for insulators.
- $\rho_{alloy} > \rho_{semiconductor} > \rho_{conductor}$

Effect of Stretching a Wire on Its Resistance

- If the length of wire is changed, then $\frac{R_1}{R_2} = \frac{\ell_1^2}{\ell_2^2}$
- If the radius of wire is changed, then $\frac{R_1}{R_2} = \frac{r_2^4}{r_2^4}$
- If the area of wire is changed, then $\frac{R_1}{R_2} = \frac{A_2^2}{A_1^2}$
- If x% change is brought in length of a wire, it's resistance will change by 2x%. This is true for x < 5% only.
- If a conductor is stretched such that it's radius is reduced to $1/n^{th}$ of it's original values, then resistance will increases n^4 times similarly resistance will decrease n^4 times if radius is increased n times by contraction.
- Keeping volume of the conductor constant, its resistance $R = \rho\frac{L}{A} = \rho\frac{LA}{A^2} = \frac{\rho V}{A^2} = \frac{\rho m}{A^2 d}$

  Where m = mass and d = density of material

Example 18:

Resistance of a conductor of length ℓ and area of cross section A is R. If its length is doubled and area of cross section is halved then find its new resistance.

Solution:

Initial length = ℓ, Area = A

So, initial resistance R = $\rho\frac{l}{A}$

Final length ℓ' = 2ℓ, Area A' = $\frac{A}{2}$

New resistance R'= $\rho\frac{\ell'}{A'} = \rho\frac{2\ell}{\left(\frac{A}{2}\right)} = 4\rho\frac{\ell}{A}$ = 4R

Concept Builder-2

Q.1 A potential difference of 200 volt is maintained across a conductor of resistance 100 ohm. Calculate the number of electrons flowing through it in one second. Charge on electron, e = 1.6 × 10^{-19} C.

Q.2 In a wire of length 8m and diameter 3mm, a current of 10 ampere is passed. The potential difference across the wire is found to be 6 volt. The resistance of wire will be–

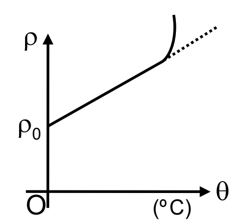
Q.3 Resistivity of a conductor of length ℓ and area of cross section A is ρ. If its length is doubled and area of cross section is halved, then its new resistivity will be

Q.4 A wire of resistance 5 ohm is drawn out so that its length is increased to twice its original length. Calculate its new resistance.

Q.5 A given piece of wire length ℓ, cross sectional area A and resistance R is stretched uniformly to a wire of length 2ℓ. What will be the new resistance.

7. Temperature Dependence of Resistance

If the temperature of a conductor increases, the atoms of the lattice vibrate with more amplitude and velocities. Furthermore, the conduction electron move with greater speeds.



$\rho = \rho_0(1+\alpha\theta)$upto certain temperature

Since $\sigma \propto \tau\left(\frac{\lambda}{\bar{v}}\right)$ and $\bar{v}$ increases with temperature we can say that σ decreases or ρ increases with temperature hence the rate of collision of the conduction electrons with the lattice sites increases. It means that the resistivity of the conductor increases.

- It is experimentally verified that the resistivity of a conductor varies linearly with temperature upto certain temperature. If ρ_0 = resistivity at 0°C, the resistivity at θ°C is given as

  $\rho_\theta = \rho_0\,(1+\alpha\theta)$

  where α = temperature coefficient of resistivity given as

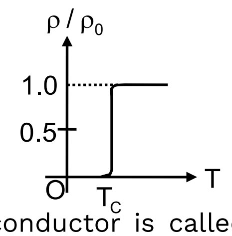
  $\alpha = \frac{\rho_\theta - \rho_0}{\rho_0\theta}$ and its unit is K^{-1} or $°C^{-1}$.

  In differential form, $\boxed{\alpha = \frac{d\rho}{\rho d\theta}}$

Then, resistance R_θ at any temperature θ can be given as $R_\theta = R_0(1 + \alpha\theta)$ where R_0 = resistance At 0°C and α = average temperature coefficient of resistance.

- The alloys have very small value of α. Hence, their resistance does not change appreciably with increase or decrease in temperature. Therefore, the alloys can be used for making resistances of constant value.

7.1 Superconductivity



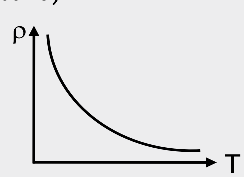
At a very low temperature, the resistivity of a metal is considerably lesser than that at room temperature. Some metal lose their resistances completely at temperature near 0 K (absolute zero). This property of a conductor is called super conductivity and the material is called "super-conductor". The temperature at which a material becomes superconductor is called critical temperature T_C.

- A superconducting ring can retain electric currents of hundreds of amperes for a year without any external source.

Key Points

- $R_2 = R_1 [1 + \alpha (t_2 - t_1)]$. This formula gives an approximate value.
- Resistance of the conductor decreases linearly with decrease in temperature and becomes zero at a specific temperature. This temperature is called critical or transition temperature, at this temperature conductor becomes a superconductor.
- There is no loss of energy in a circuit formed by superconductors. Current passed in loop formed by superconductor will continue flowing for infinite time if there is no resistance in the loop.
- Resistivity of a material is found to depend on the temperature. In conductors

  resistivity $\rho = \dfrac{m}{ne^2\tau}$, where $\rho \propto \dfrac{1}{n}$ and $\rho \propto \dfrac{1}{\tau}$.
- When the temperature of conductor increases, average speed of free electrons increases. As a result collision frequency increases or relaxation time decreases. In metals n is not dependent on temperature to any appreciable extent and ρ increases with rise in temperature.
- For semiconductors, α is negative as their resistivity decreases with rise in temperature (n increases with rise in temperature)



Temperature dependence of resistivity ρ of a semiconductor is as shown in figure.

8. Colour Coding of Resistors

Commercially produced resistors are of two major types

(a) Wire bound resistors (b) Carbon resistors

Wire bound resistors are made by winding wires of an alloy i.e. manganin, constantan nichrome etc. These wire are chosen because their resistivities are relatively insensitive to temperature. These resistances are in the range of a fraction of an ohm to a few hundred ohm.

Resistors of range higher than wire bound resistors are mostly made of carbon. Carbon resistors are small, compact and less expensive, so are used widely in electronic circuits. Their resistances are measured from their colour code.

Colour	Number	Multiplier	Tolerance(%)
Black	0	1	
Brown	1	10^1	
Red	2	10^2	
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
No colour			20

A carbon resistor has a set of coaxial coloured rings in them, whose significance are listed in above table.

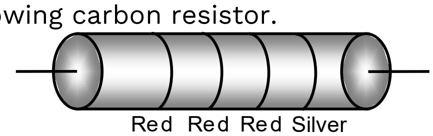
First two bands: First two digits of the resistance in ohm.

Third band: Decimal multiplier as shown in table.

Last band: Tolerance or possible variation in percentage as per the indicated value. For gold ±5%, for silver +10% and no colour ±20%

Example 19:

Find the resistance of following carbon resistor.



Solution:

First two bands = Red and Red So, first two significant figures of the resistance = 22

Third band = Red

So decimal multiplier = 10^2

Last band = silver

So tolerance = ±10%

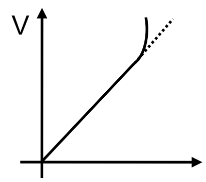
$\therefore$ R = $(22 \times 10^2)\Omega \pm 10\%$

9. Limitations of Ohm's Law

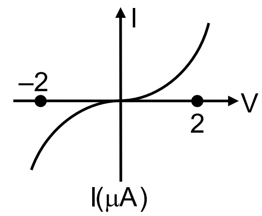
The proportionality of V and l does not hold for certain materials and devices used in electric circuits.

Following are few types of deviations.

(i) V ceases to be proportional to I for a good conductor

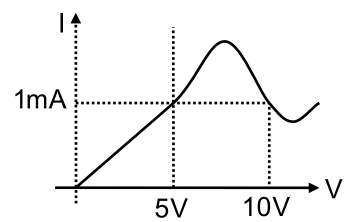


(ii) Value of current is different for same potential difference on reversing the direction of V in semiconductors



Characteristic curve of diode

(iii) Value of potential is different for same current



Variation of current v/s voltage for GaAs

10. Combination of Resistors

10.1 Series Combination

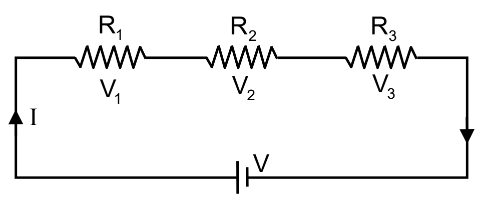
The combination of resistors will be termed as series, if same amount of current is flowing through the resistors.

$V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$

Sum of the voltages across resistances is equal to the voltage applied across the circuit i.e.

$V = V_1 + V_2 + V_3 \Rightarrow V = IR_1 + IR_2 + IR_3$

$$\frac{V}{I} = R_1 + R_2 + R_3 = R$$



Where, R = equivalent resistance

In series combination, the potential drop across the circuit is divided in the ratio of resistance

i.e. $V_1 : V_2 : V_3 = R_1 : R_2 : R_3$ & $V_1 + V_2 + V_3 = V$

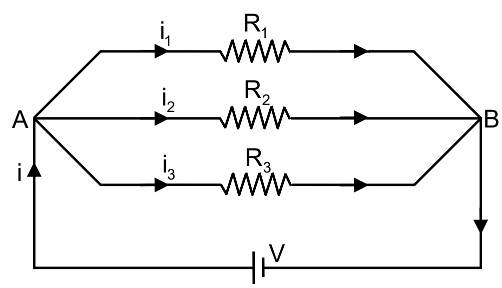
so $V_1 = \frac{R_1}{R_1 + R_2 + R_3} V$; $V_2 = \frac{R_2}{R_1 + R_2 + R_3} V$ & $V_3 = \frac{R_3}{R_1 + R_2 + R_3} V$

10.2 Parallel Combination

"Resistors will be parallel if the potential drop across them is same"

Current in each resistance is inversely proportional to the value of resistance i.e.

$$i_1 = \frac{V}{R_1}, \; i_2 = \frac{V}{R_2}, \; i_3 = \frac{V}{R_3}$$



Current flowing in the circuit is sum of the currents in individual resistances i.e.

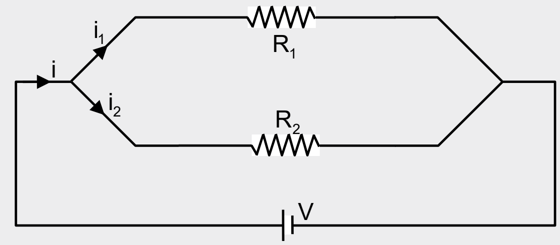
$$i = i_1 + i_2 + i_3 \Rightarrow i = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{i}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \Rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad \left(\because \frac{i}{V} = \frac{1}{R}\right)$$

where R = equivalent resistance

Key Points

- There is same drop of potential across each resistance.
  (i) The equivalent resistance of parallel combination is lower than the value of lowest resistance in the combination.
  (ii) For a parallel combination of two resistances



$$i = i_1 + i_2 = \frac{V(R_1 + R_2)}{R_1R_2} \; ; \; R = \frac{R_1R_2}{R_1 + R_2}$$

If N identical resistances (i.e. each R) are connected

(i) in series, their equivalent resistance will be $R_s = nR$

(ii) in parallel, their equivalent resistance will be $R_p = R/n$

(iii) $\frac{R_s}{R_p} = n^2$

Example 20:

Two resistances 12Ω and 4Ω are supplied to you. Find the maximum and minimum resistance that can be achieved by using them.

Solution:

$R_1 = 12\Omega$, $R_2 = 4\ \Omega$

Maximum resistance is obtained, when they are used in series

$R_S = R_1 + R_2 = (12 + 4)\Omega = 16\Omega$

Minimum resistance is obtained when they are in parallel

$$R_P = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{12} + \frac{1}{4}\right)^{-1} = \frac{48}{16} = 3\Omega$$

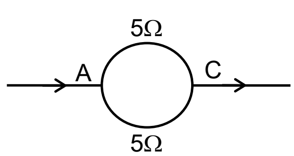
Example 21:

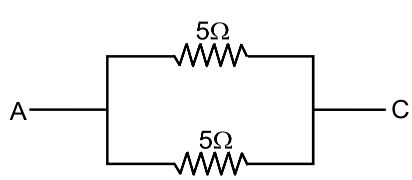
A wire of resistance 10 Ω is bent to form a complete circle. It's resistance between two diametrically opposite points will be (in Ω)

(1) 3.5 (2) 5 (3) 2.5 (4) 1.5

Solution:

The configuration is similar to

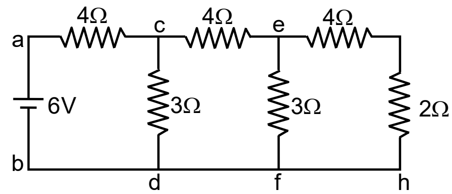




Hence, equivalent resistance$= \frac{5 \times 5}{5 + 5}\Omega = 2.5\Omega$

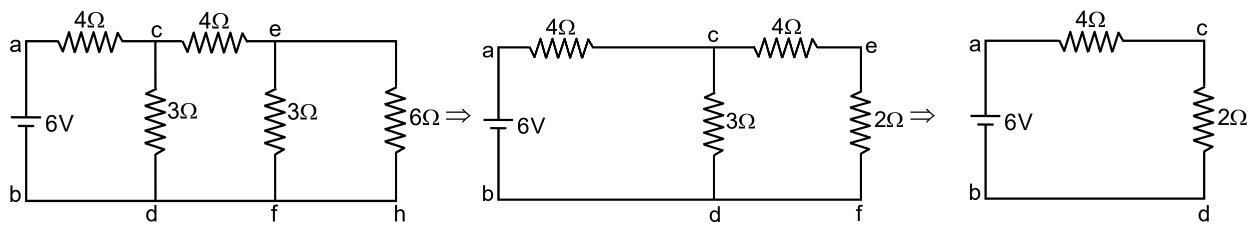
Example 22:

Find the equivalent resistance and current supplied by the battery in the diagram shown –



Solution:

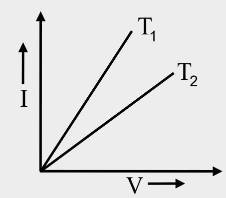
Solving the circuit one by one as follows.



Hence current supplied by the battery = $\dfrac{6V}{6\Omega}$ = 1 A

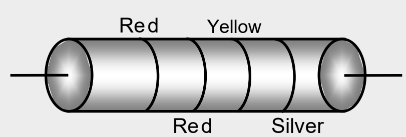
Concept Builder-3

Q.1 The current voltage graph for a given metallic wire at two different temperatures T_1 and T_2 are shown in fig. Which is true –



(1) $T_1 = T_2$ (2) $T_1 > T_2$ (3) $T_1 < T_2$ (4) None

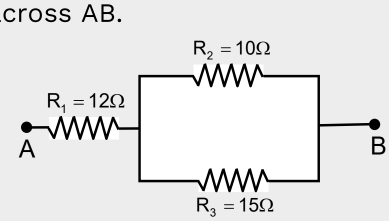
Q.2 Find the resistance of following carbon resistor.



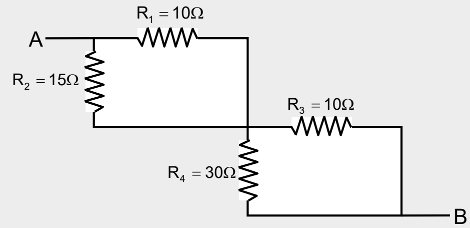
Q.3 How will you represent a resistance of 3700Ω ±10% by colour code ?

Q.4 Resistance R, 2R, 4R, 8R..................... ∞ are connected in parallel. What will be their equivalent resistance ?

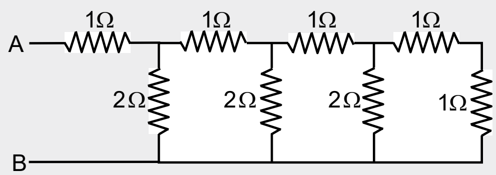
Q.5 Find the resistance across AB.



Q.6 Find the resistance across AB.



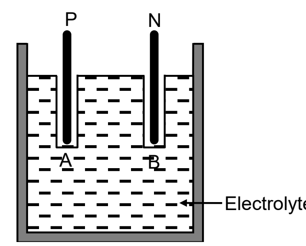
Q.7 What will be the resultant resistance between the points A and B in the following diagram ?



11. Cell : EMF, Internal Resistance & Terminal Voltage

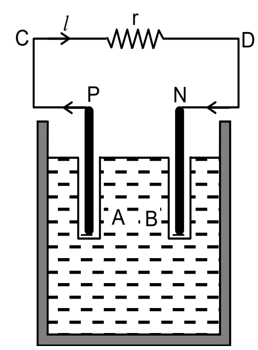
11.1 Cell & Battery

An electrolytic cell consists of two electrodes, called anode (P) and cathode (N) immersed in an electrolyte solution as shown in figure.



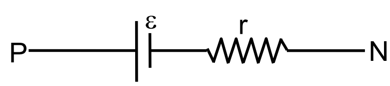
Electrodes exchange charges with the electrolyte.

Battery can be considered as combination of multiple cells



When there is no current, the electrolyte is at same potential throughout, so the potential difference between P and N is known as electromotive force (emf) of the cell and denoted by ε. emf is a potential difference not a force. When a resistance R is connected across the cell as shown in figure, a current I flows from C to D. A steady current flows from P to N through the resistance R and flows from N to P through the electrolyte. the electrolyte through which current passes has a finite resistance r known as internal resistance of the cell.

A cell can be represented as



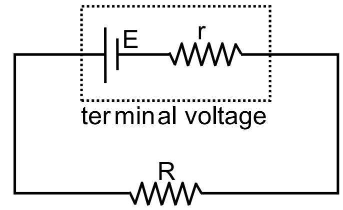
11.2 Parameter of Cell:

(a) Electro Motive Force (EMF)

The energy given by the cell in the flow of unit charge in the whole circuit (including the cell) is called the EMF of the cell. The potential difference across the terminals of a cell when it is not giving any current is called EMF of the cell. $E = \dfrac{W}{Q}$

- emf depends on:
  (i) nature of electrolyte
  (ii) metal of electrodes
- emf does not depend on:
  (i) area of plates
  (ii) distance between the electrodes
  (iii) quantity of electrolyte
  (iv) size of cell

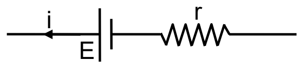
(b) Terminal Voltage (V)



- When current is drawn through the cell or current is supplied to cell then, the potential difference across its terminals is called terminal voltage.

  When i current is drawn from cell, then terminal voltage is less than it's emf E.

  V = E – i r



  Where V = terminal voltage, r = internal resistance of battery

- When current is supplied to the cell, the terminal voltage is greater than the emf E i.e. V = E + i r
- Units of both emf and terminal voltage are volt.

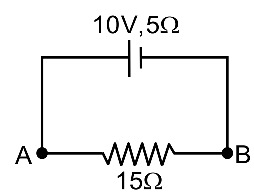
(c) Internal Resistance (r)

The resistance offered by the electrolyte of the cell to the flow of current through it is called internal resistance of the cell.

- Distance between two electrodes ↑ r ↑
- Area dipped in electrolyte ↑ r ↓
- Concentration of electrolyte ↑ r ↓
- Temperature ↑ r ↓

Example 23:

A cell of emf 10 V and internal resistance 5Ω is connected across a resistance 15Ω. Find potential difference across AB.



Solution:

Above circuit can be redrawn as Current I through R is from A to B.

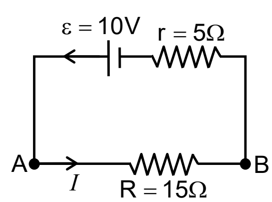
Network is simple series network.

Total resistance = R + r = (15 + 5) Ω = 20Ω

Current $I = \frac{\varepsilon}{R+r} = \frac{10V}{20\Omega} = 0.5$ A

Potential difference across AB

$V_A - V_B = IR = (0.5 \text{ A}) \times 15\Omega = 7.5$ V



Example 24:

What is the relationship between potential difference acros the terminals of a cell and emf of the cell ?

Solution:

When the cell is discharging then potential difference across its terminals is less than emf i.e. $V = \varepsilon - Ir$.

When the cell is being charged by passing current l through it, potential difference across its terminals is more than emf i.e. $V = \varepsilon + Ir$.

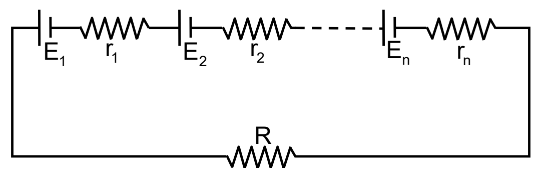
11.3 Combination of Cell:

(a) Series Combination

When the cells are connected in series the total e.m.f. of the series combination is equal to the sum of the e.m.f.'s of the individual cells and internal resistance of the cell also come in series. Equivalent internal resistance

$r = r_1 + r_2 + r_3 + \ldots$

Equivalent emf $E = E_1 + E_2 + E_3 + \ldots$



Current $I = \dfrac{E_{net}}{r_{net} + R}$

If all n cells are identical then $I = \dfrac{nE}{nr + R}$

- If $nr >> R$, $I = \dfrac{E}{r}$
- If $nr << R$, $I = \dfrac{nE}{R}$

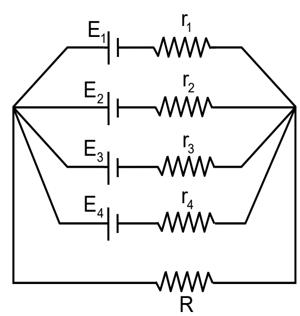
(b) Parallel Combination

When the cells are connected in parallel, the cells can be replaced with a single cell of emf E_{net} & internal resistance r_{net}.

Internal resistance is

$$\frac{1}{r_{net}} = \frac{1}{r_1} + \frac{1}{r_2} + \ldots.$$

and $E_{net} = \dfrac{\dfrac{E_1}{r_1} + \dfrac{E_2}{r_2} + \ldots..}{\dfrac{1}{r_1} + \dfrac{1}{r_2} + \ldots..}$



If m identical cell connected in parallel then total internal resistance of this combination

$r_{net} = \dfrac{r}{m}$

Total e.m.f. of this combination $E_T = E$

Current in the circuit

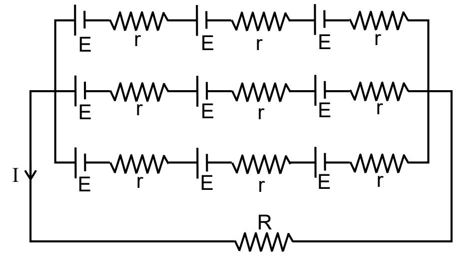
$$I = \frac{E_T}{R + \frac{r}{m}} = \frac{E}{R + \frac{r}{m}} = \frac{mE}{mR + r}$$

If $r << mR$; $I = \dfrac{E}{R}$

If $r >> mR$; $I = \dfrac{mE}{r}$ = m x (current from one cell)

(c) Mixed Combination

Total number of identical cells in this circuit is nm. If n cells connected in series and their are m such branches in the circuit.



The internal resistance of the cells connected in a row = nr

Total internal resistance of the circuit $r_{net} = \frac{nr}{m}$

($\because$ There are such m rows)

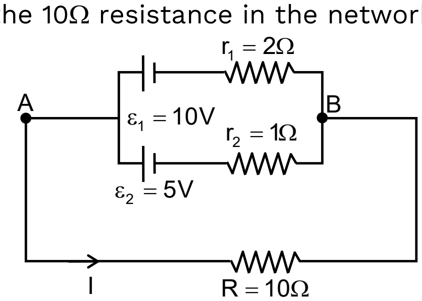
Total e.m.f. of the circuit = total e.m.f. of the cells connected in a row i.e. E_T or $E_{net} = nE$

$$I = \frac{E_{net}}{R + r_{net}} = \frac{nE}{R + \frac{nr}{m}}$$

Current in the circuit is maximum when external resistance in the circuit is equal to the total internal resistance of the cells $R = \frac{nr}{m}$

Example 25:

Find the current I through the 10Ω resistance in the network shown in figure.

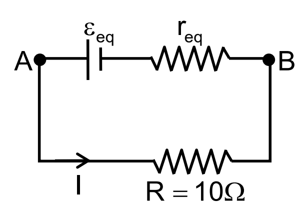


Solution:

Across A and B two cells are used in parallel so above circuit can be redrawn as

$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} = \frac{10 \times 1 + 5 \times 2}{1 + 2} = \frac{20}{3} V$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2} = \frac{1 \times 2}{1 + 2} = \frac{2}{3}\Omega$$

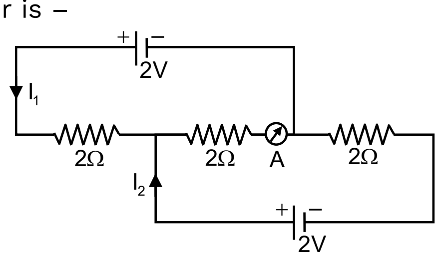


current through R

$$I = \frac{\varepsilon_{eq}}{R + r_{eq}} = \frac{\frac{20}{3}}{10 + \frac{2}{3}} = \frac{20}{32} A = \frac{5}{8} A$$

Example 26:

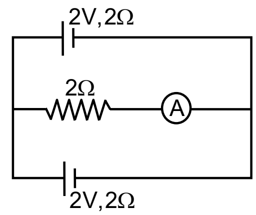
The reading in the ammeter is –



(1) 1 A (2) 2 A (3) 0.67 A (4) 1.5 A

Solution:

The circuit can be redrawn as



so the current flowing through the load will be (as based on parallel combination of cells)

$$I = \frac{E_r}{R + \frac{r}{m}} = \frac{E}{R + \frac{r}{m}} = \frac{2}{2 + \frac{2}{2}} = 0.67 \text{ Amp}$$

12. Kirchhoff's Rule

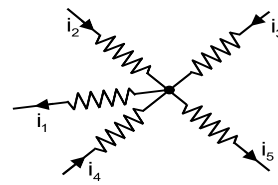
Kirchhoff in 1842 gave two laws for solving complicated electrical circuits. These laws are as follows–

12.1 First Law

In an electrical circuit, the algebraic sum of the current meeting at any junction in the circuit is zero.

OR

Sum of the currents entering the junction is equal to sum of the currents leaving the junction



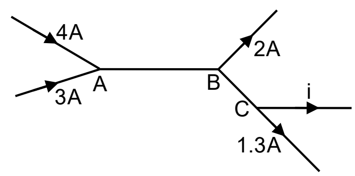
$\Rightarrow \quad \Sigma i = 0$

$i_1 - i_2 - i_3 - i_4 + i_5 = 0$ or $i_1 + i_5 = i_2 + i_3 + i_4$

This law is based on law of conservation of charge. In other words, when a steady current flows in a circuit then their is neither accumulation of charge at point in the circuit nor any charge is removed from there.

Example 27:

The value of current i in the following circuit is.



(1) 2.7 A (2) 3.7 A

(3) 3 A (4) 4A

Solution:

$i = ((4 + 3) - 2 - 1.3) = 3.7$ A

12.2 Second Law

In a 'closed' mesh of a circuit the algebraic sum of the products of the current and the resistance in each part of the mesh is equal to the algebraic sum of the e.m.f.'s in that mesh.

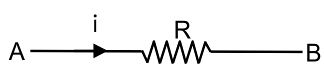
i.e. $\Sigma iR = \Sigma E$

Important notes

(i) In applying this law, when we traverse in the direction of current then the product of the current and the corresponding resistance is taken as positive, and the emf is taken as positive when we traverse from the negative to the positive electrode of the cell through the electrolyte.

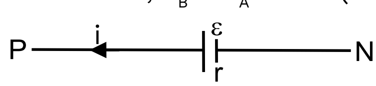
(ii) This law is based on 'law of conservation of energy'.

12.3 Sign Conventions



If the current is flowing through the resistance R from A to B, then potential difference across AB is $V_A - V_B = iR$ (i is determined to be positive).

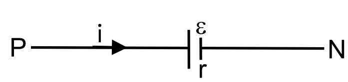
Similarly potential difference across BA is, $V_B - V_A = -iR$ (i is determined to be negative).



then, potential difference across the cell

$V = V_P - V_N = \varepsilon - ir$

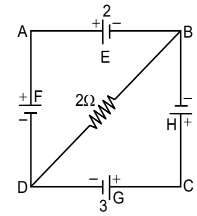
If the current is flowing from P to N



then $V = V_P - V_N = \varepsilon + ir$

Example 28:

In the circuit shown in fig. E, F, G and H are cells of emf 2, 1, 3 and 1 volts and their internal resistances are 2, 1, 3 and 1 ohm respectively. Calculate -



(i) the potential difference between B and D

(ii) the potential difference across the terminals of each of the cells G and H.

Solution:

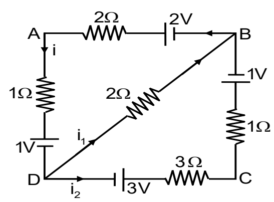
Applying Kirchhoff's first law at point D,

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

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

$2i + i + 2i_1 = 2 - 1 = 1$

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



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

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

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

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

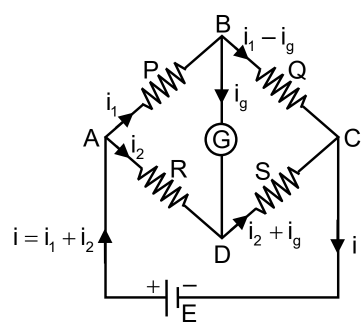
$i_1 = \frac{1}{13}$ A, $i_2 = \frac{6}{13}$ A and $i = \frac{5}{13}$ A

(i) p.d. between B and D $= 2i_1 = 2\left(\frac{1}{13}\right)$ V

(ii) p.d. across G $= E - i_2 R = 3 - \frac{6 \times 3}{13} = 1.61$ V

p.d. across H $= 1 - \left(\frac{-6}{13}\right)(1) = 1.46$ V

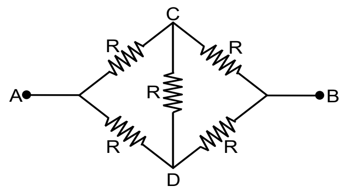
13. Wheat Stone Bridge

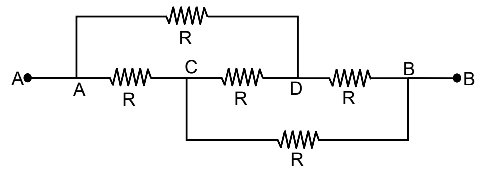


- The configuration in the adjacent figure is called wheat stone bridge.
- If $i_g = 0$ i.e. current in galvanometer is zero, then bridge is said to be balanced.
- For $i_g = 0$ (i) $V_D = V_B$ (ii) $\frac{P}{Q} = \frac{R}{S}$
- Equivalent resistance in balanced condition $= \frac{(P+Q)(R+S)}{P+Q+R+S}$
- If $\frac{P}{Q} < \frac{R}{S}$ then $V_B > V_D$ and current will flow from B to D.
- If $\frac{P}{Q} > \frac{R}{S}$, then $V_B < V_D$ and current will flow from D to B.
- Meter bridge and post office box work on this principle.

Example 29:

In the following figures, the resistance between A and B will respectively be –





(1) R/2, R (2) 2R, R (3) R, R (4) 3R, R

Solution:

This is a balanced bridge (P/Q = R/S)
For this bridge, we can ignore the resistor between b and d.
Hence both the above fig can be put as fig (iii).
Equivalent resistance in balanced condition

$$= R_{AB} = \frac{2R \times 2R}{2R + 2R} = R$$

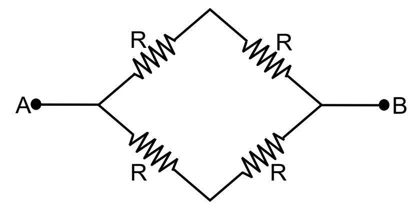
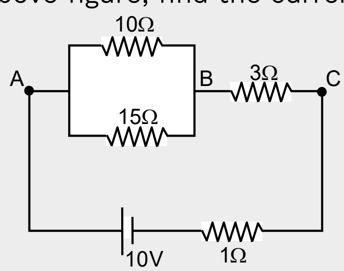


Fig. (iii)

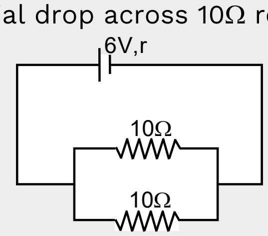
Concept Builder-4

Q.1 In the network shown in the above figure, find the current through 3Ω and 10Ω resistances.



Q.2 A battery of emf 6 volts and internal resistance 0.4Ω is being charged. The potential difference between terminal of the battery is 7 V, then what is the current supplied to the battery ?

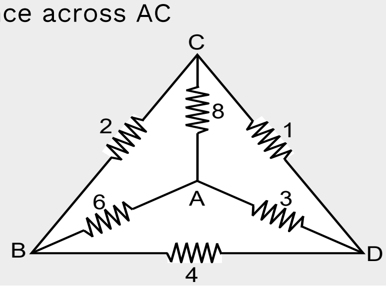
Q.3 Calculate the value of r if potential drop across 10Ω resistance is 4V.



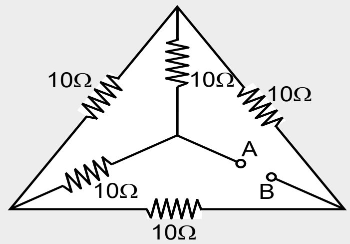
Q.4 Kirchhoff's first and second laws respectively show the conservation of

(1) Charge and energy (2) Energy and charge
(3) Mass and charge (4) Charge and mass

Q.5 Calculate equivalent resistance across AC



Q.6 In the adjoining network of resistors, each is of resistance 10 ohm, the equivalent resistance between points A and B is –



14. Shorting / Equipotential Points

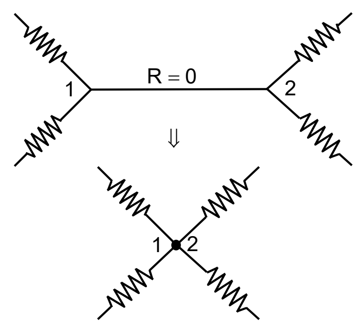
Equipotential Points

In a current carrying electrical network, two points are said to be equipotential if they are at same potential. Between the points 1 and 2,

if $\Delta V = iR = 0$.

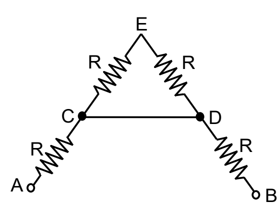
$\Delta V = 0$

$V_1 = V_2$ (equipotential)



Then we have two cases, if $R = 0$, $\Delta V = 0$ ($i \neq 0$) and if $i = 0$ (R is finite) $\Delta V = 0$. The first case tells that when we connect any two points by an ideal conductor, the potential difference between them becomes zero. It is called "short circuiting". The second case tells that, if we connect any two points by a non-zero resistor and find no current along the resistor, we can call these points equipotential. After finding equipotential points join them to a single point to simplify the given circuit.

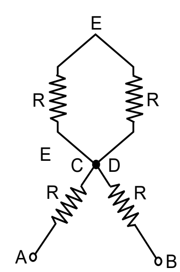
Example 30: Find R_{AB}.



Solution:

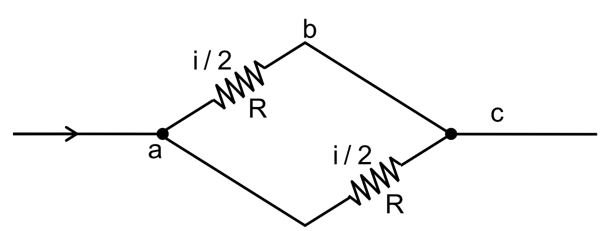
Since C and D are connected with a zero resistor they are equipotential. Then superimpose C and D to obtain the simplified circuit as shown. Since no current flows in the branches CE and ED,

hence $R_{AB} = R + R = 2R$



15. Electric Symmetry

If the branches ab and ac have same resistances, and same current, same potential will be dropped along them. hence the branches ab and ac are electrically symmetrical. In this case, case, the points b and c are equipotential points. Then you can join these points



16. Earthing of a Circuit Point

If any Node/junction of the circuit is earthed, the potential of that node/junction becomes zero. i.e. the same node/junction becomes the reference potential.

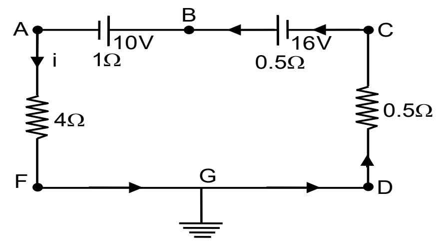
Example 31:

From the fig. determine

(i) potential at A

(ii) potential at C

(iii) reading of the voltmeter connected across the 10V battery



Solution:

The current in circuit is (consider loop (CBAFGDC)

$$I = \frac{E_2 - E_1}{r_1 + r_2 + R_1 + R_2} = \frac{16 - 10}{1 + 0.5 + 4 + 0.5} = 1A$$

(i) $V_A - V_F = IR = 4$ volt

Because $V_F = 0$(grounded), therefore $V_A = 4$ volt

(ii) $V_D - V_C = 1 \times 0.5 = 0.5$ volt

$\therefore V_D = 0$ (grounded).

So $V_C = -0.5$ volt

(iii) The 10V battery is being charged therefore

$V = E + Ir = 10 + 1 \times 1 = 11$ volt

17. Electrical Energy & Power

17.1 Electric Energy

When a potential difference is applied across a wire, current starts flowing in it. The free electrons collide with the positive ions of the metal and lose energy. Thus energy taken from the battery is dissipated. The battery constantly provide energy to continue the motion of electron and hence electric current in the circuit. This energy is given to ions of the metal during collision and thus temperature of wire rises. Thus, energy taken from the battery gets transferred in to heat. This energy is called electrical energy. This effect is also called 'Heating Effect of Current'.

If

R = Resistance of wire

I = Current in wire

V = Potential difference across wire.

Flow of charge in 'dt' time = Idt.

Energy dissipated dW = Vdq = VIdt,

$\because \quad V = IR,$

$$\therefore \quad dW = VIdt = I^2Rdt = \frac{V^2}{R}dt = Vdq \text{ (joule)}$$

This energy is equal to work done by battery or heat produced in the wire.

Joule can be converted into calorie by using

1 calorie = 4.2 Joules

17.2 Electrical Power

The rate of loss of energy in an electrical circuit is called electrical power. It is denoted by 'P'

$$P = \frac{dW}{dt} = I^2 R = IV = \frac{V^2}{R}$$

units of power = joule/sec, watt, horse power

1 watt = 1 joule/sec, 1 HP = 746 watt

unit of electrical energy = watt second, kilowatt hour

1 kilowatt hour (kwh) = 36×10^5 Joule

17.3 Power Loss in Transmission Lines

Consider a device of resistance R to be operated at voltage V and current through is I, then power of devices P = VI. If resistance of connecting wires from power station to the device, then

$$P_c = I^2R_c = \frac{P^2R_c}{V^2}$$

Therefore, to drive a device of power P, the power wasted in the connecting wires

$$P_c \propto \frac{1}{V^2} \propto R_c$$

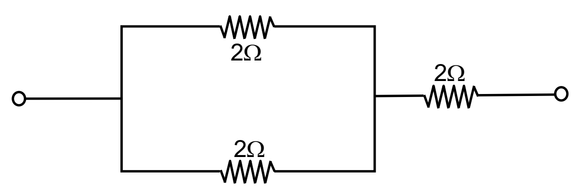
As the distance of power station is very large, R_c is considerable. So to decrease P_c, these wires carry current at enormous values of V and this is the reason for high voltage danger signs on transmission lines. These voltages are lowered to a value suitable for use by a device known as transformer.

Key Points

- **Fuse Wire :** Fuse wire is used in a circuit to control the maximum current flowing in a circuit. It is a thin wire having high resistance and is made up of a material with low melting point. Current capacity $I \propto r^{3/2}$, $I \propto \ell^0$
- House wiring circuits are in parallel therefore the voltage across each bulb is constant. The power of the bulb is given by the formula : $P = V^2/R$. For constant voltage $P \propto (1/R)$ therefore, the great the resistance, the smaller is the power.
- If we take two bulbs of 60W and 100W, then the resistance of 60W bulb will be more than the resistance of 100 W bulb.
  The filament of 60W bulb is thinner than the filament of 100 watt bulb.

Example 32:

Three resistances each of 2 ohm is joined as shown in the figure and each one can have maximum power of 18 watt (otherwise it will melt). The maximum power the whole circuit can take is



(1) 27 W (2) 9 W
(3) 81 W (4) 18 W

Solution:

Electric power expended in a wire of resistance R is $P = i^2R$

$\therefore$ maximum current in any wire of the circuit $i = \sqrt{\left(\frac{P}{R}\right)} = \sqrt{\left(\frac{18}{2}\right)} = 3A$

This circuit has two 2Ω wires in parallel and a third 2Ω wire in series with this parallel combination.

Hence the equivalent resistance of the whole circuit is $R' = \frac{2\Omega \times 2\Omega}{2\Omega + 2\Omega} + 2\Omega = 3\Omega$.

$\therefore$ maximum power expended in the whole circuit is $P_{max} = i^2 R' = (3)^2 \times 3 = 27$ watt

Example 33:

A current of 5.0 A flows through an electric press of resistance 11Ω. Calculate the energy consumed by the press in 5 minutes.

Solution:

Here I = 5.0 A; R = 11 Ω;
t = 5 min = 5 × 60 = 300 s
Electric energy consumed in 5 min
$= I^2Rt = (5.0)^2 \times 11 \times 300 = 8.25 \times 10^4$ J

18. Connection of Electrical Appliances

18.1 Rating

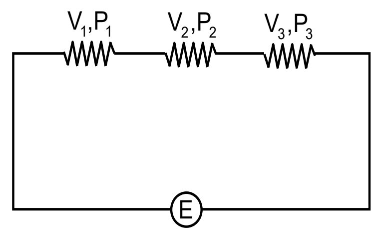
If 220V and 40W is written on an electrical instrument then this is called it's standard Ratings. It means that if 220V is applied across this instrument then 40W of power will be generated. Thus the resistance will be given by

$$R = \frac{V^2}{P} = \frac{(220)^2}{40} \text{ ohm}$$

18.2 Series Combination

- If total power dissipated if P, then

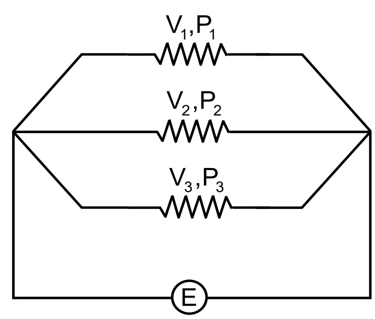
$$\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} \text{........(1)}$$



- In this combination, the bulb with least power will glow most and bulb with highest power will glow least or we can say that bulb with highest R will glow brightest and bulb with least R will glow least.

18.3 Parallel Combination

- Net power dissipation $P = P_1 + P_2 + P_{3.}$......(2)



- Bulb with least power will glow least or the bulb in which maximum current is flowing will glow brightest and vice–versa.

Note:

(1) These formulae eq. (1) & (2) are applicable only if the voltage ratings of all the instruments are equal along with the power source. If voltage ratings are different then circuit is solved by considering equivalent resistances of the instruments as follows.

(2) Replace the instrument by it's equivalent resistance. If standard rating is (V&P) then it resistance is $R = V^2/P$

(3) Find the currents and voltages in different branches using Kirchhoff's first and second laws.

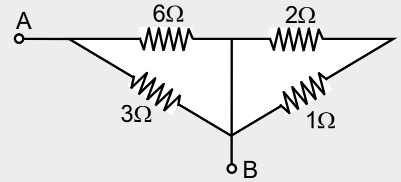
(4) If rating of a bulb is changed from (V_1,P_1) to (V_2,P_2) then $\frac{V_1^2}{P_1} = \frac{V_2^2}{P_2} = R$ or $P_2 = \frac{V_2^2}{V_1^2} P_1$

Key Points

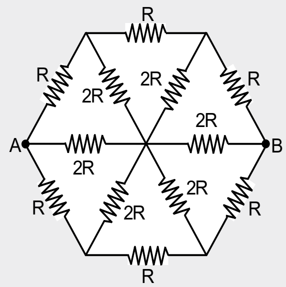
- Two identical heater coils gives total heat H_s when connected in series and H_p when connected in parallel than $H_p/H_s = 4$ [In this, it is assumed that supply voltage is same]
- If a heater boils m kg water in time T_1 and another heater boils the same water in time T_2, then both connected in series will boil the same water in time $T_s = T_1 + T_2$ and if in parallel $T_p = T_1T_2/(T_1 + T_2)$
- Instruments based on heating effect of current, works on both A.C. and D.C. Equal value of A.C. (RMS) and D.C. produces, equal heating effect. That's why brightness of bulb is same whether it is operated by A.C. or same value D.C.

Concept Builder-5

Q.1 Calculate equivalent Resistance across AB



Q.2 Find R_{AB}.



Q.3 A lamp of 100 W works at 220 volt. What is its resistance and current capacity ?

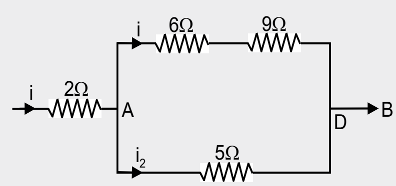
Q.4 A 220 volt 100 watt bulb is connected to a 110 volt source. The power consumed by the bulb will be

(1) 25 W (2) 20 W (3) 484 W (4) 120 W

Q.5 If heat generated in 5 ohm resistor due to current flowing in it is 45 J/s then find the rate of heat generated in 2 ohm resistor and potential different across 6 ohm resistor.

(1) 32 J/s, 6V (2) 16 J/s, 3V

(3) 8 J/s, 1V (4) 64 J/s, 12V

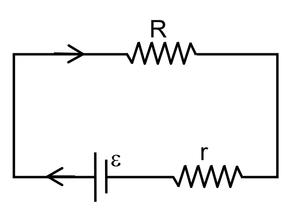


Q.6 A 60 W –200 V bulb and 100 W – 220 V bulb are connected in parallel to mains supply. Which bulb will draw more current ?

19. Power Distribution by Cell

(i) When a load resistance 'R' is connected with a battery of EMF ε & internal resistance 'r'. then

(a) Current through the load $I = \frac{\varepsilon}{R+r}$



Power delivered at the load

$P = I^2R = \frac{\varepsilon^2 R}{(R+r)^2}$

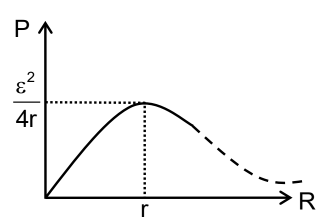
Power delivered at load is maximum, when

$\frac{dP}{dR} = 0$

Solving above equation R = r

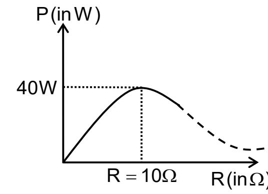
$P_{max} = \frac{\varepsilon^2 r}{(r+r)^2} = \frac{\varepsilon^2}{4r} = \frac{\varepsilon^2}{4R}$

(b) P versus R graph will be



Example 34:

The power delivered across a variable load varies with load resistor as shown. Find out its emf & internal resistance



Solution:

For maximum power delivery

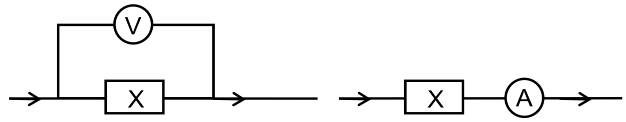
$r = R = 10\Omega$

$P_{max} = 40W = \frac{\varepsilon^2}{4r} \quad \Rightarrow \quad \varepsilon = 40\ V$

Measuring Devices

20. Current & Voltage Measurement

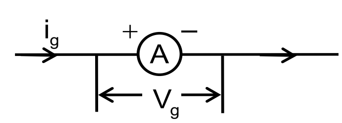
In D.C. circuits, we talked about emf, voltage, current and resistance. We measure the unknown resistance by using Ohm's law as $R = \frac{V}{I}$. The voltage across any circuit element can be measured by "voltmeter" and current along any branch can be measured by "ammeter". The emf of a cell can be measured by "potentiometer". Generally, we measure the voltage and current in a circuit element X by connecting the voltmeter and ammeter in two possible ways. The basic instrument that can be used for measuring both voltage and current is called "galvanometer". A galvanometer can be used as an ammeter and voltmeter by attaching it with a suitable resistance.



20.1 Galvanometer

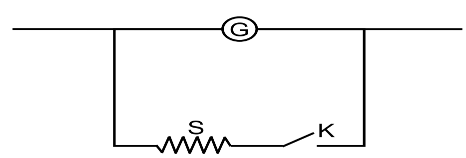
This device measures the current by means of magnetic force which will be discussed in next chapter. The maximum current that can flow through the galvanometer is current i_g (or full scale deflection) and the corresponding voltage drop across the galvanometer is V_g. Then $\frac{V_g}{i_g}$ = Galvanometric resistance = G. The deflection θ in moving coil galvanometer is directly proportional to current i flowing through it.

$i \propto \theta$; or $i = k\theta$; (k is called galvanometric constant), where $\frac{\theta}{i} = \frac{1}{k}$ is called sensitivity which is defined as the current per unit deflection.



(A) Shunt:

The small resistance connected in parallel to galvanometer coil, in order to control current flowing through the galvanometer is known as shunt.



(B) Merits of Shunt:

- To protect the galvanometer coil from burning
- It can be used to convert any galvanometer into ammeter of desired range.

(C) Demerits of Shunt:

Shunt resistance decreases the sensitivity of galvanometer.

Example 35:

If only one hundredth part of total current flowing in the circuit is to be passed through a galvanometer of resistance GΩ, Then the value of shunt resistance required will be-

(1) G/10 (2) G/100 (3) G/99 (4) G/999

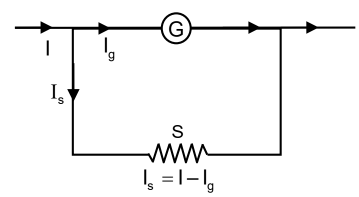
Solution:

$$S = \frac{G}{n-1} = \frac{G}{100-1} = \frac{G}{99}\,\Omega$$

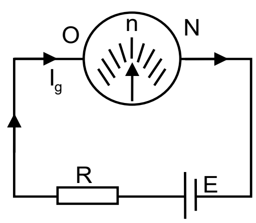
20.2 Ammeter

- Ammeter is a shunted galvanometer which is used to measure current in a circuit.
- It is always connected in series so that the entire current passes through it.
- In principle, the current in the circuit must not change when a current measuring device like ammeter is introduced in the circuit therefore, **AN IDEAL AMMETER MUST HAVE ZERO RESISTANCE.**
- However in practice, a moving coil meter has some resistance. Due to this the current in circuit is modified (reduced) when a moving coil ammeter is connected in circuit.

20.3 Conversion of Galvanometer into Ammeter



- A galvanometer can be converted into an ammeter of a given range by connecting low resistance in parallel to its coil.
- From fig. $I_g G = (I - I_g)S$ or $S = \frac{I_g G}{I - I_g}$



- Higher is the range of I of ammeter, lower is the value of S required for conversion of galvanometer into ammeter.
- Let n is the deflection (in division) in the galvanometer. Let N is the total number of division on the scale of galvanometer, then

  $I_g = \frac{E}{R+G}\left(\frac{N}{n}\right)$

  The effective resistance of the ammeter is

  $$R_A = \frac{GS}{G+S}$$

  For an IDEAL AMMETER, $R_A = 0$

Example 36:

A galvanometer has a coil of resistance of 60Ω and shows a full-scale deflection for 50 μA current. To convert this galvanometer into an ammeter of range 10 mA, required shunt resistance will be–

(1) 0.30 Ω (2) 0.20 Ω (3) 0.6 Ω (4) 0.40 Ω

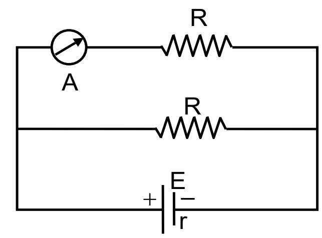
Solution:

Given $I_g = 50\ \mu A = 50 \times 10^{-6}$ A

$I = 10$ mA $= 10 \times 10^{-3}$ A, G = 60 Ω thus $S = \frac{I_g G}{I - I_g} = \frac{50\times10^{-6}\times60}{10\times10^{-3} - 50\times10^{-6}} = 0.30\ \Omega$

Example 37:

In the circuit shown below, if the value of R is increased then what will be the effect on the reading of ammeter if the internal resistance of cell is not negligible-



(1) The reading of A will decrease
(2) The reading of A will increase
(3) The reading of A will remain unchanged
(4) The reading of A will become zero.

Solution:

Current in the ammeter

$$I = \frac{ER}{r + \frac{RR'}{R+R'}} = \frac{E(R+R')R}{Rr + R'r + RR'} \qquad \Rightarrow \; I = \frac{E(R+R')}{R' + r\left[1 + \frac{R'}{R}\right]}$$

On increasing the value of R, the denominator will decrease and consequently the value of I will increase.

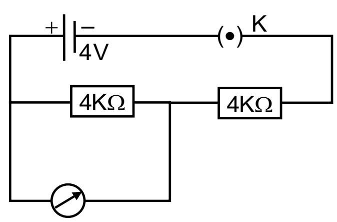
Both R & R' are connected in parallel. If R increases then current in R' increases

20.4 Voltmeter

Voltmeter is a device used to measure p.d. across two points in an electrical circuit. It is connected in parallel to these points. i.e. in parallel to the circuit.

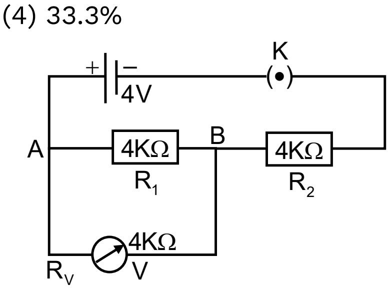
Example 38:

In the circuit shown below fig. if the resistance of voltmeter is 4KΩ, then the error in the reading of voltmeter will be-



(1) 50% (2) 68% (3) 17% (4) 33.3%

Solution:



The potential difference between A and B in the absence of voltmeter = 2 Volt.

Current flowing in the circuit

$$I = \frac{E}{R_2 + \frac{R_1 R_V}{R_1 + R_V}} \qquad I = \frac{4}{4 + \frac{4\times 4}{4+4}} = \frac{2}{3}\,A$$

⇒ Potential difference measured by voltmeter

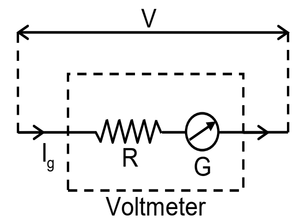
$$V'_{AB} = IR' = \frac{2}{3} \times 2 = \frac{4}{3}\,V$$

⇒ Error in the reading of voltmeter

$$= V_{AB} - V'_{AB} = 2 - \frac{4}{3} = \frac{2}{3}\,V$$

$$\Rightarrow \% \text{ error} = \frac{V_f - V_i}{V_i} \times 100 \qquad = \frac{\frac{4}{3} - 2}{2} \times 100 = -33.3\ \%$$

20.5 Conversion of Galvanometer into Voltmeter:



- A galvanometer is converted into a voltmeter by connecting a high resistance R in series with the galvanometer.
- From fig.

  $I_g (R + G) = V$ or $R = \frac{V}{I_g} - G$
- Higher is the range of V of the voltmeter, higher is the value of R required for conversion of galvanometer into voltmeter.
- The effective resistance of the voltmeter is $R_V = R + G$

  For an IDEAL VOLTMETER, $R_V = \infty$.

Example 39:

A voltmeter, an ammeter and a resistance are connected in series to an accumulator. There is a deflection in the voltmeter but the deflection in ammeter is negligible. Why?

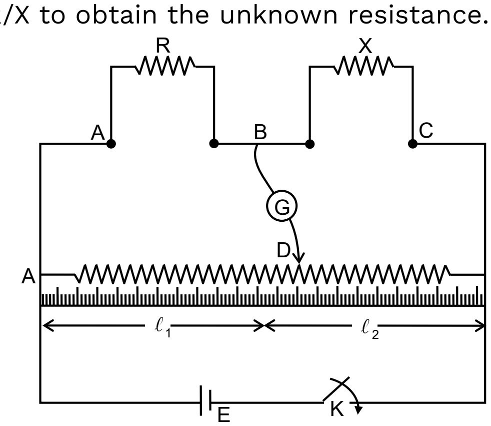
Solution:

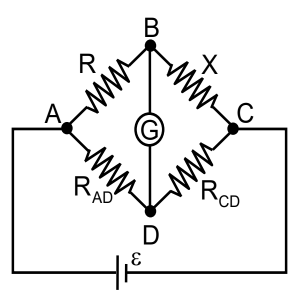
The voltmeter being in series, the resistance of the circuit becomes very high and so the current very low. This current on passing through the coil of the voltmeter produces some deflection, but in ammeter most of its part goes through the shunt of the ammeter and so the current going in the coil of the ammeter is too small to produce any deflection.

21. Meter Bridge

It is an instrument based on the balanced Wheatstone bridge to measure the unknown resistance X, say fitted between the tapping points B and C when a known resistance R is fitted between the tapping points A and B. The slider D is moved along the rheostat AC till i_g will be zero at any point D, (say).

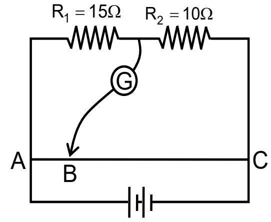
Then, $\frac{R_{AD}}{R_{DC}} = \frac{\ell_1}{\ell_2}$, where ℓ_1 and ℓ_2 are the lengths of the resistance R_{AD} and R_{DC} measured by the scale. If $\ell_1 + \ell_2 = 1$ m, $\ell_1 = y$, we have $\ell_2 = (1 - y)$. After finding the value of $\frac{\ell_1}{\ell_2}$, equate it with the ratio R/X to obtain the unknown resistance.





Example 40:

In the meter bridge shown in figure. find the length AB for null deflection in galvanometer.



Solution:

Let AB = ℓ cm then BC = $(100 - \ell)$cm

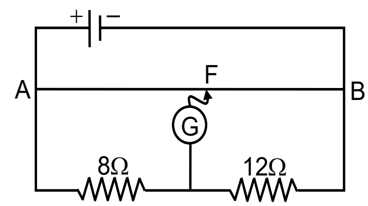
At zero deflection of galvanometer,

$$\frac{R_1}{R_2} = \frac{R_{AB}}{R_{BC}} = \frac{\ell}{100 - \ell}$$

$\Rightarrow \quad \frac{15}{10} = \frac{\ell}{100-\ell} \quad \Rightarrow \frac{3}{2} = \frac{\ell}{100-\ell}$

$\Rightarrow \quad 5\ell = 300 \quad \Rightarrow \ell = 60$ cm

Example 41:



Let the meter bridge wire AB shown in figure is 40 cm long. When the sliding contact (jockey) is pressed at F, the galvanometer shows zero (null) deflection. The balancing length AF is-

(1) 8 cm (2) 16 cm

(3) 24 cm (4) 40 cm

Solution:

For balancing point to be at F,

$\frac{\text{length AF}}{\text{length FB}} = \frac{8}{12} \quad$ or $\quad \frac{\ell}{40-\ell} = \frac{8}{12}$ or ℓ = 16cm

Concept Builder-6

Q.1 The deflection of a moving coil galvanometer falls from 60 divisions to 12 divisions when a shunt of 12Ω is connected. What is the resistance of the galvanometer

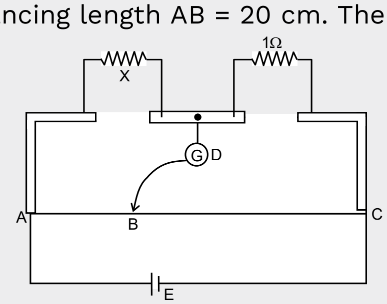
Q.2 The shunt required for 10% of main current to be sent through the moving coil galvanometer of resistance 99Ω will be-

(1) 0.9 Ω (2) 11 Ω (3) 90 Ω (4) 9.9 Ω

Q.3 What value of shunt is required to measure a current of 10.1 amp by using a galvanometer of rating $\frac{1}{10}$ amp, 6Ω ?

Q.4 A galvanometer having 30 divisions has a current sensitivity of 20 μA/divisions. It has a resistance of 25 Ω. To convert it into an ammeter measuring upto 1A and voltmeter reading upto 1 volt, the resistances required will be respectively–

Q.5 In the metre bridge, the balancing length AB = 20 cm. The unknown resistance X is equal to

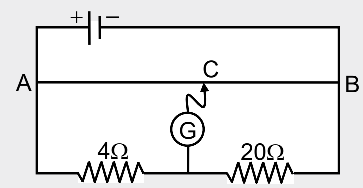


Q.6 An unknown resistance R_1 is connected in series with 10Ω. When the combination is connected to left gap of a meter bridge and R_2 is connected to right gap, balance point from left end is at 50 cm. When the 10Ω is removed the balance point shifts to 40 cm. The value of R_1 is

Q.7 Let In a meter bridge (length 1m) the galvanometer shows null deflection then balancing length BC will be

(1) 10 cm (2) 40 cm

(3) 25 cm (4) 16 cm

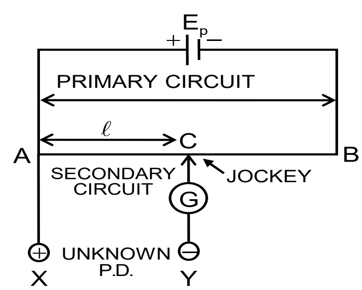


22. Potentiometer

- It is an ideal instrument for measuring the emf of a cell or potential difference between two points of an electric circuit.
- It is equivalent to a voltmeter with infinite resistance because, when it is used in an electric circuit, it does not draw any current from the main circuit. That's why it is called 'Ideal Voltmeter'.
- Potentiometer consists of a long wire (1m to 10m long) of uniform cross–section and homogeneous material.
- Potentiometer wire is made of material for which temperature coefficient = Low, and Resistivity = High.
- Materials used to construct potentiometer are alloys e.g. eureka, manganin, constantan etc.

22.1 Principle

The potentiometer is based upon the principle that when a constant current is passed through a wire of uniform area of cross–section, the potential drop across any portion of wire is directly proportional to the length of that portion.



$E_P \rightarrow$ e.m.f. of cell used in primary circuit

$E_S \rightarrow$ e.m.f of cell used in secondary circuit

$R_W \rightarrow$ Resistance of potentiometer wire

$L \rightarrow$ length of potentiometer wire

- In balanced stage it does not draw any current from the main circuit, whose p.d. is being measured.
- When we connect unknown p.d. between X and Y and if galvanometer does not show any deflection then p.d across A and C = p.d. across X and Y
- Also, at this stage no current flows from X to A or A to X or C to Y or Y to C. i.e. primary circuit and secondary circuit work independently.

22.2 Potential Gradient (ϕ)

(i) The fall of potential per unit length of potentiometer wire is known as potential gradient

From above fig. $\phi = \dfrac{V_{AB}}{L} = \dfrac{IR_w}{L}$

(ii) ϕ **directly depends upon–**

- the resistance per unit length of potentiometer wire ρ $\left(\therefore \rho = \dfrac{R_w}{L}\right)$
- the radius of potentiometer wire
- the specific resistance of the material of potentiometer wire (ρ)
- the current flowing through potentiometer wire.

$$I = \frac{E_p}{R + r + R_w}$$

(iii) ϕ **indirectly depends on–**

- the e.m.f. of battery in the primary circuit (E_p)
- the resistance of rheostat in the primary circuit (R_h)
- the total resistance of potentiometer wire R and its total length $\left(R_w = \frac{\rho L}{A}\right)$
- When no resistance other than the potentiometer wire is connected in the potentiometer circuit.

  $\phi = \frac{E_p}{L}$

  E_p = e.m.f. of the battery used in primary circuit.

  L = length of potentiometer wire.
- When the current flowing in the primary circuit is given

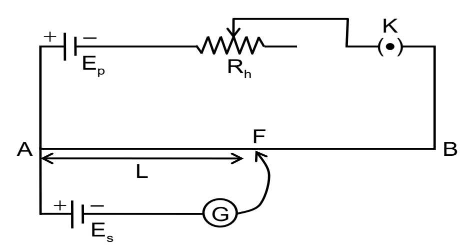
  $\phi = \frac{E_P}{L} = \frac{IR_w}{L} = \frac{I\rho L}{LA} = \frac{I\rho}{A}$

  A = cross-sectional area of wire
- When potential difference V is constant. Then $\frac{\phi_1}{\phi_2} = \frac{L_2}{L_1}$
- When two wires of lengths L_1 and L_2 and resistance ρ_1 and ρ_2 are joined together to form the potentiometer wire, them $\frac{\phi_1}{\phi_2} = \frac{R_1}{R_2} \cdot \frac{L_2}{L_1}$
- potential gradient, $\phi = \frac{E_p R_w}{(R_w + R + r)L}$

  If $r \to 0$ & $R \to 0$ then $\phi_{max} = \frac{E_p}{L}$
- If the length of potentiometer wire and potential difference across its ends are kept constant and if its diameter is changed from d_1 to d_2 then potential gradient remains unchanged i.e. $\phi_1 = \phi_2$
- If the specific resistance of material of wire is changed from ρ_1 to ρ_2, then also potential gradient remains unchanged.
- The unit of potential gradient is V/m or V/cm.
- The dimension of ϕ are $MLT^{-3} A^{-1}$.

22.3 Standardization of Potentiometer

The process of determining potential gradient experimentally is known as standardization of potentiometer.



22.4 Sensitivity

- A potentiometer is said to be more sensitive, if it measures a small potential difference more accurately.
- The sensitivity of potentiometer is assessed by its potential gradient. The sensitivity is inversely proportional to the potential gradient.
- In order to increase the sensitivity of potentiometer, the resistance in primary circuit will have to increase.
- the length of potentiometer wire will have to be increased so that the length may be measured more accurately.

22.5 Difference Between Potentiometer and Voltmeter

(A) Potentiometer

- Its resistance is infinite
- It does not draw any current from the source of known e.m.f.
- The potential difference measured by it is the actual potential difference
- Its sensitivity is high
- It is a versatile instrument
- It is based on zero deflection method.

(B) Voltmeter

- Its resistance is high but finite.
- It draws some current from source of e.m.f.
- The potential difference measured by it < actual potential difference.
- Its sensitivity is low.
- It measures only e.m.f. or potential difference.
- It is based on deflection method.

Example 42:

A potentiometer having 10 m long wire is connected to an accumulator having a steady emf. A leclanche cell gives a null point at 750 cm from one end of potentiometer. If the length of the potentiometer wire is increased by 100 cm, then the new position of null point will be-

(1) 8.25 m (2) 8.25 cm (3) 82.5 cm (4) 825 cm

Solution:

$\ell = \frac{L'}{L}\ell$ Given : L = 10m, L' = 11m, ℓ = 7.50 m

$\therefore \quad \ell = \frac{11}{10} \times 7.5 = 8.25 \text{ m} = 825 \text{ cm}$

Example 43:

An accumulator of e.m.f. 2.2 volt and a rheostat of range 22Ω are connected in the primary circuit of potentiometer. If the length of potentiometer wire is 10m and its resistance is 18Ω then the minimum and maximum potential gradients in V/m will respectively be-

(1) 0.09 and 0.22 (2) 0.06 and 0.22 (3) 0.09 and 0.06 (4) 0.09 and 0.04

Solution:

$$\phi_{min} = \frac{ER_p}{(R_{max} + R_p)L} = \frac{2.2 \times 18}{40 \times 10} = 0.09 \text{ V/m}$$

$$\phi_{max} = \frac{E}{L} = \frac{2.2}{10} = 0.22 \text{ V/m}$$

22.6 Based on the Principle of Potentiometer

- Consider the circuit shown in fig. If on switching on the key K, the current in the circuit remains the same then what is the emf E_1?

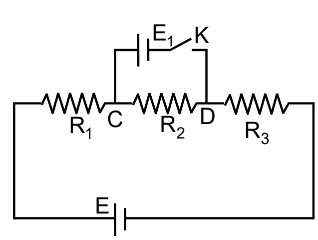
  Obviously, the p.d. across points C, D is equal to emf E_1

  $E_1 = IR_2$

  where current I in the circuit is

  $I = E/(R_1 + R_2 + R_3)$

  Thus $\quad E_1 = ER_2/(R_1 + R_2 + R_3)$



Example 44:

If the current in the primary circuit of a potentiometer wire is 0.2 A, specific resistance of the material of wire 40×10^{-8} Ωm and area of cross–section of wire is 8×10^{-7} m^2. The potential gradient will be–

(1) 0.1 V/m (2) 0.001 V/m (3) 0.1 V/cm (4) 0.01 V/m

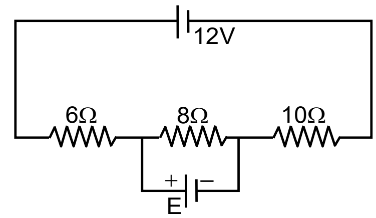
Solution:

$$\phi = I(R_W/L) = I\ \rho/\pi r^2 \quad [\therefore R_W = \rho\frac{L}{A} = \rho.\frac{L}{\pi r^2}\ ]$$

$$= 0.2 \times 40 \times 10^{-8}/8 \times 10^{-7} = 0.1 \text{ V/m}$$

Example 45:

In the circuit shown in fig, if the current distribution remains unchanged on connecting E, then the value of E will be –



(1) 12 V (2) 6 V

(3) 4 V (4) 2 V

Solution:

$$I = \frac{E_p}{R_1 + R_2 + R_3} = \frac{12}{6+8+10} = 0.5 \text{ A} \quad .....(1)$$

$R_2 = 8\Omega$, Voltage across 8Ω resistance

$V_2 = I\ R_2 = 0.5 \times 8$

$V_2 = 4$ volt .....(2)

For current distribution to remain unchanged

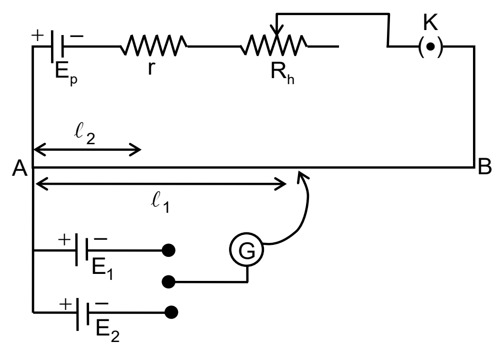
$V_2 = E = 4$ Volt

23. Application of the Potentiometer

23.1 Comparison of EMF's:

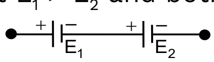
Let ℓ_1 and ℓ_2 be the balancing lengths with the cells E_1 and E_2 respectively then $E_1 \propto \ell_1$ and $E_2 \propto \ell_2$

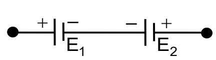
$$\Rightarrow \quad \frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$$



Note:

Let $E_1 > E_2$ and both are connected in series.

(a) 

(b) 

- For combination (a) let ℓ_1 be balancing length, then $E_1 + E_2 = \phi\ \ell_1$
- For combination (b) let ℓ_2 be the balancing length, then $E_1 - E_2 = \phi\ \ell_2$
- $\dfrac{E_1}{E_2} = \dfrac{\ell_1 + \ell_2}{\ell_1 - \ell_2}$

Example 46:

With a certain cell the balance point is obtained at 0.60m from one end of the potentiometer. With another cell whose emf differs from that of the first by 0.1 V, the balance point is obtained at 0.55 m. Then, the two emf's are-

(1) 1.2 V, 1.1 V (2) 1.2 V, 1.3 V

(3) –1.1 V, –1.0 V (4) none of the above.

Solution:

$E_1 = \phi\,(0.6)$

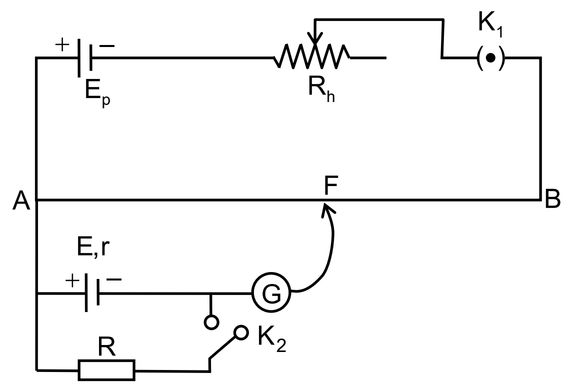
$E_2 = E_1 - 0.1 = \phi\,(0.55)$

dividing $= \dfrac{E_1}{E_1 - 0.1} = \dfrac{0.6}{0.55}$

or $\quad 55\,E_1 = 60\,E_1 - 6 \qquad$ or $\qquad E_1 = \dfrac{6}{5} = 1.2\text{ V}$

thus $\quad E_2 = 1.1\text{ V}$

23.2 Measurement of Internal Resistance

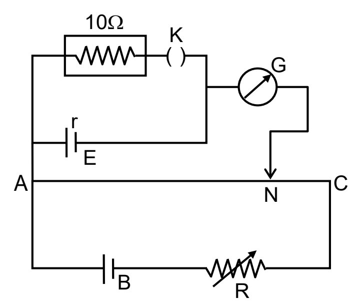


- The balance point (ℓ_1) is found with the key K_2 open, this measures E, since no current is flowing from the cell. $E = \phi\ell_1$
- The key K_2 is now closed and a second balanced point (ℓ_2) is found. This measure the p.d. (V) between the terminals of the cell (in this case, some current flows through resistor R so V < E) $V = \phi\,\ell_2$
- $\because\ E = V + Ir \Rightarrow\ r = \dfrac{E - V}{I} \Rightarrow r = \left(\dfrac{E - V}{V}\right)R$

or $\ r = \left(\dfrac{\ell_1 - \ell_2}{\ell_2}\right)R \qquad (\ell_1 > \ell_2$ always)

Example 47:

In the given potentiometer circuit, internal resistance r of the cell of emf ε is to be determined. When K is open, balance point is at N_1, AN_1 = 60cm. When K is close, balance point is obtained at N_2, AN_2 = 50 cm, what is the value of r ?



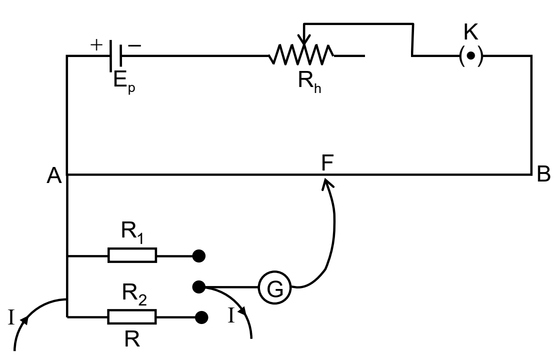
Solution:

If ℓ_1 = 60 cm (when K is off)

ℓ_2 = 50 cm (when K is on), then

$r = \left(\dfrac{\ell_1 - \ell_2}{\ell_2}\right)R = \left(\dfrac{60 - 50}{50}\right)10\Omega \qquad = \dfrac{1}{5} \times 10\Omega = 2\Omega$

23.3 Comparison of Resistances



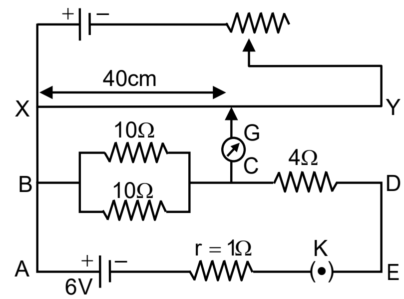
- If the balancing length for R_1 and R_2 are respectively, ℓ_1 and ℓ_2

Then, $IR_1 = \phi\,\ell_1 \qquad IR_2 = \phi\ell_2$

So, $\qquad \dfrac{R_1}{R_2} = \dfrac{\ell_1}{\ell_2}$

Example 48:

In the following circuit the potential difference between the points B and C is balanced against 40 cm length of potentiometer wire. In order to balance the potential difference between the points C and D, where should jockey be pressed?



(1) 32 cm (2) 16 cm

(3) 8 cm (4) 4 cm

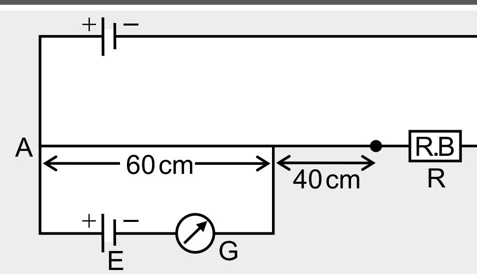
Solution:

$$\frac{1}{R_1} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10} = \frac{1}{5} \text{ or } R_1 = 5\Omega \quad R_2 = 4\Omega,\ \ell_1 = 40 \text{ cm},\ \ell_2 = ?$$

$$\ell_2 = \ell_1 \frac{R_2}{R_1} \text{ or } \ell_2 = \frac{40 \times 4}{5} = 32 \text{ cm}$$

Concept Builder-7

Q.1 In the following circuit diagram the resistance of potentiometer wire is 4Ω and its length is 100 cm. If the potential difference across R=200Ω resistance is 1 volt then e.m.f. of cell in millivolt will be-



(1) 1.5 (2) 3

(3) 6 (4) 12

Q.2 The length of a potentiometer wire is 1m and its resistance is 4Ω. A current of 5 mA is flowing in it. An unknown source of e.m.f. is balanced on 40 cm length of this wire, then the e.m.f. of the source will be-

(1) 6 mV (2) 12 mV (3) 10 mV (4) 8 mV

Q.3 A steady current flows through the potentiometer wire. When an unknown emf is measured the balance, point is found to be at the position of 45 cm from positive end of the potentiometer wire. When a standard cell with emf 1.018 V is used, the jockey position is 30 cm at balance. What is the unknown emf ?

(1) 1.018 V (2) 0.679 V (3) 1.527 V (4) none of the above.

Q.4 The balancing lengths corresponding to two cells are in the ratio 2 : 1. When the cells are connected so as to support each other then balancing length is ℓ_1. When they are connected so as to oppose each other, the balancing length is ℓ_2. The value of $\ell_1 : \ell_2$ will be-

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

Q.5 Two cells of emf E_1 and E_2 are to be compared in a potentiometer ($E_1 > E_2$). When the cells are used in series with same polarity, the balancing length obtained is 400 cm. When they are used in series but E_2 is connected with reverse polarity, the balancing length obtained is 200 cm. Ratio of emf of cells is

ANSWER KEY FOR CONCEPT BUILDERS

CONCEPT BUILDER-1

1. 3.2×10^{-11} amp
2. 1.16×10^{-12} amp
3. 3.6 A/mm^2
4. 0.15 mm/s
5. $P = 2.55 \times 10^{-7}$ N-s
6. (1)

CONCEPT BUILDER-2

1. 1.25×10^{19}
2. $R = 0.6\ \Omega$
3. ρ remains the same
4. 20Ω
5. $R' = 4R$

CONCEPT BUILDER-3

1. (3)
2. $(22 \times 10^4)\Omega \pm 10\%$
3. Orange, Violet, Red, Silver
4. $R_{eq} = R/2$
5. $R_{AB} = 18\Omega$
6. $R_{AB} = 13.5\ \Omega$
7. $R_{AB} = 2\Omega$

CONCEPT BUILDER-4

1. $I_{10\Omega} = \frac{3}{5}$ A; $I_{3\Omega} = 1$A
2. $I = 2.5$ A
3. $r = 2.5\ \Omega$
4. (1)
5. $R_{eq} = 2\Omega$
6. $R_{eq} = r = 10\Omega$

CONCEPT BUILDER-5

1. $R_{eq} = 2\Omega$
2. $\frac{28}{27}R$
3. $R = 484\ \Omega$, $I = 0.45$ A
4. (1)
5. (1)
6. 100 W, 220 V will draw more current

CONCEPT BUILDER-6

1. $R_g = 48\ \Omega$
2. $S = 11\Omega$
3. $S = 0.06\ \Omega$
4. $S = 0.015\ \Omega$, $R = 1641.67\ \Omega$
5. $x = \frac{1}{4}\Omega$
6. $R_1 = 20\Omega$
7. (4)

CONCEPT BUILDER-7

1. (4)
2. (4)
3. (3)
4. (1)
5. $\frac{E_1}{E_2} = \frac{3}{1}$

Exercise - I

Electric Current, Average Current, Types of Current, Instantaneous & Average Current

1. A current of 5 A exist on a 10 ohm resistance for 4 min. How much charge pass through any cross-section of the resistor in this time ?

(1) 12 coulombs (2) 120 coulombs
(3) 1200 coulombs (4) 12000 coulombs

2. A charge of 2×10^{-2} C moves at 30 revolution per second in a circle of diameter 0.80 m. The current linked with the circuit will be -

(1) 0.1 A (2) 0.2 A
(3) 0.4 A (4) 0.6 A

3. The current in a conductor varies with time t is $I = 2t + 3t^2$ where I is in ampere and t in seconds. Electric charge flowing through a section of conductor during t = 2 sec to t = 3 sec. is -

(1) 10 C (2) 24 C
(3) 33 C (4) 44 C

Current Density, Drift Velocity, Free Charge Density, Mean Relaxation Time, Mean Free Path

4. The drift velocity of electrons in a conducting wire is of the order of 1 mm/s, yet the bulb glows very quickly after the switch is put on because :

(1) The random speed of electrons is very high, of the order of 10^5 m/s
(2) The electrons transfer their energy very quickly through collisions
(3) Electric field is set up in the wire very quickly, producing a current through each cross section, almost instantaneously
(4) All of above

5. A steady current is passing through a linear conductor of non-uniform cross-section. The net quantity of charge crossing any cross-section per second is -

(1) independent of area of cross-section
(2) directly proportional to the length of conductor
(3) directly proportional to the area of cross-section
(4) inversely proportional to the lengths of conductor

6. A current (I) flows through a uniform wire of diameter (d) when the mean drift velocity is v. The same current will flow through a wire of diameter d/2 made of the same material then the mean drift velocity of the electron is -

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

7. A wire of non-uniform cross-section is carrying a steady current along the wire -

(1) current and current density are constant
(2) only current is constant
(3) only current density is constant
(4) neither current nor current density is constant

8. A cross–sectional area of a copper wire is 3×10^{-6} m^2. The current of 4.2 amp is flowing through it. The current density in amp/m^2 through the wire is –

(1) 1.4×10^3 (2) 1.4×10^4
(3) 1.4×10^5 (4) 1.4×10^6

Ohm's Law, Resistance, Conductance, Mobility

9. The current in a copper wire is increased by increasing the potential difference between its end. Which one of the following statements regarding n, the number of charge carriers per unit volume in the wire and v the drift velocity of the charge carriers is correct -

(1) n is unaltered but v is decreased
(2) n is unaltered but v is increased
(3) n is increased but v is decreased
(4) n is increased but v is unaltered

10. A current flow in a wire of circular cross-section with the free electrons travelling with a mean drift velocity $\vec{v}$. If an equal current flows in a wire of twice the radius, new mean drift velocity is -

(1) $\vec{v}$ (2) $\vec{v}/2$
(3) $\frac{\vec{v}}{4}$ (4) None of these

11. There is a current of 1.344 amp in a copper wire whose area of cross-section normal to the length of the wire is $1mm^2$. If the number of free electrons per cm^3 is 8.4×10^{22}, then the drift velocity would be -

(1) 1.0 mm per sec (2) 1.0 metre per sec
(3) 0.1 mm per sec (4) 0.01 mm per sec

12. When the resistance of copper wire is 0.1 Ω and the radius is 1 mm, then the length of the wire is (specific resistance of copper is 3.14×10^{-8} ohm x m) :

(1) 10 cm (2) 10 m
(3) 100 m (4) 100cm

13. When a potential difference (V) is applied across a conductor, the thermal speed of electrons is -

(1) zero
(2) proportional to $\sqrt{T}$
(3) proportional to T
(4) proportional to V

14. Specific resistance of a wire depends on the

(1) length of the wire
(2) area of cross–section of the wire
(3) resistance of the wire
(4) material of the wire

15. The resistance of wire is 20Ω. The wire is stretched to three times its length. Then the resistance will now be –

(1) 6.67 Ω (2) 60 Ω
(3) 120 Ω (4) 180 Ω

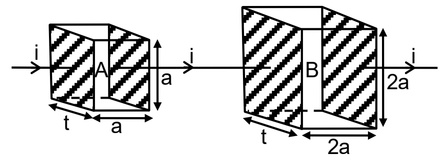
16. The dimensions of a manganin block are 1 cm × 1 cm × 100 cm. The electrical resistivity of manganin is 4.4×10^{-7} ohm–meter. The resistance between the opposite rectangular faces is –

(1) 4.4×10^{-7} ohm
(2) 4.4×10^{-3} ohm
(3) 4.4×10^{-5} ohm
(4) 4.4×10^{-1} ohm

17. When the resistance wire is passed through a die the cross–section area decreases by 1%, the change in resistance of the wire is -

(1) 1% decrease (2) 1% increase
(3) 2% decrease (4) 2% increase

18. In the following diagram two parallelepiped A and B are of the same thickness. The arm of B is double that of A. Compare these resistances and find out the value of R_A/R_B is –



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

19. The resistance of a semi-conductors -

(1) increases with increase of temperature
(2) decreases with increase of temperature
(3) does not change with change of temperature
(4) first decreases and then increases with increase of temperature

20. Ohm's law is valid when the temperature of the conductor is -

(1) constant (2) very high
(3) very low (4) varying

21. A certain piece of copper is to be shared into a conductor of minimum resistance. Its length and diameter should be respectively:

(1) ℓ, d (2) 2ℓ, d
(3) $\ell/2$, 2d (4) 2ℓ, d/2

22. A wire has a resistance of 10Ω. A second wire of the same material is having length double and radius of cross-section half that of the wire. The resistance of the second wire is-

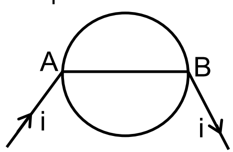
(1) 20Ω (2) 40Ω
(3) 80Ω (4) 10Ω

23. A cylindrical copper rod is reformed to twice its original length with no change in volume. The resistance between its ends before the change was (R). Now its resistance -

(1) 8R (2) 6R
(3) 4R (4) 2R

24. The length of a conductor is halved. Its conductance will be -
(1) halved (2) unchanged
(3) doubled (4) quadrupled

25. A wire of resistance $0.5\Omega\ m^{-1}$ is bent into a circle of radius 1m. The same wire is connected across a diameter AB as shown in fig. The equivalent resistance is -



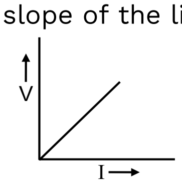
(1) $\pi\ \Omega$ (2) $\frac{\pi}{\pi+2}\Omega$

(3) $\frac{\pi}{\pi+4}\ \Omega$ (4) $(\pi + 1)\ \Omega$

26. A wire of resistance 2Ω is redrawn so that its length becomes four times. The resistance of the redrawn wire is –
(1) 2Ω (2) 8Ω
(3) 16Ω (4) 32Ω

27. A wire is cut into 4 pieces, which are put together side by side to obtain one conductor. If the original resistance of the wire was R. The resistance of the bundle will be -
(1) R/4 (2) R/8
(3) R/16 (4) R/32

28. The current -voltage variation for a wire of copper of length (L) and area (A) is shown in fig. The slope of the line will be -



(1) less if experiment is done at a higher temperature
(2) more if a wire of silver of same dimensions is used
(3) will be doubled if the lengths of the wire is doubled
(4) will be halved if the length is doubled

29. A wire has resistance 12 ohms. It is bent in the form of a circle. The effective resistance between the two points on any diameter of the circle is -
(1) $12\ \Omega$ (2) 24Ω
(3) $6\ \Omega$ (4) 3Ω

30. Consider two conducting wires of same length and material, one wire is solid with radius r. The other is a hollow tube of outer radius 2r while inner radius r. The ratio of resistance of the two wires will be -
(1) 1 : 1 (2) 1 : 2
(3) 1 : 3 (4) 1 : 4

31. If a copper wire is stretched to make its radius decrease by 0.1%, then the percentage increase in resistance is approximately -
(1) 0.1% (2) 0.2%
(3) 0.4% (4) 0.8%

32. The sides of a rectangular block are 2cm, 3cm and 4 cm. The ratio of maximum to minimum resistance between its parallel faces is -
(1) 4 (2) 3
(3) 2 (4) 1

33. When a piece of aluminium wire of finite length is drawn through a series of dies to reduce its diameter to half its original value, its resistance will become-
(1) two times
(2) four times
(3) eight times
(4) sixteen times

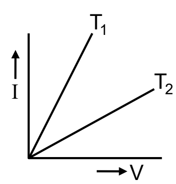
Resistivity, Colour Coding, Temperature Dependence of Resistivity, Concept of Super Conductors

34. The resistance of some substances become zero at very low temperature, then these substances are called –
(1) good conductors
(2) super conductors
(3) bad conductors
(4) semi conductors

35. If the temperature of iron and silicon wires is increased from 30°C to 50°C, the correct statement is –
(1) resistance of both wires increase
(2) resistance of both wires decrease
(3) resistance of iron wire increases and the resistance of silicon wire decreases
(4) resistance of iron wire decreases and the resistance of silicon wire increases

36. When the temperature of a metallic conductor is increased, its resistance -
(1) always decreases
(2) always increases
(3) may increase or decrease
(4) remains the same

37. The current (I) and voltage (V) graphs for a given metallic wire at two different temperature (T_1) and (T_2) are shown in fig. It is concluded that -



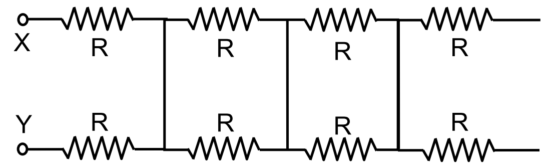
(1) $T_1 > T_2$ (2) $T_1 < T_2$
(3) $T_1 = T_2$ (4) $T_1 = 2T_2$

38. A carbon and an aluminium wire connected in series. If the combination has resistance of 30 ohm at 0°C, what is the resistance of carbon and aluminium 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 $\alpha_{Al} = 4 \times 10^{-3}\ (C°)^{-1}$]
(1) $\frac{10}{3}\Omega, \frac{80}{3}\Omega$ (2) $\frac{80}{3}\Omega, \frac{10}{3}\Omega$
(3) 10 Ω, 80 Ω (4) 80 Ω, 10 Ω

39. A potential difference of 200 V is applied to a coil at a temperature of 15°C and the current is 10A. What will be the mean temperature of the coil when the current has fallen to 5A, the applied voltage being the same as before -
(Given $\alpha = \frac{1}{234}\ C^{-1}$ at 0°C)
(1) 254° (2) 256°
(3) 258° (4) 264°

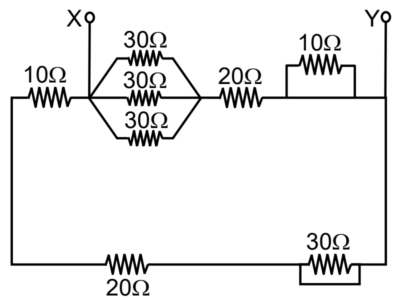
Combination of Resistors

40. Net resistance between X and Y is –



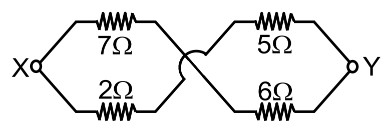
(1) R (2) 2R
(3) $\frac{R}{2}$ (4) 4R

41. Net resistance between X and Y is -



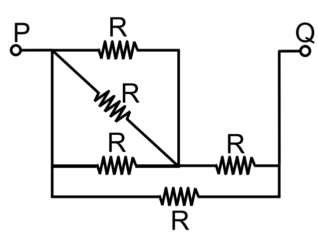
(1) 5 Ω (2) 10 Ω
(3) 15 Ω (4) 60 Ω

42. Net resistance between X and Y is -



(1) 4 Ω (2) 4.55 Ω
(3) 2 Ω (4) 20 Ω

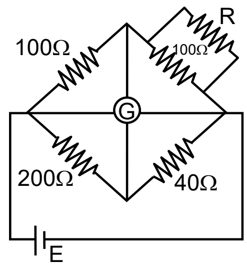
43. The equivalent resistance between the terminal point P and Q is 4Ω in the given circuit, then find out the resistance of R in ohms -



(1) 7 (2) 4
(3) 2 (4) 5

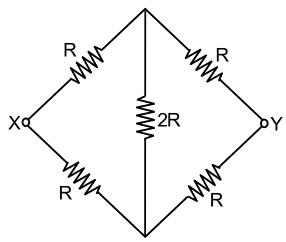
44. In a closed circuit the sum of total emf is equal to the sum of the –
(1) currents
(2) resistances
(3) products of current and the resistances
(4) none of the above

45. For following diagram, the galvanometer shows zero deflection, then the value of R is:



(1) 52 Ω (2) 50 Ω
(3) 100 Ω (4) 25 Ω

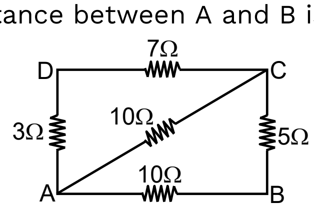
46. For following circuit, the value of total resistance between X and Y in ohm is -



(1) R (2) 4 R
(3) 5 R (4) 6 R

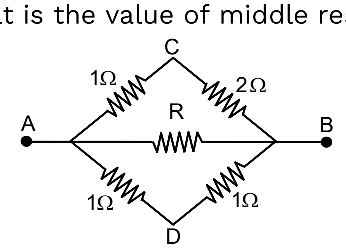
47. The equivalent resistance in series combination is-
(1) smaller than the largest resistance
(2) larger than the largest resistance
(3) smaller than the smallest resistance
(4) larger than the smallest resistance

48. Five resistance are connected as shown in the adjoining figure. The equivalent resistance between A and B is -



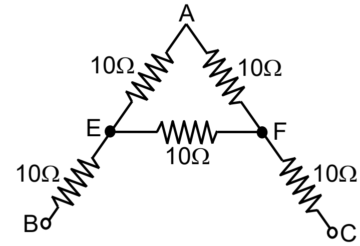
(1) 35Ω (2) 5Ω
(3) 15/4Ω (4) 25Ω

49. The equivalent resistance between points (A) and (B) in the adjoining fig. is one ohm. What is the value of middle resistance -



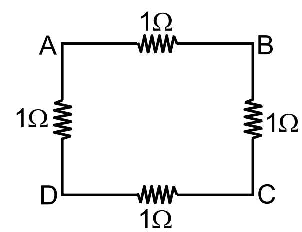
(1) 9Ω (2) 1Ω
(3) 6Ω (4) 3Ω

50. The effective resistance (in Ω) between (B) and (C) is



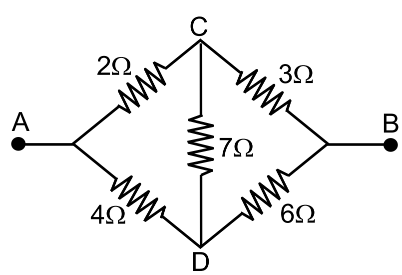
(1) 60 (2) 40
(3) 80/3 (4) 160/9

51. Four identical resistances are joined as shown in fig. The equivalent resistance between points A and B is R_1. The equivalent resistance between points A and C is R_2 then ratio of R_1/R_2 is -



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

52. Five resistances are connected as shown in fig. The effective resistance between the points A and B is -

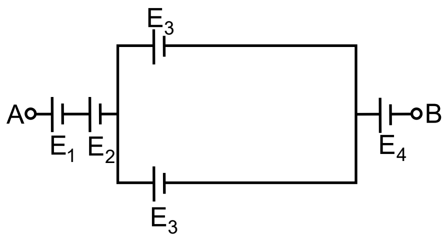


(1) 10/3Ω (2) 20/3 Ω
(3) 15Ω (4) 6Ω

53. Twelve wires of equal resistance (R) are connected to form a cube. The effective resistance between two diagonal ends will be -
(1) 5/6 R (2) 6/5 R
(3) 3R (4) 12 R

Introduction of Cells, EMF, Internal Resistance, Terminal P.D., Grouping of Cells

54. In the following circuit the resultant emf between AB is -



(1) $E_1 + E_2 + E_3 + E_4$

(2) $E_1 + E_2 + 2E_3 + E_4$

(3) $E_1 + E_2 + (E_3/2) + E_4$

(4) $E_1 + E_2 + (E_3/4) + E_4$

55. A cell of e.m.f (E) and internal resistance (r) is connected in series with an external resistance (nr) then the ratio of the terminal p.d. to E.M.F is-

(1) 1/n (2) 1/(n+1)
(3) n/(n+1) (4) (n+1)/n

56. The terminal potential difference of a cell, when cell is short circuited is -

(1) E (2) E/2
(3) zero (4) E/3

57. Five dry cell each of e.m.f 1.5V are connected in parallel. The e.m.f of the combination is -

(1) 7.5 V (2) 0.3 V
(3) 3V (4) 1.5 V

58. The internal resistance of cell is 0.1Ω and its emf is 2V. When a current of 2A is being drawn from it, the potential difference across its terminals will be -

(1) more than 2V
(2) 2V
(3) 1.8V
(4) none of the above

59. A dry cell has an e.m.f of 1.5V and internal resistance 0.5Ω. If the cell sends a current of 1A through an external resistance, the p.d. of the cell will be -

(1) 1.5V (2) 1V
(3) 0.5V (4) 0V

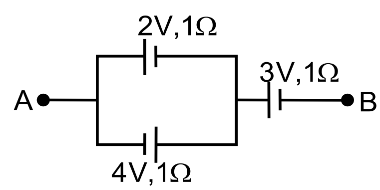
60. Five cells each of e.m.f (E) and internal resistance (r) are connected in series. If one cell is connected wrongly, then the equivalent e.m.f and internal resistance of the combination is -

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

61. A cell of e.m.f (E) volt and internal resistance (r) ohms is connected to an external resistance of (r) ohms. The potential difference across the terminals of the cell will be

(1) E volt (2) E/2 Volt
(3) E/4 volt (4) 2E volt

62. The potential difference between points A and B is -



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

63. The number of dry cells, each of e.m.f. 1.5 volt and internal resistance 0.5 Ω that must be joined in series with a resistance of 20 ohm so as to send a current of 0.6 ampere through the circuit is -

(1) 2 (2) 8
(3) 10 (4) 12

64. Two batteries of different e.m.f. and internal resistance are connected in series with each other and with an external load resistor. The current is 3.0 amp. When the polarity of one battery is reversed, the current becomes 1.0 amp. The ratio of the e.m.f. of the two batteries is -

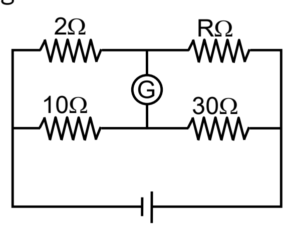
(1) 2.5 (2) 2.0
(3) 1.5 (4) 1.0

65. When a cell is connected to 1 ohm resistance, 1 ampere current flows through the circuit. When 3 ohm resistance is used then 0.5 amp current flows, then internal resistance of the cell is -

(1) 1 Ω (2) 1.5 Ω
(3) 2 Ω (4) 2.5 Ω

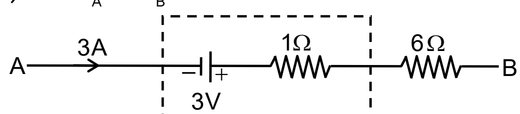
Kirchhoff's Law, (KVL & KCL), Wheat Stone Bridge

66. In the adjoining fig. there is no deflection in the galvanometer. Then R is equal to -



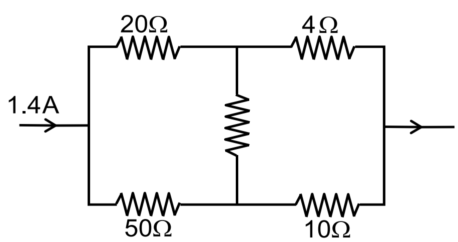
(1) 2Ω (2) 30Ω
(3) 6Ω (4) (2/3)Ω

67. Fig represents a part of a closed circuit. The potential difference between (A) and (B) i.e. $V_A - V_B$ is -



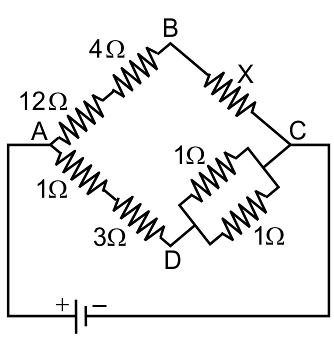
(1) 24 V (2) 0 V
(3) 6 V (4) 18 V

68. In the following figure the current through 4 ohm resistor is -



(1) 1.4 A (2) 0.4 A
(3) 1.0 A (4) 0.7 A

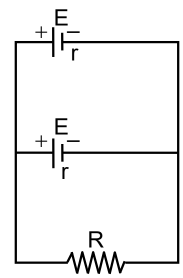
69. In the arrangement of resistances shown in the circuit, the potential difference between points B and D will be zero, when the unknown resistance X is –



(1) 4Ω (2) 3Ω
(3) 2Ω (4) 1Ω

Electrical Energy, Power Distribution for Series Parallel Combination, Maximum Power

70. Two cells of same emf E and internal resistance r are connected in parallel with a resistance of R. To get maximum power in the external circuit, the value of R is -



(1) $R = \frac{r}{2}$ (2) R = r
(3) R = 2 r (4) R = 4r

71. Two bulbs, one of 50 watt and another of 25 watt are connected in series to the mains, the ratio of the current through them is -
(1) 2 : 1
(2) 1 : 2
(3) 1 : 1
(4) can't be determined without the p.d. of the main supply

72. Constant voltage is applied between the two ends of a uniform metallic wire. The heat developed is doubled if -
(1) both the length and radius of the wire are halved
(2) both the length and radius of the wire are doubled
(3) the radius of wire is doubled
(4) the length of the wire is doubled

73. Two electric bulbs rated P_1 watt V volt and P_2 watt V volt are connected in parallel across V volt mains then the total power is:

(1) $P_1 + P_2$ (2) $\sqrt{P_1P_2}$

(3) $\frac{P_1P_2}{(P_1+P_2)}$ (4) $\frac{(P_1+P_2)}{P_1P_2}$

74. Lamps used for the house lightening are connected in -
(1) series (2) parallel
(3) mixed grouping (4) arbitrary manner

75. Two electric bulbs whose resistances are in the ratio of 1 : 2 are connected in parallel to a constant voltage source. The power dissipated in them have the ratio -

(1) 1 : 2 (2) 1 : 1

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

76. An electric bulb is rated 220 volt and 100 watt. The resistance of the filament of the electric bulb is -

(1) 2.2 Ω (2) 2.2×10^4 Ω

(3) 484 Ω (4) 100 Ω

77. Three electric bulbs 40W, 60W and 100W are designed to work on a 220V mains. Which bulb will glow most brightly if they are connected in series across 220V mains:

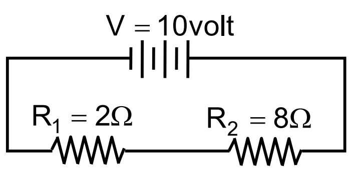
(1) 100W bulb

(2) 60W bulb

(3) 40 W bulb

(4) all bulbs will glow equally brightly

78. In fig the ratio of power dissipated in resistors R_1 and R_2 is



(1) 1 : 4 (2) 4 : 1

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

79. A house is served by a 220V supply line. In a circuit protected by a fuse marked 9A. The maximum number of 60W lamps in parallel that can be turned on is -

(1) 44 (2) 20

(3) 22 (4) 33

80. Two bulbs 25 watt, 220 volt and 100 watt, 220 volt are connected in series across a 440 volt line -

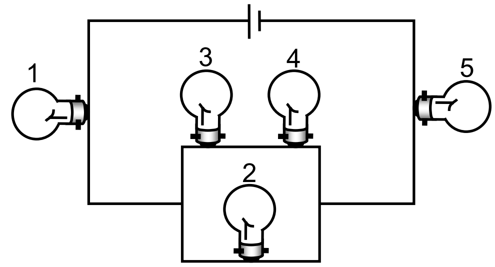
(1) only 100 watt bulb will fuse

(2) only 25 watt bulb will fuse

(3) both bulbs will fuse

(4) none of the bulb will fuse

81. All bulbs in figure below are identical, which bulb light most brightly -



(1) 1 only (2) 2 only

(3) 3 and 4 only (4) 1 and 5

82. The same mass of copper is drawn into two wires 1 mm thick and 2 mm thick. If the two wires are connected in series and the current is passed, the heat produced in the wires will be in the ratio-

(1) 2 : 1 (2) 4 : 1

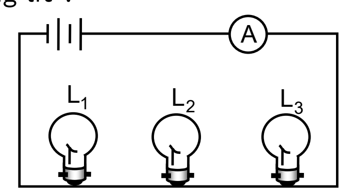
(3) 1 : 16 (4) 16 : 1

83. Two bulbs of 500 watt and 200 watt are manufactured to operate on 220 volt line. The ratio of heat produced in 500 watt and 200 watt, in two cases, when first they are joined in series and secondly in parallel, will be -

(1) $\frac{5}{2}, \frac{2}{5}$ (2) $\frac{5}{2}, \frac{5}{2}$

(3) $\frac{2}{5}, \frac{5}{2}$ (4) $\frac{2}{5}, \frac{2}{5}$

84. In the circuit below, ammeter (A) reads 0.5A. Bulbs L_1 and L_2 are brightly lit, but L_3 is not lit. What is the reason for L_3 not being lit ?



(1) The ammeter is faulty

(2) The filament of L_3 is broken

(3) The resistance of L_3 is much lower than that of L_1 and L_2

(4) There is a break in the connecting wire between L_2 and L_3

85. How much electrical energy in kilo-watt hour is consumed in operating ten 50 watt bulbs for 10 hours per day in a month of 30 days ?

(1) 1500 (2) 15000
(3) 15 (4) 150

86. Two bulbs 100 W, 250 V and 200 W, 250 V are connected in parallel across a 500 V line. Then -

(1) 100 W bulb will fused
(2) 200 W bulb will fused
(3) Both bulbs will be fused
(4) No bulb will fused

87. A uniform wire connected across a supply produces heat H per second. If the wire is cut into n equal parts and all the parts are connected in parallel across the same supply, the heat produced per second will be -

(1) $\frac{H}{n}$ (2) nH
(3) n^2H (4) $\frac{H}{n^2}$

88. Two electric bulbs 40 W, 200 V and 100 W, 200 V are connected in series. Then the maximum voltage that can be applied across the combination, without fusing either bulb is -

(1) 280V (2) 400V
(3) 3000V (4) 200V

89. The resistance of 3Ω and 6Ω are joined in series and connected across a battery of emf 10 V and internal resistance 1Ω. The power dissipated by battery is -

(1) 3 W (2) 8 W
(3) 9 W (4) 10 W

90. A 24 V battery of internal resistance 4Ω is connected to a variable resistor. The rate of heat production in the resistor is maximum when the current in the circuit is –

(1) 2 A (2) 3 A
(3) 4 A (4) 6 A

Meter Bridge, Ammeter, Voltmeter

91. A galvanometer having a coil resistance of 60 Ω shows full scale deflection when a current of 1.0 A passes through it. It can be converted into an ammeter to read currents upto 5.0 A by :

(1) putting in parallel a resistance of 240 Ω
(2) putting in series a resistance of 15 Ω
(3) putting in series a resistance of 240 Ω
(4) putting in parallel a resistance of 15 Ω

92. A milli voltmeter of 25 milli volt range is to be converted into an ammeter of 25 ampere range. The value (in ohm) of necessary shunt will be :

(1) 0.001 (2) 0.01
(3) 1 (4) 0.05

93. A galvanometer can be changed into ammeter by connecting :

(1) high resistance in parallel
(3) high resistance in series
(3) low resistance in parallel
(4) low resistance in series

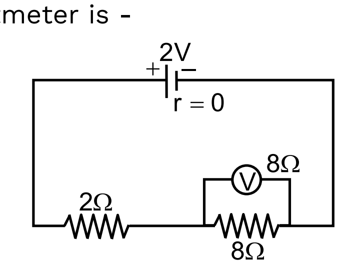
94. There is a voltmeter in a circuit. In order to triple its range, the resistance of how much value should be used?

(1) 2R (2) R/2
(3) 3R (4) 4R

95. In Wheat stone's bridge P = 9 ohm, Q = 11 ohms, R = 4 ohm and S = 6 ohms. How much resistance must be put in parallel to the resistance (S) to balance the bridge

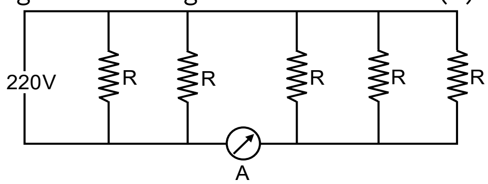
(1) 24 ohms (2) (44/9) ohm
(3) 26.4 ohms (4) 18.7 ohms

96. In the circuit shown in fig, the reading of voltmeter is -



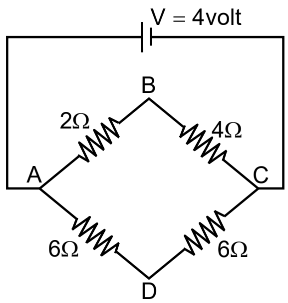
(1) 1.33 V (2) 0.8 V
(3) 2.0 V (4) 1.6V

97. Five identical lamps each resistance R = 1100Ω are connected to 220V as shown in fig. The reading of ideal ammeter (A) is -



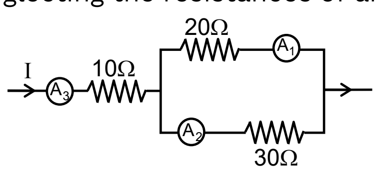
(1) 1/5 A (2) 2/5 A
(3) 3 /5 A (4) 1 A

98. If fig. the difference of potential between (B) and (D) is -



(1) + 0.67V (2) – 0.67V
(3) 2V (4) 1.33V

99. If the reading of ammeter A_1, in figure is 2.4 A, what will the ammeter A_2 and A_3 read ? (Neglecting the resistances of ammeters) -



(1) 1.6 A, 2.3 A (2) 1.6 A, 4.0 A
(3) 4.0 A, 1.6 A (4) 2.3 A, 1.6 A

Potentiometer

100. The potential gradient of a potentiometer wire is defined as :
(1) the fall of potential per unit length
(2) the fall of potential per unit area
(3) the fall in potential across the ends of wires
(4) None of the above

101. For the same potential difference, a potentiometer wire is replaced by another one of a high specific resistance. The potential gradient then ($r = R_h = 0$) :
(1) decreases
(2) remains same
(3) increases
(4) data is incomplete

102. The length of the potentiometer wire is kept larger so that the value of potential gradient may :
(1) increase
(2) decrease
(3) remain uniform all over the length of its wire
(4) None of the above

103. If the current in a potentiometer increases, the position of the null point will :
(1) be obtained at a larger length than the previous one
(2) be equal to the previous length
(3) be obtained at a smaller length than the previous
(4) None of the above

104. The potentiometer wire 10 m long and 20 ohm resistance is connected to a 3 volt emf battery and a 10 ohm resistance. The value of potential gradient in volt/m of the wire will be :
(1) 1.0 (2) 0.2
(3) 0.1 (4) 0.02

105. In a potentiometer wire, whose resistance is 0.5 ohm/m, a current of 2 ampere is passing. The value of potential gradient in volt/m will be :
(1) 0.1 (2) 0.5
(3) 1.0 (4) 4

(1) 40 (2) 100
(3) 75 (4) 25

106. The potential gradient of potentiometer is 0.2 volt/m. A current of 0.1 amp is flowing through a coil of 2 ohm resistance. The balancing length in meters for the p.d. at the ends of this coil will be:
(1) 2 (2) 1
(3) 0.2 (4) 0.1

107. It is observed in a potentiometer experiment that no current passes through the galvanometer, when the terminals of the cell are connected across a certain length of the potentiometer wire. On shunting the cell by a 2Ω resistance, the balancing length is reduced to half. The internal resistance of the cell is-
(1) 4Ω (2) 2Ω
(3) 9Ω (4) 18Ω

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	3	4	2	3	1	3	2	4	2	3	3	2	2	4	4	1	4	1	2	1	3	3	3	3	3
Que.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Ans.	4	3	3	4	3	3	1	4	2	3	2	2	2	4	2	3	2	1	3	4	1	2	2	3	3
Que.	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Ans.	3	1	1	1	3	3	4	3	2	3	2	1	3	2	1	3	4	3	3	1	3	2	1	2	3
Que.	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ans.	3	3	1	4	2	4	4	3	3	4	3	3	1	4	2	4	1	3	1	3	1	3	1	2	1
Que.	101	102	103	104	105	106	107																		
Ans.	2	2	3	2	3	2	2																		

Exercise - II

1. In a potentiometer experiment, it is found that no current passes through the galvanometer when the terminals of the cell are connected across 52 cm of the potentiometer wire. If the cell is shunted by a resistance of 5 Ω, a balance is found when the cell is connected across 40 cm of the wire. Find the internal resistance of the cell.

(1) 1 Ω (2) 1.5 Ω
(3) 2 Ω (4) 2.5 Ω

2. On interchanging the resistances, the balance point of a metre bridge shifts to the left by 10 cm. The resistance of their series combination is 1 kΩ. How much was the resistance of the left slot before interchanging the resistances ?

(1) 990 Ω (2) 505 Ω
(3) 550 Ω (4) 910 Ω

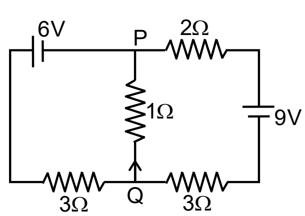
3. A galvanometer having a coil resistance of 100Ω gives a full-scale deflection, when a current of 1 mA is passed through it. The value of the resistance, which can convert this galvanometer into ammeter giving a full scale deflection for a current of 10 A, is :

(1) 0.01 Ω (2) 2 Ω
(3) 0.1 Ω (4) 3 Ω

4. When 5 V potential difference is applied across a wire of length 0.1 m, the drift speed of electrons is $2.5\times10^{-4}\,ms^{-1}$. If the electron density in the wire is $8\times10^{28}m^{-3}$, the resistivity of the material is close to:

(1) $1.6\times10^{-8}\,\Omega m$ (2) $1.6\times10^{-7}\,\Omega m$
(3) $1.6\times10^{-6}\,\Omega m$ (4) $1.6\times10^{-5}\,\Omega m$

5. In the circuit shown, the current in the 1Ω resistor is:



(1) 1.3 A, from P to Q
(2) 0 A
(3) 0.13 A, from Q to P
(4) 0.13 A, from P to Q

6. In a large building, there are 15 bulbs of 40 W, 5 bulbs of 100 W, 5 fans of 80 W and 1 heater of 1 kW. The voltage of the electric mains is 220 V. The minimum capacity of the main fuse of the building will be:

(1) 8 A (2) 10 A
(3) 12 A (4) 14 A

7. Two electric bulbs of 25 W – 220 V and 100 W – 220 V are connected in series with 440 V source. Which bulb which be fused ?

(1) Both (2) 100 W
(3) 25 W (4) None of these

8. Resistance of a given wire is obtained by measuring the current flowing in it and the voltage difference applied across it. If the percentage errors in the measurement of the current and the voltage difference are 3% each, then errors in the value of resistance of the wire is

(1) 6% (2) Zero
(3) 1% (4) 3%

9. If a wire is stretched to make it 0.1% longer, its resistance will :

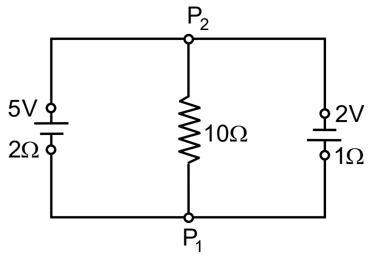
(1) 0.05% increment
(2) 0.2% increment
(3) 0.2% decrement
(4) 0.05% decrement

10. Two conductors have the same resistance at 0°C but their temperature coefficients of resistance are α_1 and α_2. The respective temperature coefficients of their series and parallel combinations are nearly

(1) $\frac{\alpha_1+\alpha_2}{2},\alpha_1+\alpha_2$ (2) $\alpha_1+\alpha_2,\frac{\alpha_1+\alpha_2}{2}$

(3) $\alpha_1+\alpha_2,\frac{\alpha_1\times\alpha_2}{\alpha_1+\alpha_2}$ (4) $\frac{\alpha_1+\alpha_2}{2},\frac{\alpha_1+\alpha_2}{2}$

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



(1) 0.27 A, from P_2 to P_1
(2) 0.03 A, from P_1 to P_2
(3) 0.03 A, from P_2 to P_1
(4) 0.27 A, from P_1 to P_2

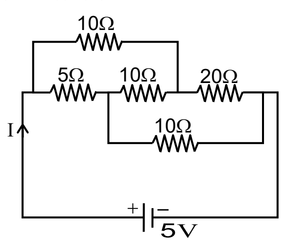
12. The resistance of a wire is 5 ohm at 50 °C and 6 ohm at 100°C. The resistance of the wire at 0°C will be

(1) 2 Ω (2) 1 Ω
(3) 4 Ω (4) 3 Ω

13. A material B has twice the specific resistance of A. A circular wire made of B has twice the diameter of a wire made of A. Then for the two wires to have the same resistance, the ratio l_B / l_A of their respective lengths must be

(1) 1/2 (2) 1/4
(3) 2 (4) 1

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



(1) 0.5 A (2) 0.67 A
(3) 0.17 A (4) 0.33 A

15. The resistance of a bulb filament is 100 Ω at a temperature of 100°C. If its temperature coefficient of resistance be 0.005 per °C, its resistance will become 200 Ω at a temperature of

(1) 400°C (2) 500°C
(3) 200°C (4) 300°C

16. An electric bulb is rated 220 V – 100 W. The power consumed by it when operated on 110 V will be

(1) 40 W (2) 25 W
(3) 50 W (4) 75 W

17. A moving coil galvanometer has 150 equal divisions. Its current sensitivity is 10 divisions per milliampere and voltage sensitivity is 2 divisions per millivolt. In order that each division reads 1 volt, the resistance in ohms needed to be connected in series with the coil will be

(1) 10^5 (2) 10^3
(3) 9995 (4) 99995

18. 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

(1) $R = R_2 - R_1$
(2) $R = R_2 \times (R_1+R_2)/R_2 - R_1)$
(3) $R = R_1R_2/(R_2-R_1)$
(4) $R = R_1R_2/(R_1+R_2)$

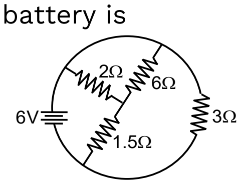
19. A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be

(1) four time (2) doubled
(3) half (4) one-fourth

20. 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

(1) 0.5 Ω (2) 1 Ω
(3) 2 Ω (4) 4 Ω

21. The total current supplied to the circuit by the battery is



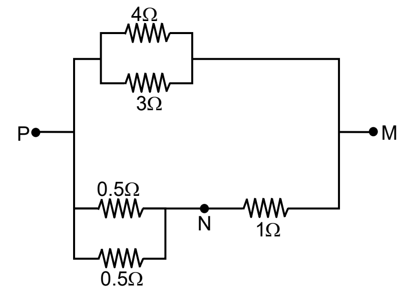
(1) 1 A (2) 6 A
(3) 4 A (4) 2 A

22. 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

(1) 3 (2) 2

(3) 8/9 (4) 1/3

23. In the circuit shown, the current through the 4Ω resistor is 1 A when the points P and M are connected to a DC voltage source. The potential difference between the points M and N is :



(1) 1.5 V (2) 1.0 V

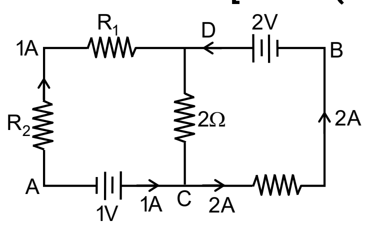
(3) 0.5 V (4) 3.2 V

ANSWER KEY																							
Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Ans.	2	3	1	4	3	3	3	1	2	4	3	3	3	1	1	2	3	1	2	3	3	4	4

Exercise – III (Previous Year Question)

1. In the circuit shown in the figure, if potential at point A is taken to be zero the potential at point B is :

[AIPMT (Mains) 2011]



(1) –1V (2) + 2V
(3) – 2V (4) + 1V

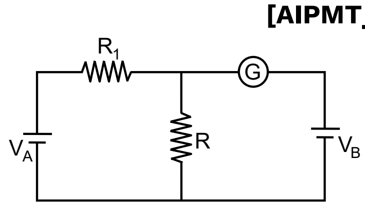
2. A milli voltmeter of 25 milli volt range is to be converted into an ammeter of 25 ampere range. The value (in ohm) of necessary shunt will be :

[AIPMT_Pre_2012]

(1) 0.001 (2) 0.01
(3) 1 (4) 0.05

3. In the circuit shown the cells A and B have negligible resistances. For V_A = 12V, R_1 = 500Ω and R = 100Ω the galvanometer (G) shows no deflection. The value of V_B is:

[AIPMT_Pre_2012]



(1) 4V (2) 2V
(3) 12V (4) 6V

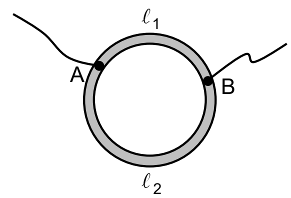
4. If voltage across a bulb rated 220 Volt - 100 Watt drops by 2.5 % of its rated value, the percentage of the rated value by which the power would decrease is :

[AIPMT_Pre_2012]

(1) 20 % (2) 2.5 %
(3) 5 % (4) 10 %

5. A ring is made of a wire having a resistance R_0 = 12 Ω. Find the points A and B as shown in the figure, at which a current carrying conductor should be connected so that the resistance R of the circuit between these points is equal to $\frac{8}{3}\Omega$.

[AIPMT_Pre_2012]

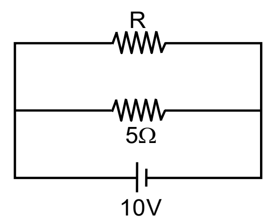


(1) $\frac{\ell_1}{\ell_2}=\frac{5}{8}$ (2) $\frac{\ell_1}{\ell_2}=\frac{1}{3}$

(3) $\frac{\ell_1}{\ell_2}=\frac{3}{8}$ (4) $\frac{\ell_1}{\ell_2}=\frac{1}{2}$

6. The power dissipated in the circuit shown in the figure is 30 Watts. The value of R is:

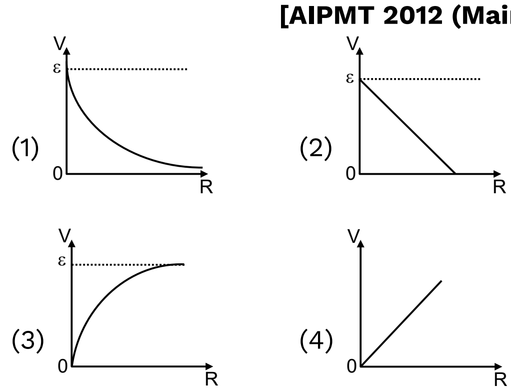
[AIPMT 2012 (Mains)]



(1) 20 Ω (2) 15 Ω
(3) 10 Ω (4) 30 Ω

7. Cell having an emf ε and internal resistance r is connected across a variable external resistance R. As the resistance R is increased, the plot of potential difference V across R is given by :

[AIPMT 2012 (Mains)]



8. A wire of resistance 4 Ω is stretched to twice its original length. The resistance of stretched wire would be : **[NEET 2013]**

(1) 4 Ω (2) 8 Ω
(3) 16 Ω (4) 2 Ω

9. The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10Ω is: **[NEET 2013]**

(1) 0.5 Ω (2) 0.8 Ω

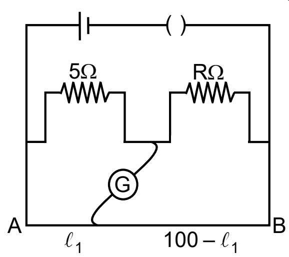
(3) 1.0 Ω (4) 0.2 Ω

10. The resistances of the four arms P, Q, R and S in a Wheatstone's bridge are 10 ohm, 30 ohm, 30 ohm and 90 ohm, respectively. The e.m.f. and internal resistance of the cell are 7 Volt and 5 ohm respectively. If the galvanometer resistance is 50 ohm, the current drawn from the cell will be: **[NEET 2013]**

(1) 0.2 A (2) 0.1 A

(3) 2.0 A (4) 1.0 A

11. The resistance in the two arms of the meter bridge are 5Ω and RΩ, respectively. When the resistance R is shunted with an equal resistance, the new balance point is at 1.6 ℓ_1. The resistance 'R' is : **[AIPMT-2014]**



(1) 10Ω (2) 15Ω

(3) 20Ω (4) 25Ω

12. A potentiometer circuit has been set up for finding the internal resistance of a given cell. The main battery, used across the potentiometer wire, has an emf of 2.0 V and a negligible internal resistance. The potentiometer wire itself is 4m long. When the resistance R, connected across the given cell, has values of :

(i) infinity (ii) 9.5Ω

The balance lengths on the potentiometer wire are found to be 3m and 2.85m, respectively. The value of internal resistance of the cell is : **[AIPMT-2014]**

(1) 0.25Ω (2) 0.95 Ω

(3) 0.5Ω (4) 0.75 Ω

13. In an ammeter 0.2% of main current passes through the galvanometer. If resistance of galvanometer is G, the resistance of ammeter will be : **[AIPMT-2014]**

(1) $\frac{1}{499}G$ (2) $\frac{499}{500}G$

(3) $\frac{1}{500}G$ (4) $\frac{500}{499}G$

14. A potentiometer wire of length L and a resistance r are connected in series with a battery of e.m.f. E_0 and a resistance r_1. An unknown e.m.f. E is balanced at a length ℓ of the potentiometer wire. The e.m.f. E will be given by : **[Re-AIPMT-2015]**

(1) $\frac{EL_0r\ell}{(r+r_1)}$ (2) $\frac{LE_0r}{\ell r_1}$

(3) $\frac{E_0r}{(r+r_1)}.\frac{\ell}{L}$ (4) $\frac{E_0\ell}{L}$

15. A circuit contains an ammeter, a battery of 30 V and a resistance 40.8 ohm all connected in series. If the ammeter has a coil of resistance 480 ohm and a shunt of 20 ohm, the reading in the ammeter will be : **[Re-AIPMT-2015]**

(1) 1 A (2) 0.5 A

(3) 0.25 A (4) 2 A

16. A potentiometer wire has length 4 m and resistance 8 Ω. The resistance that must be connected in series with the wire and an accumulator of e.m.f. 2V, so as to get a potential gradient 1 mV per cm on the wire is : **[AIPMT-2015]**

(1) 40Ω (2) 44Ω

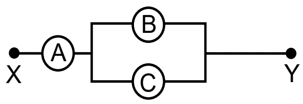
(3) 48Ω (4) 32Ω

17. The charge flowing through a resistance R varies with time t as Q = at $-bt^2$, where a and b are positive constants. The total heat produced in R is : **[NEET-I-2016]**

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

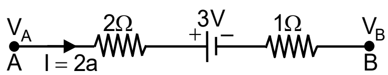
(3) $\frac{a^3R}{2b}$ (4) $\frac{a^3R}{b}$

18. A, B and C are voltmeters of resistance R, 1.5 R and 3 R respectively as shown in the figure. When some potential difference is applied between X and Y, the voltmeter readings are V_A, V_B and V_C respectively. Then: **[AIPMT-2015]**



(1) $V_A \neq V_B = V_C$ (2) $V_A = V_B \neq V_C$
(3) $V_A \neq V_B \neq V_C$ (4) $V_A = V_B = V_C$

19. The potential difference $(V_A - V_B)$ between the points A and B in the given figure is : **[NEET-II-2016]**



(1) + 6 V (2) + 9 V
(3) – 3 V (4) + 3 V

20. A filament bulb (500W, 100V) is to be used in a 230 V main supply. When a resistance R is connected in series, it works perfectly and the bulb consumes 500 W. The value of R is : **[NEET-II-2016]**

(1) 26 Ω (2) 13 Ω
(3) 230 Ω (4) 46 Ω

21. A potentiometer wire is 100 cm long and a constant potential difference is maintained across it. Two cells are connected in series first to support one another and then in opposite direction. The balance points are obtained at 50 cm and 10 cm from the positive end of the wire in the two cases. The ratio of emf's is : **[NEET-I-2016]**

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

22. The resistance of a wire is 'R' ohm. If it is melted and stretched to 'n' times its original length, its new resistance will be : **[NEET - 2017]**

(1) nR (2) $\frac{R}{n}$

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

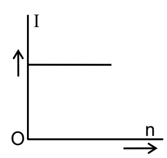
23. A potentiometer is an accurate and versatile device to make electrical measurements of E.M.F. because the method involves : **[NEET - 2017]**

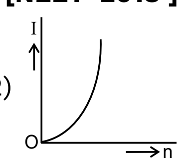
(1) Cells
(2) Potential gradients
(3) A condition of no current flow through the galvanometer
(4) A combination of cells, galvanometer and resistances

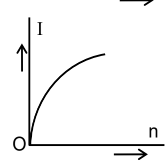
24. A set of 'n' equal resistors, of value 'R' each, are connected in series to a battery of emf E and internal resistance 'R'. The current drawn is I. Now, the 'n' resistors are connected in parallel to the same battery. Then the current drawn from battery becomes 10 I. The value of 'n' is **[NEET-2018]**

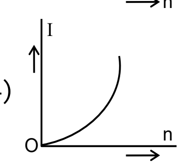
(1) 10 (2) 11
(3) 20 (4) 9

25. A battery consists of a variable number 'n' of identical cells (having internal resistance 'r' each) which are connected in series. The terminals of the battery are short-circuited and the current I is measured. Which of the graphs shows the correct relationship between I and 'n' ? **[NEET-2018]**

(1) 

(2) 

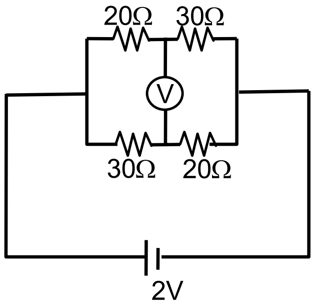
(3) 

(4) 

26. A carbon resistor of resistance (47 ± 4.7)kΩ is to be marked with rings of different colours for its identification. The colour code sequence will be **[NEET-2018]**

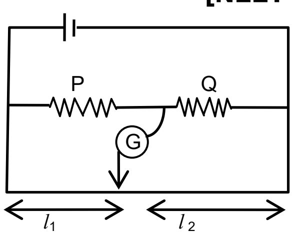
(1) Violet – Yellow – Orange – Silver
(2) Yellow – Violet – Orange – Silver
(3) Yellow – Green – Violet – Gold
(4) Green – Orange – Violet – Gold

27. The reading of an ideal voltmeter in the circuit shown is: **[NEET-2019 Odisha]**



(1) 0.6 V
(2) 0 V
(3) 0.5 V
(4) 0.4 V

28. The metre bridge shown is in balance position with $\frac{P}{Q}=\frac{l_1}{l_2}$. If we now interchange the positions of galvanometer and cell, will the bridge work ? If yes, what will be balanced condition ? **[NEET-2019 Odisha]**



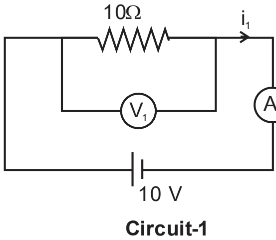
(1) yes, $\frac{P}{Q}=\frac{l_2-l_1}{l_2+l_1}$

(2) no, no null point

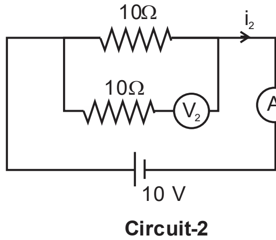
(3) yes, $\frac{P}{Q}=\frac{l_2}{l_1}$

(4) yes, $\frac{P}{Q}=\frac{l_1}{l_2}$

29. In the circuits shown below, the readings of the voltmeters and the ammeters will be : **[NEET-2019]**



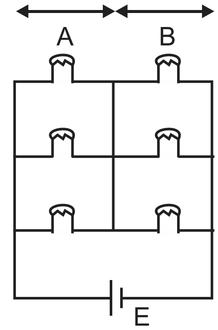
Circuit-1



Circuit-2

(1) $V_1 = V_2$ and $i_1 = i_2$
(2) $V_2 > V_1$ and $i_1 > i_2$
(3) $V_2 > V_1$ and $i_1 = i_2$
(4) $V_1 = V_2$ and $i_1 > i_2$

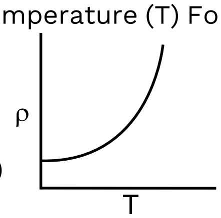
30. Six similar bulbs are connected as shown in the figure with a DC source of emf E, and zero internal resistance.

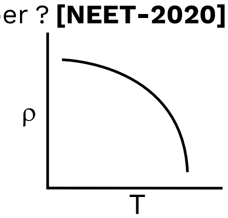


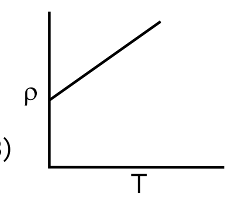
The ratio of power consumption by the bulbs when (i) all are glowing and (ii) in the situation when two from section A and one from section B are glowing will be **[NEET-2019]**

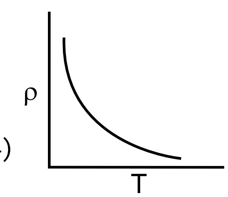
(1) 1 : 2
(2) 2 : 1
(3) 4 : 9
(4) 9 : 4

31. Which of the following graph represents the variation of resistivity (ρ) with temperature (T) For copper ? **[NEET-2020]**

(1)


(2)


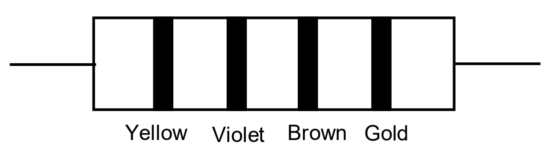
(3)


(4)


32. A charged particle having drift velocity of 7.5×10^{-4} m s^{-1} in an electric field of 3×10^{-10} Vm^{-1} has a mobility in $m^2\ V^{-1}\ s^{-1}$ of: **[NEET-2020]**

(1) 2.5×10^{-6}
(2) 2.25×10^{-15}
(3) 2.25×10^{15}
(4) 2.5×10^{6}

33. The color code of a resistance is given below:



The values of resistance and tolerance, respectively, are : **[NEET-2020]**

(1) 4.7 kΩ, 5%
(2) 470Ω, 5%
(3) 470 kΩ, 5%
(4) 47 kΩ, 10%

34. The solids which have the negative temperature coefficient of resistance are: **[NEET-2020]**

(1) semiconductors only
(2) insulators and semiconductors
(3) metals
(4) insulators only

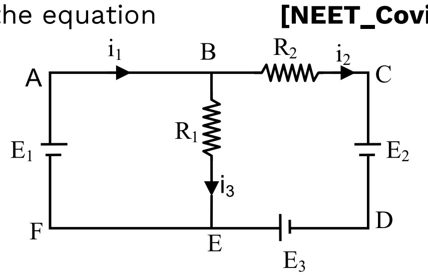
35. A resistance wire connected in the left gap of a metre bridge balances a 10 Ω resistance in the right gap at a point which divides the bridge wire in the ratio 3 : 2. If the length of the resistance wire is 1.5 m, then the length of 1Ω of the resistance wire is : **[NEET-2020]**

(1) 1.5×10^{-1} m (2) 1.5×10^{-2} m
(3) 1.0×10^{-2} m (4) 1.0×10^{-1} m

36. Two solid conductors are made up of same material, have same length and same resistance. One of them has a circular cross section of area A_1 and the other one has a square cross section of area A_2. The ratio A_1/A_2 is: **[NEET-Covid-2020]**

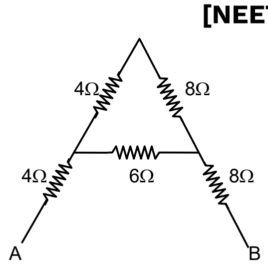
(1) 1.5 (2) 1
(3) 0.8 (4) 2

37. For the circuit given below, the Kirchhoff's loop rule for the loop BCDEB is given by the equation **[NEET_Covid_2020]**



(1) $-i_2R_2 + E_2 - E_3 + i_3R_1 = 0$
(2) $i_2R_2 + E_2 - E_3 - i_3R_1 = 0$
(3) $i_2R_2 + E_2 + E_3 + i_3R_1 = 0$
(4) $-i_2R_2 + E_2 + E_3 + i_3R_1 = 0$

38. The equivalent resistance between A and B for the mesh shown in the figure is: **[NEET_Covid_2020]**



(1) 7.2 Ω (2) 16 Ω
(3) 30 Ω (4) 4.8 Ω

39. **Column-I** gives certain physical terms associated with flow of current through a metallic conductor. **Column-II** gives some mathematical relations involving electrical quantities. Match **Column-I** and **Column-II** with appropriate relations.

Column-I		**Column-II**	
(A)	Drift Velocity	(P)	$\frac{m}{ne^2\rho}$
(B)	Electrical Resistivity	(Q)	nev_d
(C)	Relaxation Period	(R)	$\frac{eE}{m}\tau$
(D)	Current Density	(S)	$\frac{E}{J}$

(1) (A)-(R), (B)-(S), (C)-(P), (D)-(Q)
(2) (A)-(R), (B)-(S), (C)-(Q), (D)-(P)
(3) (A)-(R), (B)-(P), (C)-(S), (D)-(Q)
(4) (A)-(R), (B)-(Q), (C)-(S), (D)-(P)

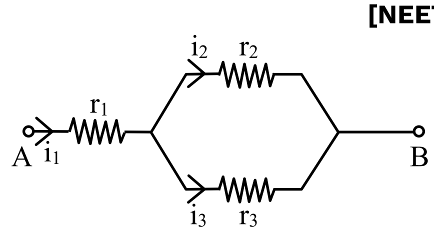
40. The effective resistance of a parallel connection that consists of four wires of equal length, equal area of cross-section and same material is 0.25 Ω. What will be the effective resistance if they are connected in series ? **[NEET-2021]**

(1) 0.25Ω (2) 0.5Ω
(3) 1Ω (4) 4Ω

41. In a potentiometer circuit a cell of EMF 1.5 V gives balance point at 36 cm length of wire. If another cell of EMF 2.5 V replaces the first cell, then at what length of the wire, the balance point occurs? **[NEET-2021]**

(1) 60 cm (2) 21.6 cm
(3) 64 cm (4) 62 cm

42. Three resistors having resistances r_1, r_2 and r_3 are connected as shown in the given circuit. The ratio $\frac{i_3}{i_1}$ of currents in terms of resistances used in the circuit is: **[NEET-2021]**



(1) $\frac{r_1}{r_2 + r_3}$ (2) $\frac{r_2}{r_2 + r_3}$
(3) $\frac{r_1}{r_1 + r_2}$ (4) $\frac{r_2}{r_1 + r_3}$

43. As the temperature increases, the electrical resistance: **[NEET-2022]**

(1) increases for both conductors and semiconductors
(2) decreases for both conductors and semiconductors
(3) increases for conductors but decreases for semiconductors
(4) decreases for conductors but increases for semiconductors

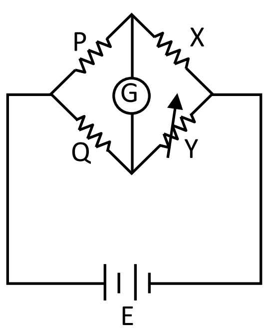
44. A copper wire of length 10 m and radius $\left(10^{-2}/\sqrt{\pi}\right)$m has electrical resistance of 10Ω. The current density in the wire for an electric field strength of 10 (V/m) is : **[NEET-2022]**

(1) 10^4 A /m^2 (2) 10^6 A /m^2
(3) 10^{-5} A /m^2 (4) 10^5 A /m^2

45. Two resistors of resistance, 100 Ω and 200 Ω are connected in parallel in an electrical circuit. The ratio of the thermal energy developed in 100 Ω to that in 200 Ω in a given time is: **[NEET-2022]**

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

46. A wheat stone bridge is used to determine the value of unknown resistance X by adjusting the variable resistance Y as shown in the figure. For the most precise measurement of X, the resistances P and Q **[NEET-2022]**

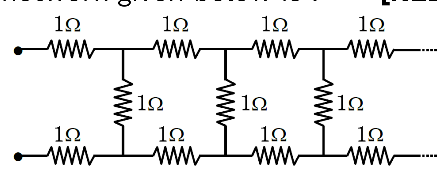


(1) should be approximately equal to 2X
(2) should be approximately equal and are small
(3) should be very large and unequal
(4) do not play any significant role

47. A cell of emf 4 V and internal resistance 0.5 Ω is connected to a 7.5 Ω external resistance. The terminal potential difference of the cell is - **[NEET-2022]**

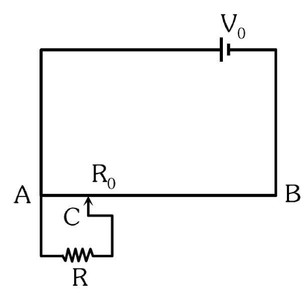
(1) 3.75 V (2) 4.25 V
(3) 4 V (4) 0.375 V

48. The equivalent resistance of the infinite network given below is : **[NEET-2022]**



(1) 2 Ω (2) $\left(1+\sqrt{2}\right)$ Ω
(3) $\left(1+\sqrt{3}\right)$ Ω (4) $\left(1+\sqrt{5}\right)$ Ω

49. The sliding contact C is at one fourth of the length of the potentiometer wire (AB) from A as shown in the circuit diagram. If the resistance drop (V) across the resistor R is : **[NEET-2022]**



(1) $\dfrac{4V_0R}{3R_0+16R}$ (2) $\dfrac{4V_0R}{3R_0+R}$
(3) $\dfrac{2V_0R}{3R_0+R}$ (4) $\dfrac{2V_0R}{3R_0+3R}$

ANSWER KEY

Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Ans.	4	1	2	3	4	3	3	3	1	1	2	3	3	3	2	4	1	4	2	1	4	3	3	1	1
Que.	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	
Ans.	2	4	4	1	4	1	4	2	2	4	2	2	2	1	4	1	2	3	4	2	2	1	3	1	