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CLASS XII

PHYSICS

THEORY & ASSIGNMENT

ON

CURRENT ELECTRICITY

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CHAPTER 3

CURRENT ELECTRICITY

- **CONDUCTOR**

  In some materials, the outer electrons of each atoms or molecules are only weakly bound to it. These electrons are almost free to move throughout the body of the material and are called free electrons. They are also known as conduction electrons. When such a material is placed in an electric field, the free electrons move in a direction opposite to the field. Such materials are called conductors.

- **INSULATOR**

  Another class of materials is called insulators in which all the electrons are tightly bound to their respective atoms or molecules. Effectively, there are no free electrons. When such a material is placed in an electric field, the electrons may slightly shift opposite to the field but they can't leave their parent atoms or molecules and hence can't move through long distances. Such materials are also called dielectrics.

- **SEMICONDUCTOR**

  In semiconductors, the behaviour is like an insulator at low levels of temperature. But at higher temperatures, a small number of electrons are able to free themselves and they respond to the applied electric field. As the number of free electrons in a semiconductor is much smaller than that in a conductor, its behaviour is in between a conductor and an insulator and hence, the name semiconductor. A freed electron in a semiconductor leaves a vacancy in its normal bound position. These vacancies also help in conduction.

ELECTRIC CURRENT

(a) Time rate of flow of charge through a cross section area is called **Current**.

$I_{av} = \frac{\Delta q}{\Delta t}$ and instantaneous current $i = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} = \frac{dq}{dt}$

(b) Direction of current is along the direction of flow of positive charge or opposite to the direction of flow of negative charge. But the current is a scalar quantity.

$\longrightarrow i$ $\qquad\qquad$ $\xleftarrow{i}$

$q\oplus \longrightarrow$ velocity $\qquad$ $q\ominus \longrightarrow$ velocity

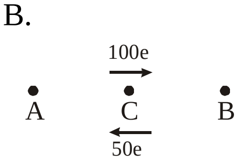
SI unit of current is ampere and

1 Ampere = 1 coloumb/sec

1 coloumb/sec = 1A

ILLUSTRATIONS

1. Two boys A and B are sitting at two points in a field. Both boys are sitting near assemblence of charged balls each carrying charge +3e. A throws 100 balls per second towards B while B throws 50 balls per second towards A. Find the current at the mid point of A and B.



Sol. Let mid point be C as shown

Charge moving to the right per unit time = $100 \times 3e = 300e$

Charge moving to the left per unit time = $50 \times 3e = 150e$

Movement of charge per unit time is $300e - 150e = 150e$ towards right

$I = 150e = 150 \times 1.6 \times 10^{-19}\,A = 2.4 \times 10^{-17}\,A$.

2. Flow of charge through a surface is given as $Q = 4t^2 + 2t$ (for 0 to 10 sec.)

(a) Find the current through the surface at $t = 5$sec. (b) Find the average current for (0 – 10 sec)

Sol. (a) Instantaneous current $I = \frac{dQ}{dt} = \frac{d}{dt}(4t^2 + 2t) = 8t + 2$ at $t = 5$ sec

$I = 8 \times 5 + 2 = 42$ Amp

(b) Average current $I = \frac{\Delta Q}{\Delta t} = \frac{Q}{t} = \frac{4 \times (10)^2 + 2 \times 10}{10} = \frac{420}{10} = 42$ Amp.

PRACTICE PROBLEM

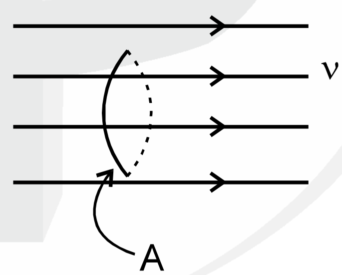
1. Charge flowing through a wire is given by $q = \alpha t - \beta t^2$ where α, β : constants. & t : time find current as a function of time t and time at which current become zero. And sketch current V/s time Graph?

2. Current through a wire is given by $i = 3t^2 + 2t$ where t is in sec. Find charge flowing through the wire in one minute.

CURRENT DENSITY

Current density, a vector, at a point have magnitude equal to current per unit normal area at that point and direction is along the direction of the current at that point.

$$\vec{J} = \frac{di}{ds}\hat{n}$$



so, $di = \vec{J}.d\vec{s}$

Current is flux of current density.

Due to principle of conservation of charge:

Charge entering at one end of a conductor = charge leaving at the other end, so current does not change with change in cross section and conductor remains uncharged when current flows through it.

ILLUSTRATIONS

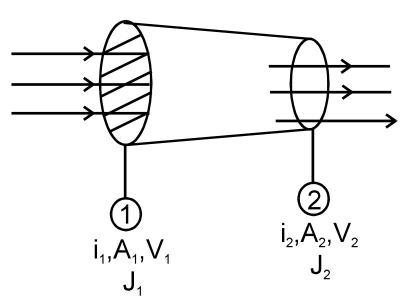
1. Current is flowing from a cylindrical conductor of non-uniform cross section area if $A_1 > A_2$ then find relation between

(a) i_1 and i_2

(b) j_1 and j_2

(c) v_1 and v_2

where i is current, j is current density and V is drift velocity.



Ans. $i_1 = i_2$, $V_1 < V_2$, $J_1 < J_2$

DRIFT VELOCITY

- A conductor contains a large no. of loosely bounded Electrons which we call free Electrons or conduction Electrons. The Remaining material is a collection of Relatively heavy positive ions which we called lattice. These ions keep on vibrating about their man-position.

- The Average amplitude depend upon temperature. The Electrons move in a zig – Zag path. As there is a large no. of free Electrons moving in Random directions. The Electric current through the area is therefore Zero. The Electron collides with heavier particle and comes to rest. If any electric field is applied these electrons again accelerates and get max^{m} velocity and again collides to come to rest. This process going on continuously. The average of maximum and zero velocity is known as drift velocity.
- Its denoted by V_d .
- The average distance moved is called free path λ .
- The average time taken b/w two consecutive collision is called average relaxation time. $\left[v_d = \frac{i}{nAe}\right]$, $\left[v_d = \frac{j}{ne}\right]$

ILLUSTRATIONS

1. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. Assume that each copper atom contributes roughly one conduction electron. The density of copper is 9.0×10^3 kg/m^3, and its atomic mass is 63.5 amu

Sol. The direction of drift velocity of conduction electrons is opposite to the electric field direction, i.e., electrons drift in the direction of increasing potential. The drift speed υ_d is given by $\upsilon_d = (I/neA)$.

Now, e = 1.6×10^{-19} C, A = 1.0×10^{-7} m^2, I = 1.5 A. The density of conduction electrons, n is equal to the number of atoms per cubic metre (assuming one conduction electron per Cu atom as is reasonable from its valence electron count of one). A cubic metre of copper has a mass of 9.0×10^3 kg. Since 6.0×10^{23} copper atoms have a mass of 63.5 g.

$$n = \frac{6.0 \times 10^{23}}{63.5} \times 9.0 \times 10^6 = 8.5 \times 10^{28} \text{ m}^{-3} \quad \text{which gives} \quad \upsilon_d = \frac{1.5}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.0 \times 1.0^{-7}} = 1.1 \times 10^{-3} \text{ ms}^{-1}.$$

2. A potential difference of 100 V is applied to the ends of a copper wire one metre long. Calculate the average drift velocity of the electrons. Compare it with thermal velocity at 27^{0}C. (use the results of Previous Illustration). given $\sigma = 5.81 \times 10^7 \Omega^{-1} m^{-1}$

Sol. Since $\Delta V = 100 V, l = 1 m$.

$\therefore$ electric field $= \frac{\Delta V}{l} = \frac{100}{1} = 100 Vm^{-1}$

Also, conductivity $\sigma = 5.81 \times 10^7 \Omega^{-1} m^{-1}$ N = 8.5×10^{28} m^{-3}

$$\therefore \upsilon_d = \frac{\sigma}{en} E = \frac{5.81 \times 10^7 \times 100}{1.6 \times 10^{-19} \times 8.5 \times 10^{28}} = 0.43 \text{ m s}^{-1}$$

PRACTICE PROBLEM

1. Find the relation between drift velocity and electric current.

2. The electron drift speed is estimated to be only a few mm/s for currents in the range of a few amperes. How then is current established almost the instant a circuit is closed?

3. The electron drift arises due to the force experienced by elertrons in the electric field inside the conductor. But force should cause acceleration. Why then do the being constantly accelerated by this electric field.

This law states that at given temperature. Potential diff (v) Across a conductor is proportional to the current i in the conductor.

$$V \alpha\, i$$

At constant temp: $[V = iR]$ R is Constant and Called Resistance

Unit of resistance is ohm. $R = \frac{V}{i} = \frac{\text{volt}}{\text{Amp}} = \underline{\text{ohm.}}$

- All metallic conductors at low temperature follow ohm's law & are called ohmic conductors. As the current increases, resistance of the metal also increases due to the heating of metal. The potential current relationship now is no more linear & the conductor becomes non-ohmic.

  P-n junction (diode) is non-ohmic circuit.

RESISTIVITY AND ITS ORIGIN

The resistance of a resistor (an element in a circuit with some resistance R) depends on its geometrical factors (length, cross-sectional area) and also on the nature of the substance of which the resistor is made. It is convenient to separate out the 'size' factors from the resistance R so that we can define a quantity that is characteristic of the material and is independent of the size or shape. Consider a rectangular slab of length l and area of cross section A. For a fixed current I, if the length of the slab is doubled, the potential drop across the slab also doubles. (It is the electric field that drives the current in the conductor and potential difference is electric field times the distance). This means that resistance of the slabs doubles with the doubling of its length. That is, $R \propto l$. Next, imagine the slab as being made of two parallel slabs, each of area $\frac{A}{2}$. If for a given voltage V, the current I flows across the full slab, it is clear that through each half-slab, the current flowing is $\frac{I}{2}$. Thus, the resistance of each half-slab is twice that of the full slab. That is, $R \propto \frac{1}{A}$. Combining the two dependences, we get

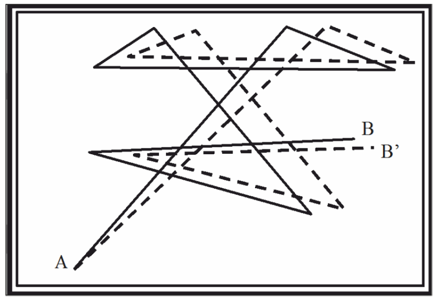
$$R \propto \frac{l}{A} \quad \text{...(iv)} \qquad \textbf{or} \qquad R = \frac{\rho l}{A} \quad \text{...(v)}$$

where ρ is a constant of proportionality called resistivity. It depends only on the nature of the material of the resistor and its physical conditions such as temperature and pressure. The unit of resistivity is ohm m (Ωm). The inverse of ρ is called conductivity, and is denoted by σ. The unit of σ is $(\Omega m)^{-1}$ or mho m^{-1} or siemen m^{-1}.

A perfect conductor would have zero resistivity and a perfect insulator would have infinite resistivity. Though these are ideal limits, the electrical resistivity of substances has a very wide range. Metals have low resistivity of 10^{-8} Ωm to 10^{-6} Ωm, while insulators like glass or rubber have resistivity, some 10^{18} times (or even more) greater. Generally, good electrical conductors like metals are also good conductors of heat, while insulators like ceramic or plastic materials are also poor thermal conductors.

ORIGIN OF RESISTIVITY

The motion of charge carriers (electrons) in a conductor is very different from that of charges in empty space. In the latter case, under an external electric field, the charge carriers would accelerate. In a conductor, on the other hand, when the current is steady, the charge carriers move with a certain average velocity called as drift velocity. At any temperature, the electrons in a metal have a certain distribution of velocities. When there is no external field, all directions are equally likely, and there is no overall drift. In the presence of an external field, each electron experiences an acceleration of $\frac{eE}{m}$ opposite to the field direction. But this acceleration is momentary, since electrons are continually making random collisions with vibrating atoms or ions or other electrons of the metal. After a collision, each electron makes a fresh start, accelerates and gets deflected randomly again.



We next define a physical quantity called current density vector, denoted by **j.** The direction of **j** is the direction of flow of positive charge (or opposite to the direction of drift of electrons in a metal). The magnitude of **j** is the amount of charge flowing per unit cross sectional area per second. Thus, if **δS** is an area element, **j**. **δS** is the amount of charge flowing across the area element per second. If **A** is taken to be the cross-sectional area of a wire (with the direction of **A** along the conventional current), **j**. **A** is nothing but the current through the wire. In this case, **j** is parallel to **A,** so

$$dI = \vec{j}.\vec{ds} \quad ; \quad I = \int \vec{j}.\vec{ds} \quad ; \quad I = jA$$

If the drift speed of electrons is υ_d, the amount of charge flowing across a unit cross-sectional area in unit time is contained in a cylinder of base of unit area and height υ_d i.e., in a volume $1 \times \upsilon_d = \upsilon_d$ (Fig.). If n is the number density of electrons in the metal, i.e., the number of electrons per unit volume, the total magnitude of charge contained in the cylinder of volume υ_d is n e υ_d . Therefore,

$$j = ne\upsilon_d \quad \text{and} \quad I = n\ e\ \upsilon_d A$$

Here, e is the magnitude of electronic charge. Then we can rewrite $j = \dfrac{E}{\rho} = \sigma E$

The more familiar form V = IR is in terms of directly measurable quantities like V and I, while the form $\vec{j} = \sigma\vec{E}$ relates the basic vector quantities of the problem, namely, current density vector and the electric field vector.

TEMPERATURE DEPENDENCE OF RESISTANCE

The resistance of most conductors and of all pure metals increases with temperature. But in carbon the resistance decreases with temperature. There are some alloys where there is no change of resistance with temperature. If R_0 and R be the resistance of a conductor at 0°C and θ°C, then it is found that $R = R_0(1 + \alpha\theta)$

where α is a constant called the temperature coefficient of resistance. $\alpha = \dfrac{R - R_0}{R_0.\theta}$ & the unit of α is K^{-1} or $°C^{-1}$.

If R_1 and R_2 be the resistance of a conductor at temperatures θ_1°C and θ_2°C, then

$$R_1 = R_0(1 + \alpha\theta_1) \text{ and } R_2 = R_0(1 + \alpha\theta_2) \quad \text{and } \alpha = \frac{R_2 - R_1}{R_1\theta_2 - R_2\theta_1}$$

COLOUR CODE FOR RESISTORS

Resistors of different values are commercially available. To make a resistor, carbon with a suitable binding agent is molded into a cylinder. Wire leads are attached to the cylinder and the entire register is encased in a ceramic or plastic jacket. The two leads connect the resistor to a circuit such as those for radios, amplifiers etc. The value of the resistance is indicated by four coloured-bands, marked on the surface of the cylinder (figure). The meanings of the four positions of the bands are shown in figure and the meanings of different colours are given in table.

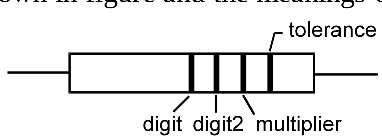


Table : Resistance codes (resistance given in ohm)

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	
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		0.1	5%
Silver		0.01	10%
No Colour			20%

For example, suppose the colours on the resistor shown in figure are brown yellow, green and gold as read from left to right. Using table, the resistance is $(14 \times 10^5 \pm 5\%)W = (1.4 \pm 0.07)\ M\Omega$.

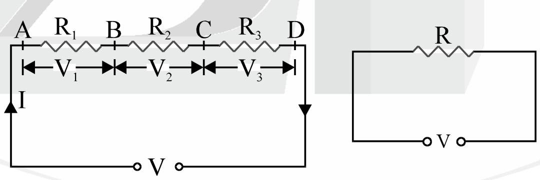
Brown	Yellow	Green	Gold
1	4	10	5%

Sometimes, the tolerance band is missing from the code so that there are only three bands. This means the tolerance is 20%.

COMBINATION OF RESISTANCES

Resistances in Series Combination

When some conductors having resistances R_1, R_2 and R_3 etc. are joined end-on-end as Figure, the are said to be connected in series. It can be proved that the equivalent resistance or total resistance between points A and D is equal to the sum of the three individual resistances. Being a series circuit, it should be remembered that (i) current is the same through all the three conductors (ii) but voltage drop across each is different due to its different resistances and is given by Ohm's Law and (iii) sum of the three voltage drops is equal to the voltage applied across the three conductors. There is a progressive fall in potential as we go from point A to D as shown in figure.



$\therefore\ V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$ (Ohm's Law)

But, V = IR

Where R is the equivalent resistance of the series combination.

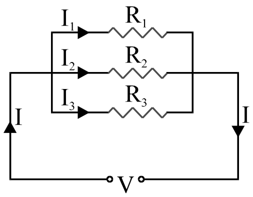
$\therefore\ IR = IR_1 + IR_2 + IR_3$ or $R = R_1 + R_2 + R_3$ Also $\frac{1}{G} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3}$

As seen from above, the main characteristics of a series circuit are :

1. same current flows through all parts of the circuit.
2. different resistors have their individual voltage drops.
3. voltage drops are additive.
4. applied voltage equals the sum of different voltage drops
5. resistances are additive

RESISTANCES IN PARALLEL COMBINATION

Three resistances, as joined as shown in figure are said to be connected in parallel. In the case (i) p.d. across all resistances is the same (ii) current in each resistor is different and is given by Ohm's Law and (iii) the total current is the sum of the three separate currents.



$$I = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

Now, $I = \dfrac{V}{R}$ where V is the applied voltage. R = equivalent resistance of the parallel combination.

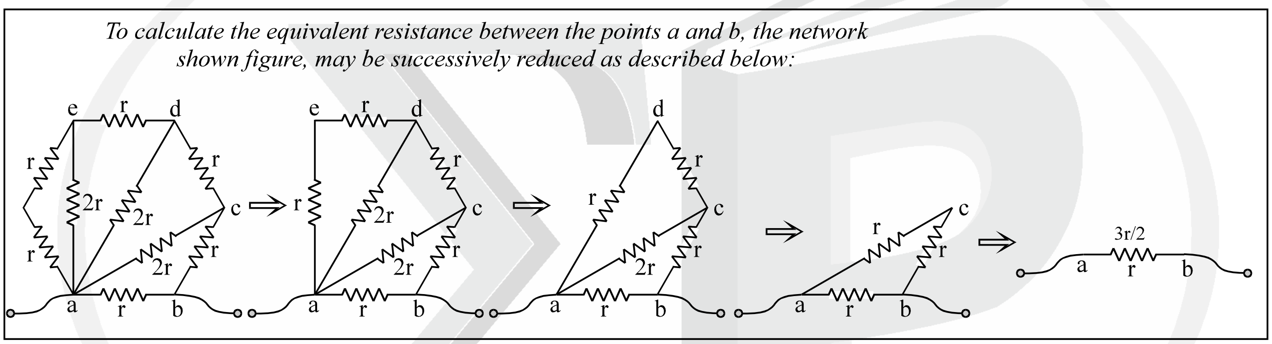
$$\therefore \quad \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \text{ or } \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Also $G = G_1 + G_2 + G_3$

RESISTANCES IN MIXED COMBINATION

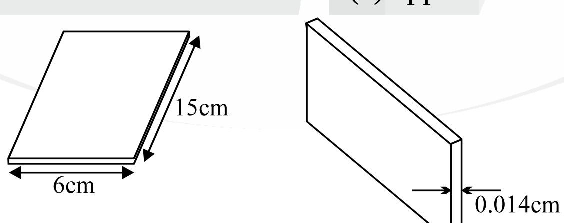
If resistance are arranged in series-parallel mixed grouping, we apply method of successive reduction to find equivalent resistance.

To calculate the equivalent resistance between the points a and b, the network shown figure, may be successively reduced as described below:



ILLUSTRATIONS

1. The resistivity of a ferric-chromium-aluminium alloy is 51×10^{-8} Ω-m. A sheet of the material is 15 cm long, 6 cm wide and 0.014 cm thick. Determine resistance between (a) opposite ends and (b) opposite faces.



(a) (b)

Sol. (a) As seen from figure (a) in this case, $\ell = 15$ cm $= 0.15$ m

$A = 6 \times 0.014 = 0.084 \text{ cm}^2 = 0.084 \times 10^{-4} \text{ m}^2$

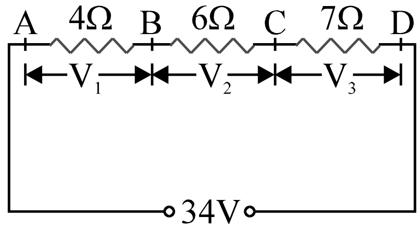
$$R = \rho\frac{\ell}{A} = \frac{51\times10^{-8}\times0.15}{0.084\times10^{-4}} = 9.1\times10^{-3}\,\Omega$$

(b) As seen from figure (b) here $\ell = 0.014$ cm $= 14 \times 10^{-5}$ m

$A = 15 \times 6 = 90 \text{ cm}^2 = 9 \times 10^{-3} \text{ m}^2$

$\therefore\ R = 51 \times 10^{-8} \times 14 \times 10^{-5}/9\times10^{-3} = 79.3 \times 10^{-10}\ \Omega$

2. Three resistors of values 4 ohm, 6 ohm and 7 ohm are in series and a potential difference of 34 V is applied across the grouping. Find the potential drop across each resistor.



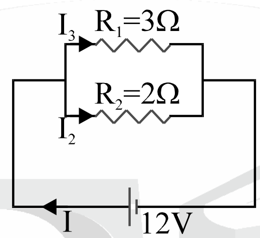
Sol. The current through the circuit $= \dfrac{34\text{V}}{(4+6+7)\text{ohm}} = 2\text{A}$

potential difference across 4 ohm resistor = IR = 2 A × 4 ohm = 8 V

potential difference across 4 ohm resistor = 2 A × 6 ohm = 12 V

potential difference across 4 ohm resistor = 2 A × 7 ohm = 14 V

3. Two resistance 3 ohm and 2 ohm are in parallel connection and a potential difference of 12 V is applied across them. Find



(a) equivalent resistance of the parallel combination, (b) the circuit current and (c) the branch currents.

Sol. (a) Two resistors R_1 and R_2 are in parallel. Their equivalent resistance R is given by $\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

or $$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{2\times 3}{2+3} = \frac{6}{5} = 1.2\ \Omega$$

(b) The circuit current = Circuit voltage/Circuit resistance $\dfrac{12\text{V}}{1.2\Omega} = 10\text{ A}$

(c) The current through 2 ohm resistor $I_2 = I \times \dfrac{3}{2+3} = 10 \times \dfrac{3}{5} = 6\text{A}$

The current through 3 ohm resistor $I_3 = I \times \dfrac{2}{2+3} = 10 \times \dfrac{2}{5} = 4\text{A}$ (Also $I_3 = I - I_2 = 10\text{ A} - 6\text{ A} = 4\text{ A}$)

PRACTICE PROBLEM

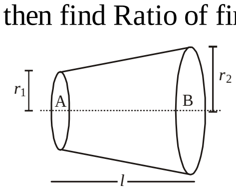
1. Derive Ohm's law with the help of free electron theory.

2. If a wire is stretched to double its length, find the new resistance if original resistance of wire was R.

3. The wire is stretched to increase the length by 1% find the percentage change in the Resistance.

4. If Radius of cylindrical conductor is reduced to half then find Ratio of final to initial resistance?

5. Find resistance between A and B, if resistivity is ρ?



6. Find resistance between the surfaces AB, CD and between remaining two surfaces.

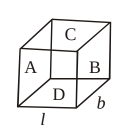
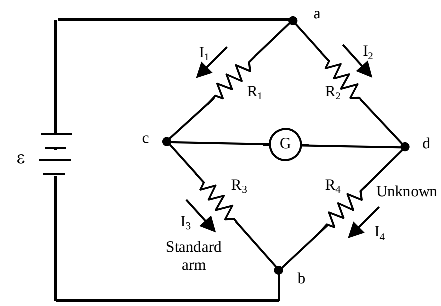


Figure shows the fundamental diagram of wheatstone bridge. The bridge has four resistive arms, together with a source of emf (a battery) and a galvanometer. The current through the galvanometer depends on the potential difference between the point c and d. The bridge is said to be balanced when the potential difference across the galvanometer is 0 V so that there is no current through the galvanometer. This condition occurs when the potential difference from point c to point a, equals the potential difference from point d to point a; or by referring to the other battery terminal, when the voltage from other point c to point b equals the voltage from point d to point b. Hence, the bridge is balanced when



$$I_1R_1 = I_2R_2 \quad \ldots(i)$$

if the galvanometer current is zero, the following conditions also exist:

$$I_1 = I_3 = \frac{\varepsilon}{R_1 + R_3} \quad \ldots(ii)$$

and $$I_2 = I_4 = \frac{\varepsilon}{R_2 + R_4} \quad \ldots(iii)$$

Combining Eqs. (i), (ii) and (iii) and simplifying, we obtain $$\frac{R_1}{R_1 + R_3} = \frac{R_2}{R_2 + R_4} \quad \ldots(iv)$$

from which we get $R_1R_4 = R_2R_3$ or $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ ...(v)

Equation (v) is the well known expression for balance of the wheatstone bridge. If three of the resistances have known values, the fourth may be determined from Equation (v). Hence, if R_4 is the unknown resistor, its resistance can be expressed in terms of remaining resistors

$$R_4 = R_3\frac{R_2}{R_1} \quad \ldots(vi)$$

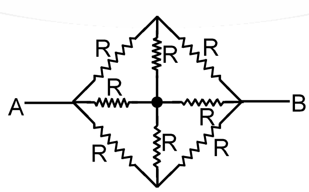
Resistance R_3 is called the standard arm of the bridge and resistors R_2 and R_1 are called the ratio arms.

SYMMETRICAL CIRCUITS

Some circuits can be modified to have simpler solution by using symmetry if they are solved by traditional method of KVL and KCL then it would take much time.

ILLUSTRATIONS

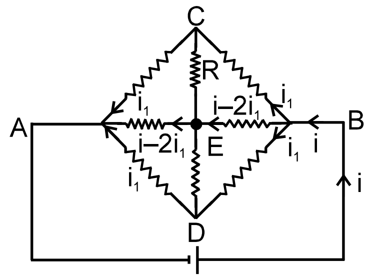
1. Find the equivalent Resistance between A and B.



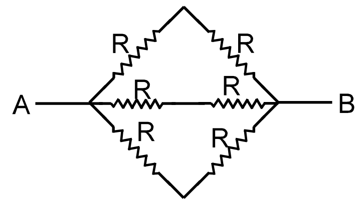
Sol. **I Method :** Here no two resistors appear to be in series or parallel no wheatstone bridge here. This circuit will be solve by using $R_{eq} = \frac{V}{I}$. The branches AC and AD are symmetrical

∴ current through then will be same.

The circuit is also similar from left side and right side current distribution while entering through B and an exiting from A will be same. Using all these facts the currents are as shown in the figure. It is clear that current in resistor between C and E is 0 and also in ED is 0. It's equivalent is shown in figure (b)



(fig. a)



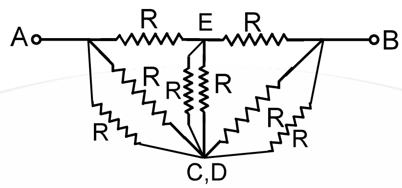
(fig. b)

$$R_{eq} = \frac{2R}{3}$$

II Method :

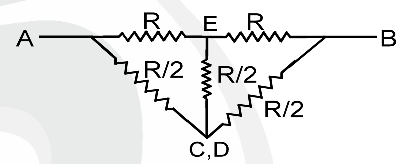
$\therefore$ The potential difference in R between (B, C) and between (B.D.) is same $V_C = V_D$

Hence the point C and D are same hence circuit can be simplified as



This called folding.

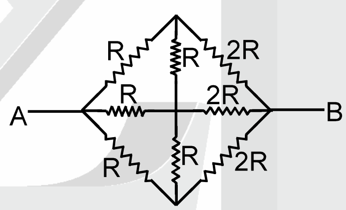
Now, it is Balanced wheatstone bridge



$$R_{eq} = \frac{2R \times R}{2R + R} = \frac{2R}{3}$$

Note : In II Method it is not necessary to know the currents in CA and DA.

2. Find the equivalent Resistance between A and B



Sol. In this case the circuit has symmetry in the two branches AC and AD at the input

$\therefore$ current in them are same but from input & from exit the circuit is not similar ($\because$ on left R & on right 2R)

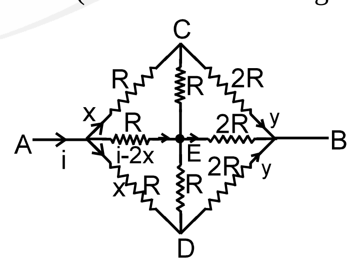
$\therefore$ on both sides the distribution of current will not be similar.

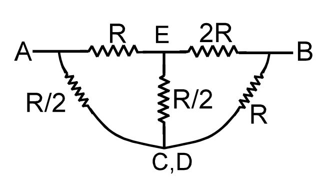
Here $V_c = V_d$

hence C and D are same point

the circuit can be simplified that

Now it is balanced wheat stone bridge

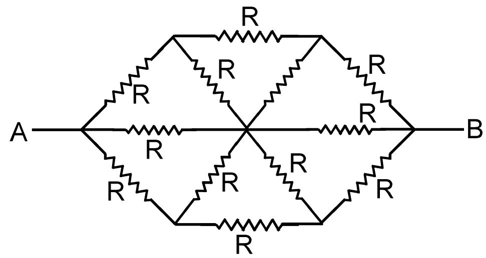




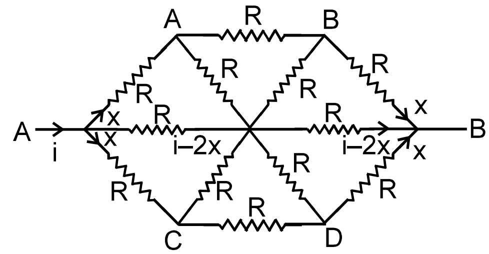
$$R_{eq} = \frac{3R \times \frac{3R}{2}}{3R + \frac{3R}{2}}$$

$$= \frac{\frac{9}{2}R}{\frac{9}{2}} = R.$$

3. Find the equivalent Resistance between A and B

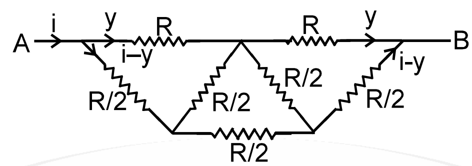


Sol.

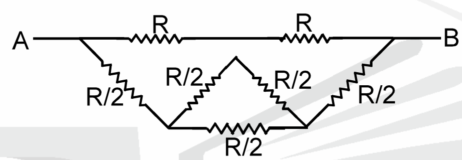


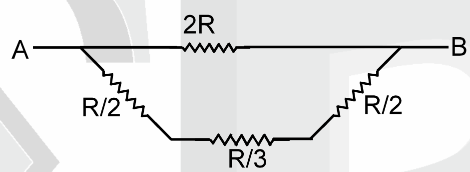
Here $V_A = V_C$ and $V_B = V_D$

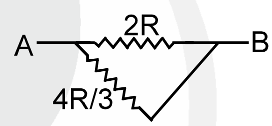
Here the circuit can be simplified as this circuit can be simplified as



$$R_{eq} = \frac{2R \times \frac{4R}{3}}{\frac{10R}{3}}$$

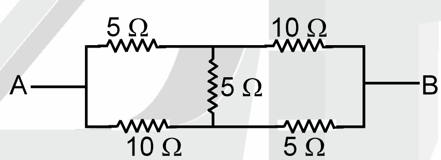




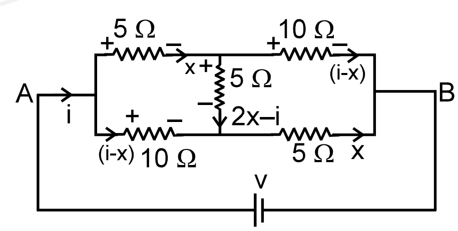


$= \frac{4R}{5}$ **Ans.**

4. Find the equivalent Resistance between A and B.



Sol. It is wheat stone bridge but not balanced. No series parallel connections. But similar values on input side and output. Here we see that even after using symmetry the circuit does not reduce to series parallel combination as in previous examples.



$\therefore$ applying kirchoff voltage law

$v - 10(i - x) - 5x = 0$

$v - 10i + 5x = 0$ ...(1)

$10(i - x) - 5(2x - i) - 5x = 0$

$10i - 10x - 10x + 5i - 5x = 0$

$15i - 25x = 0$

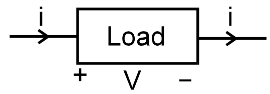
$x = \frac{15}{25} i$; $5x = 3i$ ....(2)

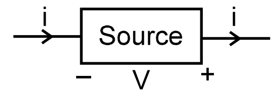
Using (2) and (1)

$\therefore v - 10i + 3i = 0$ $\frac{v}{I} = 7\Omega$ $R_{eq} = 7\Omega$ **Ans.**

Energy liberated per second in a device is called its power. The electrical power P delivered or consumed by an electrical device is given by $P = VI$, where V = Potential difference across the device & I = Current. If the current enters the higher potential point of the device then electric power is consumed by it (i.e. acts as load). If the current enters the lower potential point then the device supplies power (i.e. acts as source).

Power$= \frac{V.dq}{dt}$





$= V I$ **P = V I**

If power is constant then energy = P t. If power is variable then

Energy = $\int p dt$

Power consumed by a resistor $P = I^2R = VI = \frac{V^2}{R}$.

When a current is passed through a resistor energy is wasted in overcoming the resistance of the wire. This energy is converted into heat. $W = VIt = I^2 Rt = \frac{V^2}{R}t$

The heat generated (in joules) when a current of I ampere flows through a resistance of R ohm for T second is given by:

$H = I^2 RT$ Joule $= \frac{I^2RT}{4.2}$ Calorie

1 unit of electrical energy = 1 Kilowatt hour = 1 KWh = 3.6×10^6 Joule.

ILLUSTRATIONS

1. If bulb rating is 100 watt and 220 V then determine:

(a) Resistance of filament (b) Current through filament

(c) If bulb operate at 110 volt power supply then find power consume by bulb.

Sol. Bulb rating is 100 W and 220 V bulb means when 220 V potential difference is applied between the two ends then the power consume is 100 W

Here V = 220

$P = 100$; $\frac{V^2}{R} = 100$

So $R = 484\ \Omega$

Since Resistance depends only on material hence it is constant for bulb $I = \frac{V}{R} = \frac{220}{22 \times 22} = \frac{5}{11}$ Amp.

power consumed at 110 V

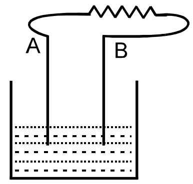
$\therefore$ power consumed $= \frac{110 \times 110}{480} = 25$ W

PRACTICE PROBLEM

1. In turning point institute 10 lamps (20W) and 6 fans (60W) run regularly for 8 hours daily along with it 4 AC of 2000W operate on an average for 4 hours. Calculate electricity bill for april 2016 if cost for 1 unit 10 Rs.

BATTERY (CELL)

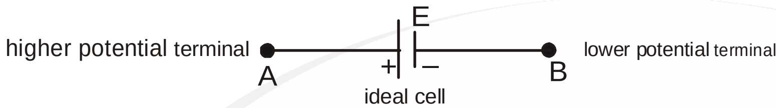
A battery is a device which maintains a potential difference across its two terminals A and B. Dry cells, secondary cells, generator and thermocouple are the devices used for producing potential difference in an electric circuit. Arrangement of cell or battery is shown in figure. Electrolyte provides continuity for current.



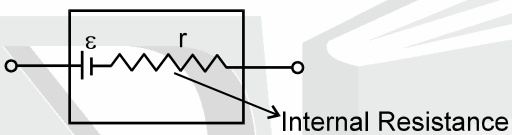
ELECTROMOTIVE FORCE : (E.M.F.)

Definition I : Electromotive force is the capability of the system to make the charge flow.
Definition II : It is the work done by the battery for the flow of 1 coloumb charge from lower potential terminal to higher potential terminal inside the battery.

Representation for battery : **Ideal cell** : Cell in which there is no heating effect.



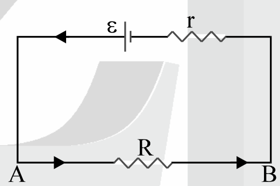
Non ideal cell : Cell in which there is heating effect inside due to opposition to the current flow internally



Non ideal cell.

GROUPING OF CELLS

If a cell of emf ε and internal resistance r be connected with a resistance R the total resistance in the circuit is (R + r).



The current through the circuit $I = \dfrac{\varepsilon}{R + r}$

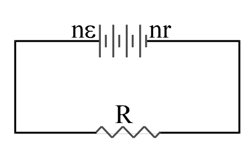
Potential difference acros the ends A and B of $R = IR = \dfrac{\varepsilon R}{R + r}$

Thus, although the emf of the cell is ε, the effective potential difference it can deliver is less than ε and it is given by $V_{AB} = \varepsilon - Ir$

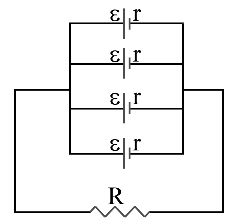
The quantity V_{AB} is called the terminal potential difference of the cell and this is also the potential difference across the external resistance R.

If $R \to \infty$, $V_{AB} \to \varepsilon$, the emf of the cell.

Cells in Series



Let there be n cells each of emf ε, arranged in series. Let r be the internal resistance of each cell. The total emf is nε and the total internal resistance is nr. If R be the external load, the current I through the circuit $I = \dfrac{n\varepsilon}{R + nr}$.



Cells in Parallel

In m cells each of emf ε and internal resistance r be connected in parallel and if this combination be connected to an external resistance R, then the emf of the circuit = ε. The internal resistance of the circuit = the resistance due to m resistances each of r in parallel = $\frac{r}{m}$.

Now the current through the external resistor $R = \frac{\varepsilon}{R + \frac{r}{m}} = \frac{m\varepsilon}{mR + r}$

Mixed Grouping of Cells

Let n identical cells be arranged in series and let m such rows be connected in parallel. Obviously the total number of cells is nm.

The emf of the system = nε

The internal resistance of the system = nr/m

The current through the external resistance R $I = \frac{n\varepsilon}{R + \frac{nr}{m}} = \frac{mn\varepsilon}{mR + nr}$

Arrangement of Cells for Maximum Current

Considering the case where total number of cell (mn) is given and it is required to find the condition for maximum current.

In this case the product mn, ε, r and R are constants and m and n alone can be varied to get I maximum.

For I_{max} denominator (mR + nr) should be minimum in equation $I = \frac{mn\varepsilon}{mR + nr}$. This happens when mR = nr or R = nr/m.

Hence the current through the external resistance R is a maximum when it is equal to internal resistance of the battery nr/m.

ILLUSTRATIONS

1. What is the meaning of 10 Amp. hr ?

Sol. It means if the 10 A current is withdrawn then the battery will work for 1 hour.

10 Amp $\longrightarrow$ 1 hr ; 1 Amp $\longrightarrow$ 10 hr ; ½ Amp $\longrightarrow$ 20 hr

2. Six cells are connected (a) in series, (b) in parallel and (c) in 2 rows each containing 3 cells. The emf of each cell is 1.08 V and its internal resistance is 1 ohm. Calculate the currents that would flow through an external resistance of 5 ohm in the three cases.

Sol. (a) The cells in series.

Given that ε = 1.08V, n = 6, r = 1 ohm, R = 5 ohm

The total emf = nε = 6 × 1.08 V

The total internal resistance nr = 6 × 1 = 6 ohm

The current in the circuit $I_s = \frac{n\varepsilon}{R + nr} = \frac{6 \times 1.08}{5 + 6} = 0.589\ A$

(b) The cells in parallel, Here ε = 1.08 v, m = 6, r = 1 ohm, R = 5 ohm

$$I_p = \frac{m\varepsilon}{mR + r} = \frac{6 \times 1.08}{6 \times 5 + 1} = \frac{6.48}{31} = 0.209\ A$$

(c) The cells in multiple arc with n = 3, m = 2 $I = \frac{mn\varepsilon}{mR + nr} = \frac{6 \times 1.08}{(2 \times 5) + (3 \times 1)} = \frac{6.48}{13} = 0.498\ A$.

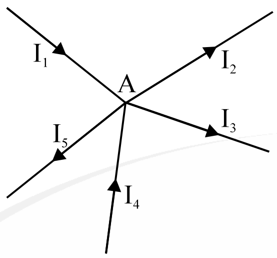
These laws are more comprehensive then Ohm's law and are used for solving electrical networks which may not be readily solved by the latter. Kirchoff's laws, two in number, are particularly useful (a) in determining the equivalent resistance of a complicated network of conductors and (b) for calculating the currents flowing in the various conductors. The two laws are :

(i) Kirchhoff's Point Law or Current Law (KCL)

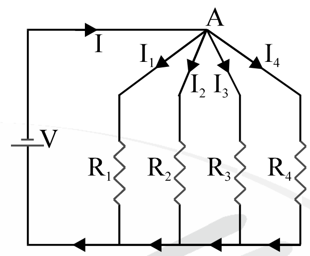
It states as follows :

in any electrical network, the algebraic sum of the currents meeting at a point (or junction) is zero.

Put in another way, it simply means that the total current leaving a junction is equal to the total current entering that junction. It is obviously true because there is no accumulation of charge at the junction of the network.



(a)



(b)

Consider the case of a few conductors meeting at a point A as in figure (a). Some conductors have current leading to point A. Whereas some have currents leading away from point A. Assuming the incoming currents to be positive and the outgoing currents negative, we have

$$I_1 + (-I_2) + (-I_3) + (+I_4) + (-I_5) = 0$$

or $I_1 - I_2 - I_3 + I_4 - I_5 = 0$ or $I_1 + I_4 = I_2 + I_3 + I_5$ or incoming currents = outgoing current

Similarly, in figure(b) for node A $+I + (-I_1) + (-I_2) + (-I_3) + (-I_4) = 0$ or $I = I_1 + I_2 + I_3 + I_4$

We can express the above conclusing thus : $\sum I = 0$ ... at a junction

(ii) Kirchhoff's Mesh Law or Voltage Law (KVL)

It state as follows :

the algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the e.m.fs. in that path is zero.

In other words, $\sum IR + \sum \text{e.m.f.} = 0$

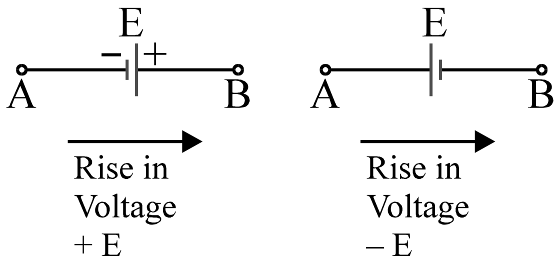
It should be noted that algebraic sum is the sum which takes into account the polarities of the voltage drops.

Working with Kirchhoff's law

In applying Kirchhoffs laws to specific problems, particular attention should be paid to the algebraic signs of voltage drops and e.m.fs. otherwise results will come out to be wrong. Following sign conventions is suggested :

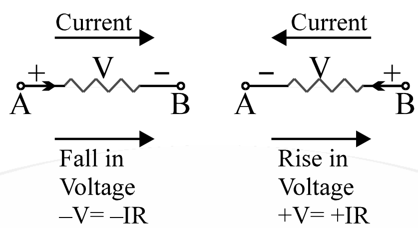
(a) Sign of Battery E.M.F.

A rise in voltage should be given a + ve sign and a fall in voltage a –ve sign. Keeping this in mind, it is clear that as we go from the –ve terminal of a battery to its +ve terminal, there is a rise in potential, hence this voltage should be given a +ve sign. If, on the other hand, we go from +ve terminal to –ve terminal, then there is a fall in potential, hence this voltage should be preceded be a –ve sing. It is important to note that the sign of the battery e.m.f. is independent of the direction of the current through that branch.



(b) Sign of IR Drop

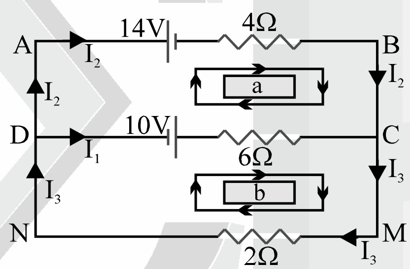
Now, take the case of a resistor as shown in figure. If we go through a resistor in the same direction as the current, then there is a fall in potential because current flows from a higher to a lower potential. Hence, this voltage fall should be taken –ve. However, if we go in a direction opposite to that of the current, then there is a rise in voltage. Hence, this voltage rise should be given a positive sign.



It is clear that the sign of voltage drop across a resistor depends on the direction of current through that resistor but is independent of the polarity of any other source of e.m.f. in the circuit under consideration.

ILLUSTRATIONS

1. Calculate the currents I_1, I_2 and I_3 in the circuit shown in figure.



Sol. Junction rule at C yields $I_1 + I_2 - I_3 = 0$ i.e., $I_1 + I_2 = I_3$ ....(1)

while loop for meshes a and b yields respectively : $-14 - 4I_2 + 6I_1 - 10 = 0$

i.e., $3I_1 - 2I_2 = 12$ ....(2)

and, $10 - 6I_1 - 2I_3 = 0$

i.e., $3I_1 + I_3 = 5$ ....(3)

Substituting I_3 from Equation (1) in (3) $4I_1 + I_2 = 5$

Solving equations (2) and (4) for I_1 and I_2, we find $I_1 = 2A$ and $I_2 = -3A$

And hence equation (1) yields, $I_3 = -1A$

The fact that I_2 and I_3 are negative implies that actual direction of I_2 and I_3 are opposite to that shown in the circuit.

Discharging and Charging Of Battery :

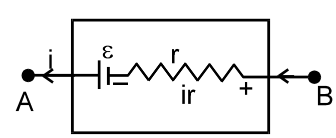
Case I :

Battery acting as a source (or battery is discharging)

$V_A - V_B = \varepsilon - ir$

$V_A - V_B \Rightarrow$ it is also called terminal voltage.

The rate at which the chemical energy of the cell is consumed = εi

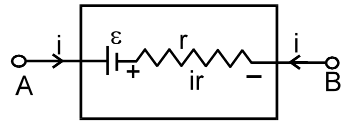


The rate at which heat is generated inside the battery or cell = i^2r

electric power output = $\varepsilon i - i^2r = (\varepsilon - ir)\,i$

Case II :

Battery acting as a load (or battery charging).



$V_A - V_B = \varepsilon + ir$

the rate at which chemical energy stored in the cell = εi

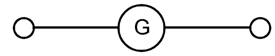
thermal power inside the cell = i^2r

electric power input = $\varepsilon i + i^2r = (\varepsilon + ir)\,i$

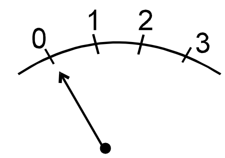
$= (v_A - V_B)\,i$

GALVANOMETER

Galvanometer is represented as follow :



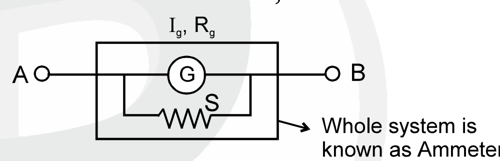
A linear scale is obtained the marking on the galvanometer are proportionate.



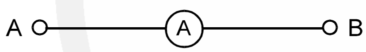
The galvanometer coil has some resistance represented by R_g . It is of the order few ohms. Its also has a maximum capacity to carry a current known as I_g. I_g is also the current required for full scale deflection. This galvanometer is called moving coil galvanometer.

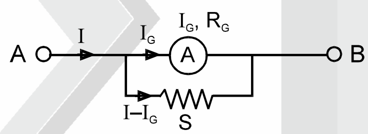
AMMETER

A shunt (small resistance) is connected in parallel with galvanometer to convert into ammeter; An ideal ammeter has zero resistance



Ammeter is represented as follow -





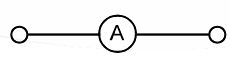
If maximum value of current to be measured by ammeter is I then $I_G \cdot R_G = (I - I_G)S$

$S = \dfrac{I_G.R_G}{I - I_G}$; $S = \dfrac{I_G \times R_G}{I}$ when $I >> I_G$.

where I = Maximum current that can be measured using the given ammeter.

For measuring the current the ammeter is connected is series.

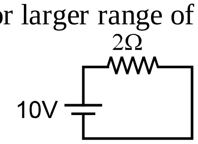
For calculation it is simply a resistance



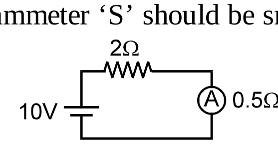
Resistance of ammeter $R_A = \dfrac{R_G.S}{R_G + S}$ for $S << R_G$ $\Rightarrow$ $R_A = S$

ILLUSTRATIONS

1. Find the current in the circuit for larger range of ammeter 'S' should be smaller (a) and (b).



(a)

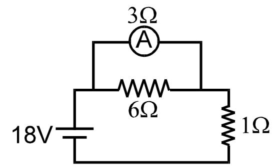


(b)

Sol. In A $I = \dfrac{10}{2} = 5A$ ln B $I = \dfrac{10}{2.5} = 4A$

here we see that the due to ammeter the current has reduced. A good ammeter has very low resistance as compared with other resistors, so that due to its presence in the circuit the current is not affected.

2. Find the reading of ammeter Is this the current through 6 Ω ?



Sol. $R_{eq} = \frac{3 \times 6}{3+6} + 1 = 3\ \Omega$

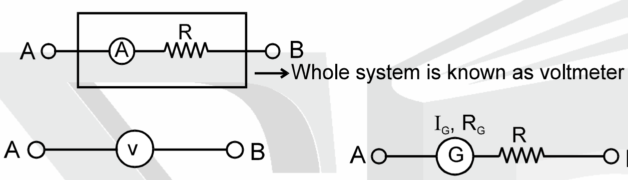
Current through battery $I = \frac{18}{3} = 6$ A So, current through ammeter = $6 \times \frac{6}{9} = 4$ A

No, it is not the current through the 6 Ω resistor.

Note : Ideal ammeter is equivalent to zero resistance wire for calculation potential difference across it is zero.

VOLTMETER

A high resistance is put in series with galvanometer. It is used to measure potential difference across a resistor in a circuit.



For maximum potential difference $V = I_G \cdot R_S + I_G R_G$ $R_S = \frac{V}{I_G} - R_G$. If $R_G << R_S \Rightarrow R_S \approx \frac{V}{I_G}$

For measuring the potential difference a voltmeter is connected across that element. (parallel to the that element it measures the potential difference that appears between terminals 'A' and 'B'.)

For calculation it is simply a resistance

Resistance of voltmeter $R_V = R_G + R_S \approx R_S$ $I_g = \frac{V_0}{R_g + R}$. $R \to \infty \Rightarrow$ Ideal voltmeter.

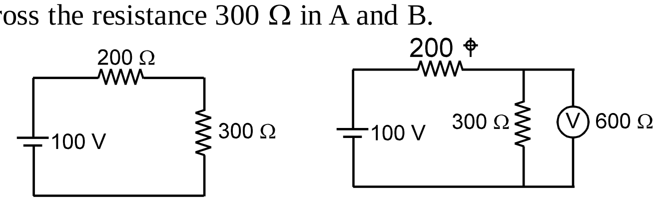
A good voltmeter has high value of resistance.

Ideal voltmeter → which has high value of resistance.

Note : For calculation purposes the current through the ideal voltmeter is zero.

ILLUSTRATIONS

1. Find potential difference across the resistance 300 Ω in A and B.



(A) (B)

Sol. In (A) : Potential difference = $\frac{100}{200+300} = 300 = 60$ volt

In (B) : Potential difference = $\dfrac{100}{200+\dfrac{300\times600}{300+600}}\times\dfrac{300\times600}{300+600}$ = 50 volt

We see that by connected voltmeter the voltage which was to be measured has changed. Such voltmeters are not good. If its resistance had been very large than 300 Ω then it would have not affected the voltage by much amount.

METRE BRIDGE (USE TO MEASURE UNKNOWN RESISTANCE)

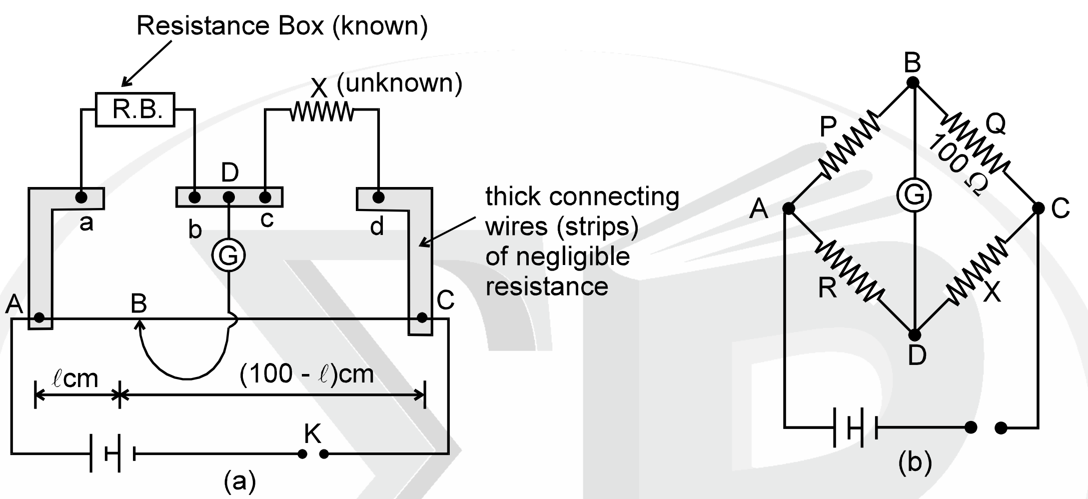
If AB = ℓ cm, then BC = $(100 - \ell)$ cm.

Resistance of the wire between A and B $R \propto \ell$

[$\because$ Specific resistance ρ and cross-sectional area A are the same for the whole of the wire]

or $R = \sigma\ell$ ...(1)

where σ is resistance per cm of wire.



Similarly, if Q is resistance of the wire between B and C, then $Q \propto 100 - \ell$

$\therefore$ $Q = \sigma(100 - \ell)$ ....(2)

Dividing (1) by (2), $\dfrac{P}{Q} = \dfrac{\ell}{100-\ell}$

Applying the condition for balanced Wheatstone bridge, we get R Q = P X

$\therefore$ $x = R\dfrac{Q}{P}$ or $X = \dfrac{100-\ell}{\ell}R$

Since R and ℓ are known, therefore, the value of X can be calculated.

Note: For batter accuracy, R is so adjusted that ℓ lies between 40 cm and 60 cm.

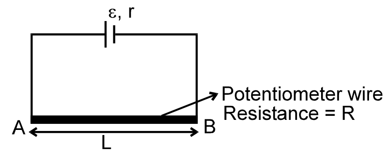
POTENTIOMETER

A potentiometer is a linear conductor of uniform cross-section with a steady current set up in it. This maintains a uniform potential gradient along the length of the wire. Any potential difference which is less then the potential difference maintained across the potentiometer wire can be measured using this.

The wire should have high resistivity and low expansion coefficient for example. Manganin or, Constantine wire etc.

$$I = \frac{\varepsilon}{r+R}$$

$$V_A - V_B = \frac{\varepsilon}{R+r}.R$$

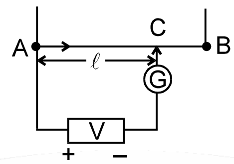


Potential gradient (x) → Potential difference per unit length of wire $x = \frac{V_A - V_B}{L} = \frac{\varepsilon}{R+r} \cdot \frac{R}{L}$

ILLUSTRATIONS

1. How to measure an unknown voltage using potentiometer.

Sol. The unknown voltage V is connected across the potentiometer wire as shown in figure. The positive terminal of the unknown voltage is kept on the same side as of the source of the top most battery. When reading of galvanometer is zero then we say that the meter is balanced. In that condition $V = x\,\ell$



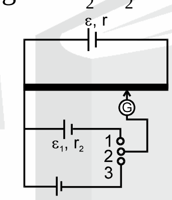
Application of potentiometer:

(a) To find emf of unknown cell and compare emf of two cells.

In case I: In figure (3) is joint to (1) then balance length = ℓ_1 $\varepsilon_1 = x\ell_1$ ....(1)

In case II: In figure (3) is joint to (2) then balance length = ℓ_2 $\varepsilon_2 = x\ell_2$ ....(2)

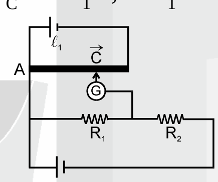
$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{\ell_1}{\ell_2}$$



If any one of ε_1 or ε_2 is known the other can be found. If x is known then both ε_1 and ε_2 can be found

(b) To find current if resistance is known $V_A - V_C = x\ell_1$; $IR_1 = x\ell_1$

$$I = \frac{x\ell_1}{R_1}$$

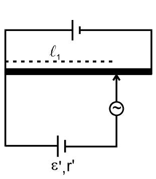


Similarly, we can find the value of R_2 also.

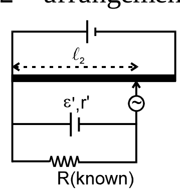
Potentiometer is ideal voltmeter because it does not draw any current from circuit, at the balance point.

(c) To find the internal resistance of cell.

I[st] arrangement



2[nd] arrangement



by first arrangement $\varepsilon' = x\ell_1$ ...(1)

by second arrangement $IR = x\ell_2$ $I = \frac{x\ell_2}{R}$, also $I = \frac{\varepsilon'}{r'+R}$

$\therefore \frac{\varepsilon'}{r'+R} = \frac{x\ell_2}{R}$ $\Rightarrow \frac{x\ell_1}{r'+R} = \frac{x\ell_2}{R}$ $r' = \left[\frac{\ell_1 - \ell_2}{\ell_2}\right]$

(d) Ammeter and voltmeter can be graduated by potentiometer.

(e) Ammeter and voltmeter can be calibrated by potentiometer.

EXERCISE

OHM'S LAW & RESISTANCE

1. A wire of resistivity ρ is stretched to twice its length. What will be its new resistivity?

2. Two wires A and B are of same metal, have the same area of cross-section and have their lengths in the ratio 2 : 1. What will be the ratio of currents flowing through them respectively, when the same potential difference is applied across length of each of them?

3. If potential difference V applied across a conductor is increased to 2V, how will the drift velocity of the electrons change?

4. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker?

5. Two electric bulbs A and B are marked 220 V, 60 W and 220 V, 100 W, respectively. Which one of the two has greater resistance?

6. Two bulbs whose resistance are in the ratio of 1 : 2 are connected in parallel to a source of constant voltage. What will be the ratio of power dissipation in these?

7. What is the largest voltage you can safely put across a resistor marked 196Ω –1W?

8. Two wires of the same material having lengths in the ratio 1 : 2 and diameters in the ratio 2 : 3 are connected in series with an accumulator. Compute the ratio of the potential difference across the two wires.

9. The number density of free electrons in a copper conduactor as estimated is 8.5×10^{28} m^{-3}. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is 2.0×10^{-6} m^2 and it is carrying a current of 3.0 A.

10. Give reasons why the electrical conductance of electrolytes is less than that of metals.

11. A wire is drawn so that its radius is halved. Its original resistance is 2Ω. What is its new resistance?

12. A potential difference V is applied across a conductor of length L and diameter D. How are the electric field E and the resistance R of conductor affected when in turn :

a. V is halved **b.** L is halved **c.** D is doubled? Justify your answer in each case.

13. A conductor of length 'l' is connected to a d.c. source of potential 'V'. If the length of the conductor is tripled by stretching it, keeping V constant, explain how do the following factors vary in the conductor :

a. Drift speed of electrons **b.** Resistance **c.** Resistivity

14. What is mobility of electrons? How is it related with the conductivity?

15. The electron drift speed is estimated to be only a few mm s^{-1} for currents in the range of a few amperes? How then is current established almost at the instant, circuit is closed?

16. Derive an expression for the resistivity of a good conductor, in terms of the relaxation time of electrons.

17. Define the term current density of a metallic conductor. Deduce the relation connecting current density (J) and the conductivity (σ) of the conductor when an electric field E is applied to it.

18. When electrons drift in a metal from lower to higher potential, does it mean that all the free electrons of the metal are moving in the same direction?

19. Define the term current density of a metallic conductor. Deduce the relation connecting current density i. and conductivity (σ) of the conductor, when an electric field E, is applied to it.

20. The electron drift arises due to the force experienced by electrons in the electric field inside the conductor. But force should cause acceleration. Why then do the electrons acquire a steady average drift speed?

21. Are the paths of electrons are straight lines in between the successive collision (with the ions of the metal) in the

a. absence of electric field **b.** precence of electric field

22. Conductor of length l is connected to a DC source of potential V. If the length of the conductor is tripled by gradually streching it, keeping V constant, how will

a. drift speed of electrons and

b. the resistance of the conductor be affected? Justify your answer.

23. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time.

24. Two metallic wires of the same material have the same length but their cross-sectional area is in the ratio of 1 : 2. They are connected

a. in series and **b.** in parallel

Compare the drift velocities of electrons in the two wires in both cases a. and b.

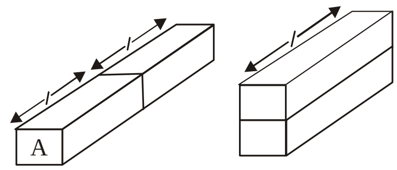
25. Of metals and alloys, which have greater value of temperature coefficient of resistance?

26. Sketch a graph showing variation of resistivity of carbon with temperature.

27. Define the term temperature coefficient of resistivity. Write its SI unit. Plot a graph showing the variation of resistivity of copper with temperature.

28. Two wires of equal length, one of copper and the other of manganin have the same resistance. Which wire is thicker?

29. Two identical slabs of given metal are joined together, in two different ways, as shown in figures a. and b. What is the ratio of these two combinations?



A B

30. A wire of resistance 8R is bent in the form of a circle. What is the effective resistance between the ends of a diameter AB?

31. A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in its resistance.

32. Three coloured bands, in a carbon resistor are red, green and yellow respectively. Write value of the resistance.

33. Sketch a graph showing variation of resistivity of carbon with temperature.

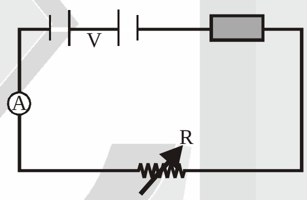
34. Draw V-I graph for ohmic and non-ohmic materials. Give one example for each.

35. A physical quantity associated with electrical conductivity, has the SI unit Ωm. Identify physical quantity.

36. Which physical quantity has units $\Omega^{-1}m^{-1}$.

37. You are required to select a carbon resistor of resistance 47 kΩ $\pm$ 10% from large collectin. What should be the sequence of colour bands used to code it?

38. The diagram shows a piece of pure semi conductor, S in series with a variable resistor, R and a source of constant voltage, V. Would you increase or decrease the value of R to keep the reading of ammeter (A) constant, when semiconductor, S in heated? Give reason.



39. Explain how the resistivity of a conductor depends upon

a. number density, n of free electrons and

b. relaxation-time λ.

40. Define the term 'temperature coefficient of resistivity'. Show graphically. The variation of resistivity with temperature for nichrome.

41. a. Three resistors 1Ω, 2Ω and 3Ω are combined in series. What is the total resistance of the combination?

b. If the combination is connected to a battery of emf 12 V and negligible internal resistance, obtain the potential drop across each resistor.

42. A heating element using nichrome connected to a 230 V supply draws an initial current of 3.2 A which settles after a few seconds to a steady value of 2.8 A. What is the steady temperature of the heating element if the room temperature is 27ºC? Temperature coefficient of resistance of nichrome averaged over the temperature range involved is 1.70×10^{-4} °C^{-1}.

43. Two wires of equal length, one of aluminium and the other of copper have the same resistance. Which of the two wires is lighter? Hence, explain why aluminium wires are preferred for overhead power cables.
($\rho_{Al} = 2.63\times10^{-8}$ Ω m, $\rho_{Cu} = 1.72\times10^{-8}$ Ω m, Relative density of Al = 2.7, of Cu = 8.9

44. At room temperature (27.0 °C) the resistance of a heating element is 100 Ω. What is the temperature of the element if the resistance is found to be 117 Ω, given that the temperature coefficient of the material of the resistor is 1.70×10^{-4} °C^{-1}?

45. A negligibly small current is passed through a wire of length 15 m and uniform cross-section 6.0×10^{-7} m^2, and its resistance is measured to be 5.0 Ω. What is the resistivity of the material at the temperature of the experiment?

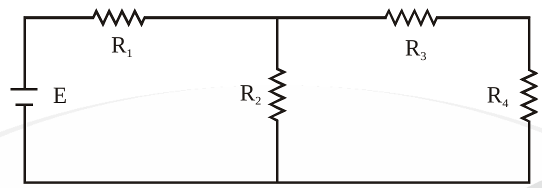
46. A set of n identical resistors, each of resistance R Ω, when connected in series have an effective resistance XΩ, and when the resistors are connected in parallel, their effective resistance is YΩ. Find the relation between R, X and Y.

47. A cylindrical metallic wire is stretched to increase its length by 5%. Calculate the percentage change in this resistance.

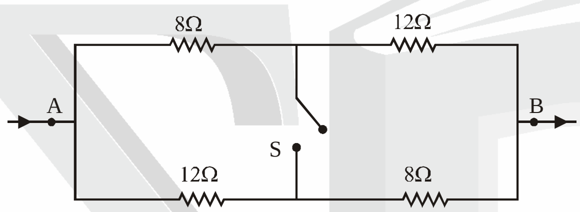
48. Two wires X, Y have the same resistivity, but their cross-sectional areas are in the ratio 2 : 3 and lengths in the ratio 1 : 2. They are first connected in series and then in parallel to a d.c. source. Find out the ratio of the drift speeds of the electrons in the two wires for the two cases.

49. A silver wire has a resistance of 2.1 Ω at 27.5 °C, and a resistance of 2.7 Ω at 100°C. Determine the temperature coefficient of resistivity of silver.

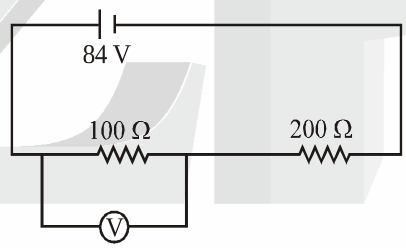
50. Determine the voltage drop across the resistor R_1 in the circuit given below with E = 65 V, R_1 = 50Ω, R_2 = 100 Ω, R_3 = 100 Ω and R_4 = 300 Ω.



51. Calculate the ratio of equivalent resistance of the resistance network between the points A and B as shown in figure, when switch S is closed and switch is open .



52. A voltmeter V of resistance 400 Ω is used to measure the potential difference across a 100 Ω resistor in the circuit shown here.



a. What will be the reading on the voltmeter?

b. Calculate the potential difference across 100 Ω resistor before the voltmeter is connected.

53. All bulbs, tubes, fans etc. in domestic electric supply are fitted in parallel arrangement, why?

EMF & VOLTAGE

54. State the condition in which terminal voltage across a secondary cell is equal to its emf.

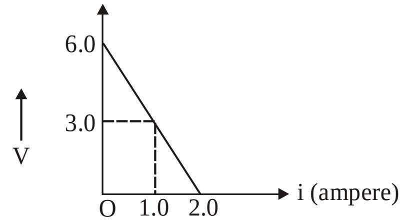
55. The storage battery of a car has an emf of 12 V. If the internal resistance of the battery in 0.4 Ω, what is the maximum current that can be drawn from the battery?

56. A battery of emf 10 V and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 0.5 A, what is the resistance of the resistor? What is the terminal voltage of the battery when the circuit is closed?

57. A storage battery of emf 8.0 V and internal resistance 0.5Ω is being charged by a 120V d.c. supply using a series resistor of 15.5Ω. What is the terminal voltage of the battery during charging? What is the terminal voltage of the battery during charging? What is the purpose of having a series resistor in the charging circuit?

58. A storage inverter battery has 12 V emf and internal resistance 1.0Ω. What is the maximum current that can be drawn from the battery?

59. The following graph shows the variation of terminal potential difference V, across a combination of three cells in series to a resistor, versus the current, i :

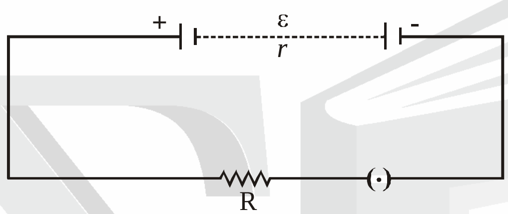


i. Calculate the emf of each cell. **ii.** For what current i, will the power dissipation of the circuit be maximum?

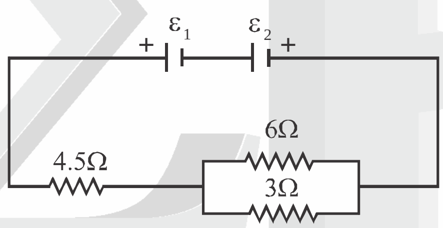
60. A (i) series, (ii) parallel combination of two given resistors is connected, one by one, across a cell. In which case will the terminal potential difference, across the cell, have a higher value?

61. A cell of emf, E and internal resistance, r is connected across a variable resistor, R. Plot a graph showing the variation of terminal potential, V with resistance, R. Predict from the graph, the condition under which V becomes equal to E.

62. When a battery of emf ε and internal resistance r is connected to a resistance R, current I flows through it. Derive a relation between ε, V, r and R. Here V is the terminal potential difference.



63. Two cells ε_1 and ε_2 in the given circuit diagram have an emf of 5 V and 9 V and internal resistance of 0.3 Ω and 1.2 Ω respectively.



Calculate the value of current flowing through the resistance of 3Ω.

64. A number of identical cells n, each of emf, E internal resistance, r connected in series, are charged by a DC-source of emf of E, using a resistor, R.

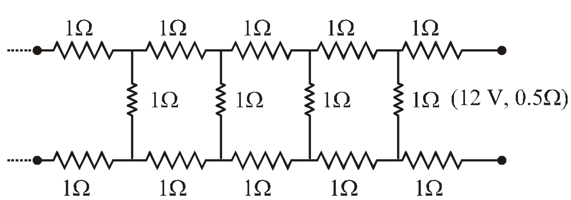
a. Draw the circuit arrangement.

b. Deduce the expressions for : **i.** changing current **ii.** potentital difference across the combination of cells.

65. A battery of emf 10 V and internal resistance 3Ω is connected to a resistor. If the current in the circuit is 0.5 A, what is the resistance of the of the resistor? What is the terminal voltage of the battery when the circuit is closed?

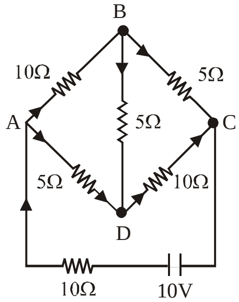
66. Six lead-acid type of secondary cells each of emf 2.0V and internal resistance 0.015 Ω are joined in series to provide a supply to a resistance of 8.5Ω. What are the current drawn from the supply & its terminal voltage?

67. Determine the current drawn from a 12 V supply with internal resistance. 0.5 Ω by the infinite network shown in figure. Each resistor has 1Ω resistance.

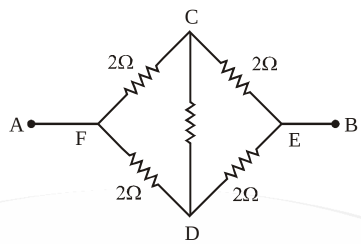


KIRCHOFF'S LAW

68. Determine the current in each branch of the network shown in figure.

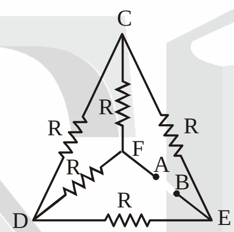


69. A potential difference of 2 V is applied between the points A and B shown in the network drawn in the figure.



Calculate : (i) equivalent resistance of the network across the points A and B, and (ii) the magnitudes of currents flowing in the arms AFCEB and AFDEB.

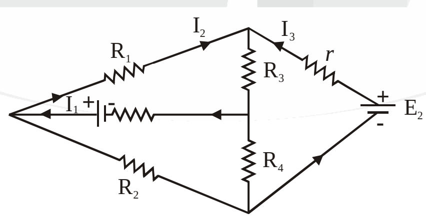
70. (i) Calculate the equivalent resistance of the given electrical network between points A and B in given figure.



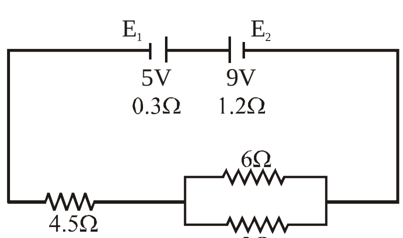
(ii) Also calculate the current through CD and ACB, if a 10 V d.c. source is connected between A and B and the value of R is assumed as 2Ω.

71. Four identical cells, each of emf 2V, are joined in parallel providing supply of current to external circuit consisting of two 15Ω resistors joined in parallel. The terminal voltage of the cells as read by an ideal voltmeter is 1.6 V. Calculate the internal resistance of each cell.

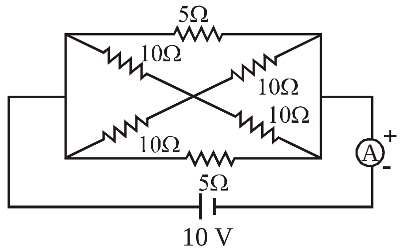
72. State the two rules that serve as general rules for analysis of electrical circuits. Use these rules to write the three equations that may be used to obtain the values of the three unknown currents in the branches shown in the circuit



73. Two cells E_1 and E_2 in the given circuit diagram have an emf of 5V and 9V and internal resistance of 0.3Ω and 1.2Ω respectively. Calculate the value of current flowing through the resistance of 3Ω.



74. Calculate the current shown by the ammeter in the circuit diagram given below in figure :



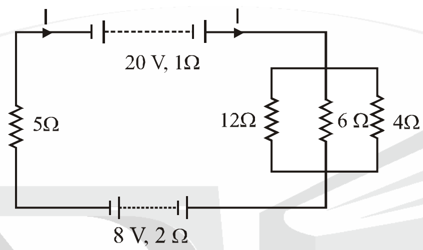
75. Three cells of emf 2.0 V, 1.8 V and 1.5 V are connected in series. Their internal resistances are 0.05Ω, and 1.0Ω, respectively. If this battery is connected to an external resistor of 4Ω, calculate :

a. the total current flowing in the circuit

b. the potential difference across the terminals of the cell of emf 1.5 V while is use

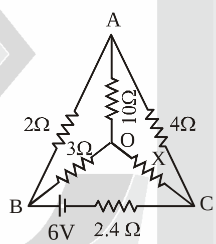
76. Three identical cells each of emf 2V and unknown internal resistance are connected in parallel. The combination is connected to a 5Ω resistor. If the terminal voltage across the cells is 1.5 V, what is the internal resistance of each cell?

77. A 20 V battery of internal resistance 1Ω is connected to three coils of 12Ω, 6Ω and 4Ω in parallel, a resistor of 5Ω and a reversed battery (emf 8 V and internal resistance 2Ω) as shown in figure. Calculate :



a. the current in the circuit **b.** current in resistor of 12Ω coil **c.** potential difference across each battery

78. Find the value of unknown resistance X in the circuit of given figure, if no current flows through the section AO. Also calculate the current drawn by the circuit from the battery of emf 6 V and negligible internal resistance.



79. Two cells of emf 1.5 V and 2 V and internal resistance 1Ω and 2Ω respectively are connected in parallel to pass a current in the same direction through an external resistance of 5Ω.

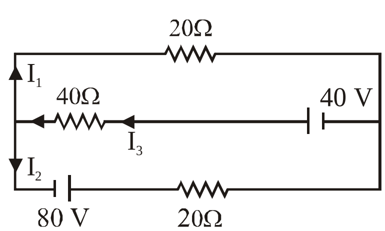
a. Draw the circuit diagram

b. Using Kirchoff's laws, calculate the current through each branch of the circuit and potential difference across the 5Ω resistor.

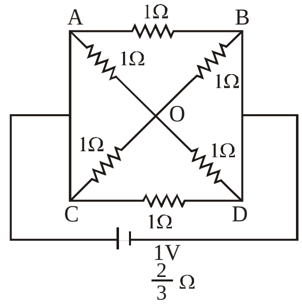
80. Two cells of emfs 1.5V and 2.0V and internal resistance 2Ω and 1Ω, respectively have their negative terminals joined by a wire of 6Ω and positive terminals by a wire of 4Ω resistance. A third resistance wire of 8Ω connects middle points of these wires. Draw the circuit diagram. Using Kirchoff's laws, find the potential difference at the ends of this third wire.

81. State Kirchoff's rules of current distribution in an electrical network.

Using these rules determine the value of the current l_1 in the electric circuit of given figure

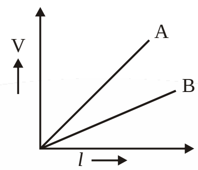


82. Find the current drawn from a cell of emf 1 V and internal resistance $\frac{2}{3}\Omega$ connected to the network shown.

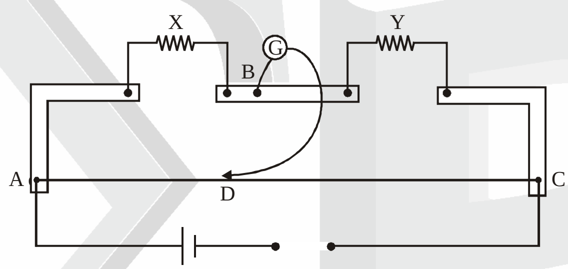


METRE BRIDGE & POTENTIOMETRE

83. The variation of potential difference V with length l in case of two potentiometers A and B is as shown in figure. Which one of these two will you prefer to comparing emfs of two primary cells?

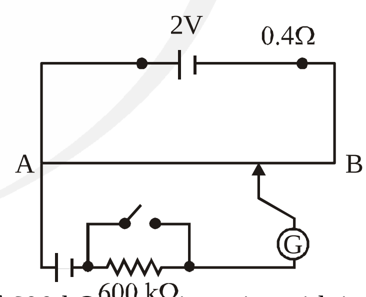


84 . a. In a metre bridge in given figure, the balance point is found to be at 39.6 cm from the end A, when the resistor Y is of 12.5 Ω. Determine the resistance of X. Why are the connections between resistors in a Wheatstone or metre bridge made of thick copper strips?



b. Determine the balance point of the bridge above if X and Y are interchanged.

c. What happen if the galvanometer and cell are interchanged at the balance point of the bridge? Would the galvanometer show any current?



85. Figure shows a potentiometer with a cell of 2.0V and internal resistance 0.40 Ω maintaining a potential drop across the resistor wire AB. A standard cell which maintains a constant emf of 1.02 V (for very moderate currents up to a few mA) gives a balance point at 67.3 cm length of the wire.
To ensure very low currents drawn from the standard cell, a very high resistance of 600 kΩ is put in series with it, which is shorted close to the balance point. The standard cell is then replaced by a cell of unknown emf ε and the balance point found similarly, turns out to be at 82.3 cm length of the wire.

a. What is the value ε ?

b. What purpose does the high resistance of 600 kΩ have?

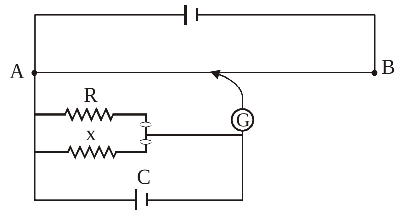
c. Is the balance point affected by this high resistance?

d. Is the balance point affected by the internal resistance of the driver cell?

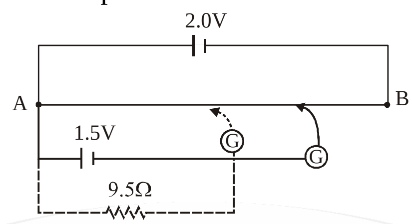
e. Would the method work in the above situation if the driver cell of the potentiometer had an emf of 1.0 V instead of 2.0 V?

f. Would the circuit work well for determining an extremely small emf, say of the order of a few mV (such as the typical emf of a thermo-couple)? If not, how will you modify the circuit?

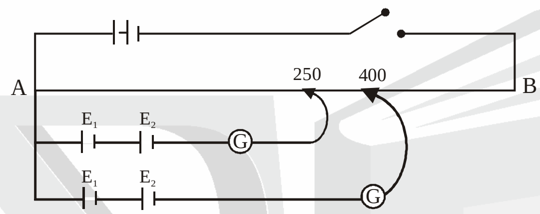
86. Figure shows a potentiometer circuit for comparison of two resistances. The balance point with a standard resistor R = 10.0 Ω is found to be 58.3 cm, while that with the unknown resistance X is 68.5 cm. Determine the value of X. What might your do if you failed to find a balance point with the given cell of emf ε ?



87. Figure, shows a 2.0 V potentiometer used for the determination of internal resistance of a 1.5 V cell. The balance point of the cell in open circuit is 76.3 cm. When a resistor of 9.5 Ω is used in the external circuit of the cell, the balance point shifts to 64.8 cm length of the potentiometer wire. Determine the internal resistance of the cell.

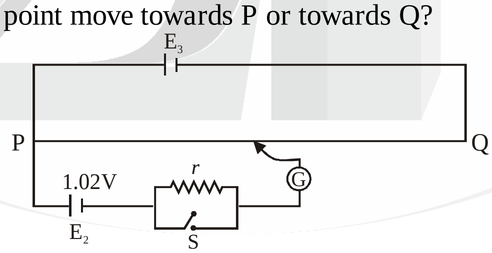


88. Two primary cells of emf E_1 & E_2 ($E_1 > E_2$) are connected to the potentiometer wire AB as shown in the figure. If the balancing lengths for the two combinations of the cells are 250 cm and 400 cm, find the ratio of E_1 and E_2.

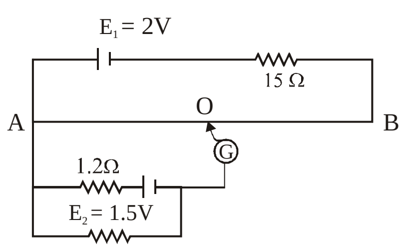


89. When two known resistances R and S are connected in the left and right gaps of a metre bridge, the balance point is found at a distance l_1 from the zero end of the metre bridge wire. An unknown resistance X is now connected in parallel to the resistance S and the balance point is now found at a distance l_2 from the zero end of the metre bridge wire. Obtain a formula for X in terms of l_1, l_2 and S.

90. Potentiometer wire PQ of 1 m length is connected to a standard cell E_1. Another cell E_2 of emf 1.02 V is connected as shown in the circuit diagram with a resistance 'r' and a switch S. With switch S open, null position is obtained at a distance of 51 cm from P. Calculate (i) potential gradient of the potentiometer wire and (ii) emf of the cell E_1. (iii) When switch S is closed, will null point move towards P or towards Q?



91. AB is 1 m long uniform wire of 10 Ω resistance. The other data are as shown in the circuit diagram given in figure. Calculate



a. Potential gradient along AB **b.** Length AO of the wire, when the galvanometer shows no deflection

92. Write the principal of working of a potentiometer. Describe briefly, with the help of a circuit diagram, how a potentiometer is used to determine the internal resistance of a given cell.

PREVIOUS YEARS QUESTIONS

CURRENT AND DRIFT VELOCITY

1. Write a relation between current and drift velocity of electrons in a conductor. Use this relation to explain how the resistance of a conductor changes with the rise in temperature? **[2013 C]**

2. When electrons drift in a metal from lower to higher potential, does it mean that all the free electrons of the metal are moving in the same direction? **[Delhi 2012]**

3. Define relaxation time of the free electrons drifting in a conductor. How is it related to the drift velocity of free electrons? Use this relation to deduce the expression for the electrical resistivity of the material. **[All India 2012]**

4. (i) Derive the relation between current density **j** and potential difference **V** across a current carrying conductor of length l, area of cross-section A and the number density n of free electrons.

(ii) Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. [Assume that the number density of conduction electrons is 9×10^{28} m^{-3}].**[Delhi 2012C]**

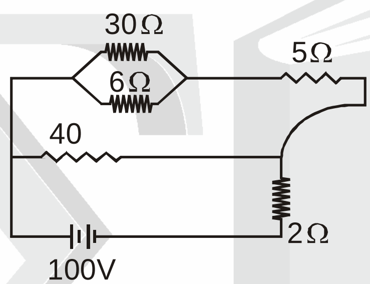
5. Derive an expression for drift velocity of free electrons in a conductor in terms of relaxation time. **[Delhi 2009]**

6. Derive an expression for the resistivity of a good conductor, in terms of the relaxation time of electrons. **[A.I. 2008]**

7. Estimate the average drift speed of conduction electrons in a copper wire of cross-sectional area 1.0×10^{-7} m^2 carrying a current of 1.5 A. Assume the density of conduction electrons to be 9×10^{28} m^{-3}. **[2014]**

8. a. Define the term 'drift velocity' of charge carriers in a conductor. Obtain the expression for the current density in terms of relaxation time.

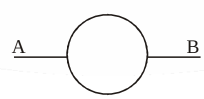
b. A 100 V battery is connected to the electric network as shown. If the power consumed in the 2 Ω resistor is 200 W, determine the power dissipated in the 5 Ω resistor: **[2014]**



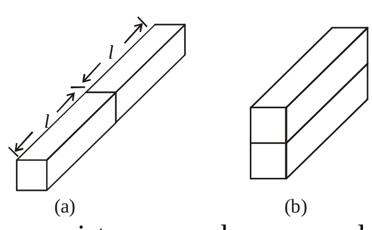
9. (i) Define the term drift velocity. **[Delhi 2016]**
(ii) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend ?
(iii) Why alloys like constantan and manganin are used for making standard resistors ?

Ohm's LAW AND RESISTANCE

10. A wire of resistance 8 R is bent in the form of a circle. What is the effective resistance between the ends of a diameter AB? **[Delhi 2010]**



11. Two identical slabs, of a given metal, are joined together, in two difference ways, as shown in figures **a.** and **b.** What is the ratio of the resistances of these two combinations? **[Delhi 2010C]**



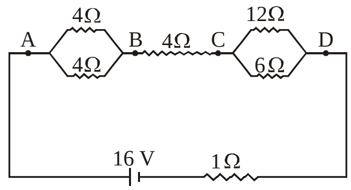
12. The three coloured bands, on a carbon resistor are red, green and yellow, respectively. Write the value of its resistance. **[All India 2009C]**

13. Plot a graph showing temperature dependence of resistivity for a typical semiconductor. How is this behaviour explained? **[Delhi 2011]**

14. The sequence of coloured bands in two carbon resistors R_1 and R_2 is

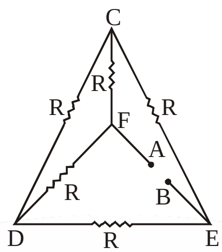
(i) brown, green, blue (ii) orange, black, green. Find the ratio of their resistances. **[Delhi 2010C]**

15. A network of resistors is connected to a 16 V battery of internal resistance of 1Ω as shown in the figure.



(i) Compute the equivalent resistance of the network. (ii) Obtain the voltage drops V_{AB} & V_{CD}. **[Foreign 2010]**

16. (i) Calculate the equivalent resistance of the given electrical network between points A and B.



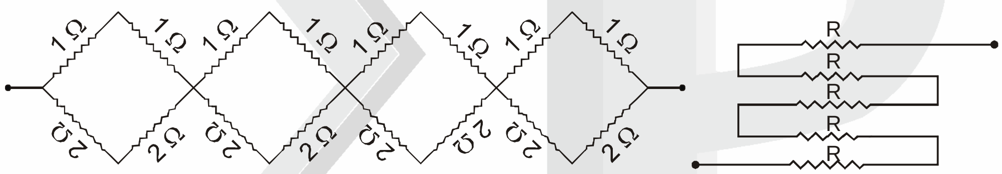
(ii) Also calculate the current through CD and ACB, if a 10 V DC source is connected between A and B and the value of R is assumed as 2Ω. **[All India 2008]**

17. a. Given n resistors each of resistance R, how will you combine them to get (i) maximum (ii) minimum effective resistance? What is the ratio of the maximum to minimum resistance?

b. Given the resistances of 1 Ω, 2 Ω, 3 Ω, how will you combine them to get an equivalent resistance of:

(i) 11/3Ω, (ii) 11/5 Ω, (iii) 6 Ω and (iv) 6/11 Ω?

c. Determine the equivalent resistance of network shown in figures. **[2015]**

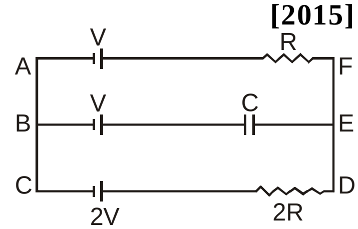


(a) (b)

18. Define the term 'electrical conductivity' of a metallic wire. Write its SI unit. **[2014]**

19. Show variation of resistivity of copper as a function of temperature in a graph. **[2014]**

20. Plot a graph showing the variation of current density (j) versus the electric field (E) for two conductors of different materials. What information from this plot regarding the properties of the conducting materials, can be obtained which can be used to select suitable materials for use in making (i) standard resistance and (ii) connecting wires in electric circuits? **[2015]**

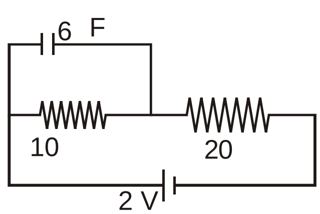


21. In the given circuit in the steady state, obtain the expressions for: **[2015]**

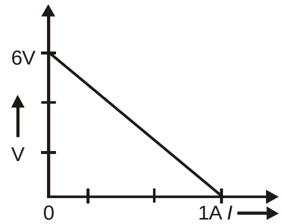
a. the potential drop **b.** the charge

c. the energy stored in the capacitor, C.

22. Find the charge on the capacitor as shown in the circuit. **[2014]**

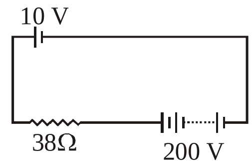


23. The plot of the variation of potential difference across a combination of three identical cells in series, versus current is shown below. What is the emf and internal resistance of each cell? **[Delhi 2016]**



CELL, E.M.F.

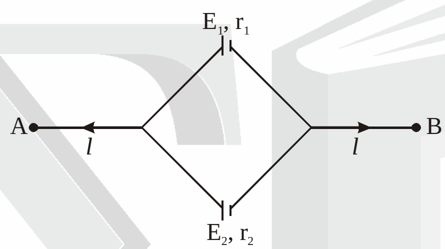
24. A 10 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 38 Ω as sown in the figure. Find the value of the current in circuit. **[Delhi 2013]**



25. The emf of a cell is always greater than its terminal voltage. Why? Give reason. **[Delhi 2013]**

26. A cell of emf E and internal resistance r draws a current l. Write the relation between terminal voltage V in terms of E, l and r. **[Delhi 2013]**

27. Two cells of emf E_1, E_2 and internal resistances r_1 and r_2 respectively are connected in parallel as shown in the figure. **[Foreign 2010]**



Deduce the expressions for: (i) the equivalent emf of the combination.

(ii) the equivalent resistance of the combination (iii) the potential difference between the points A and B.

28. A cell of emf E and internal resistance r is connected across a variable resistor R. Plot a graph showing variation of terminal voltage V of the cell versus the currect I. Using the plot, show how the emf of the cell and its internal resistance can be determined. **[2014]**

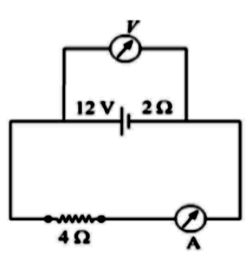
29. A cell of emf ε and internal resistance r is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I. It is found that when R = 4Ω, the current is 1 A and when R is increased to 9Ω, the current reduces to 0.5 A. Find the values of the emf ε and internal resistance r. **[2015]**

30. Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2 ? and 0.3 ? respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. **[Delhi 2016]**

31. A battery of emf 12 V and internal resistance 2Ω is connected to a 4 Ω resistor as shown in the figure.

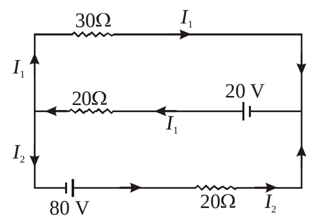
a. Show that voltmeter when placed across the cell and across the resistor, in turn, gives the same reading.

b. To record the voltage and the current in the circuit, why is voltmeter placed in parallel and ammeter in series in the circuit? **[Delhi 2016]**

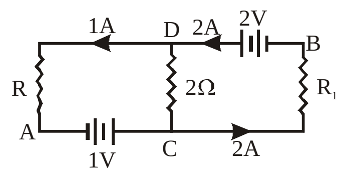


KIRCHOFF'S LAWS

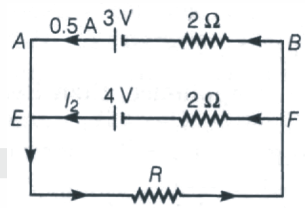
32. Use Kirchhoff's rules to determine the value of the current I_1 flowing in the circuit in figure : **[Delhi 2013C]**



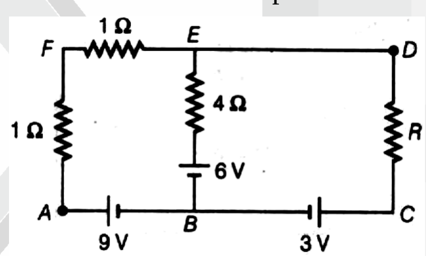
33. In the given circuit, assuming point A to be at zero potential, use Kirchhoff's rules to determine the potential at point B. **[All India 2011]**



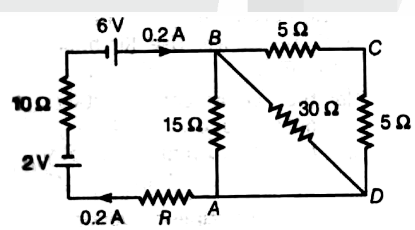
34. Using Kirchhoff's rules in the given circuit, determine
(i) the voltage drop across the unknown resistor R (ii) the current I_2 in the arm EF. **[All India 2011]**



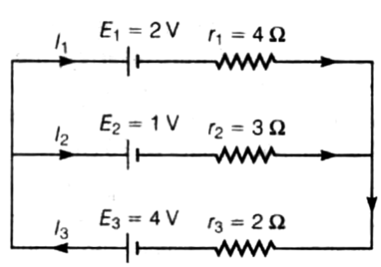
35. Using Kirchhoff's rules, determine the value of unknown resistance R in the circuit so that no current flows through 4Ω resistance. Also, find the potential difference between points A and D. **[Delhi 2012]**



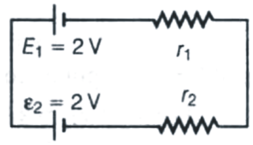
36. Calculate the value of the resistance R in the circuit shown in the figure so that the current in the circuit is 0.2 A. What would be the potential difference between points A and B? **[All India 2012]**



37. State Kirchhoff's rules. Use these rules to write the expressions for the currents I_1, I_2 and I_3 in the circuit diagram shown. **[All India 2010]**

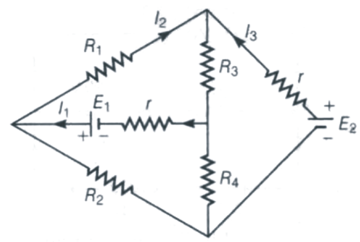


38. State Kirchhoff's rules. Use Kirchhoff's rules to show that no current flows in the given circuit. **[Foreign 2009]**



39. State the two rules that serve as general rules for analysis of electrical circuits.

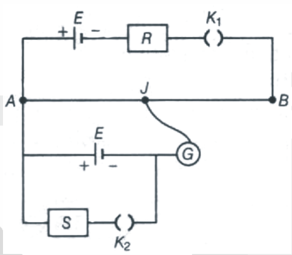
Use these rules to write the three equations that may be used to obtain the values of the three unknown currents in the branches (shown) of the circuit given below. **[All India 2008C]**



40. State the two Kirchhoff's rules used in electric networks. How are these rules justified? **[2015]**

POTENTIOMETER AND METER BRIDGE

41. Two students X and Y perform an experiment on potentiometer separately using the circuit given below



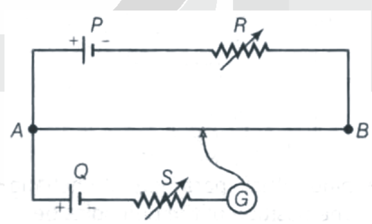
Keeping other parameters unchanged, how will the position of the null point be affected if

(i) X increases the value of resistance R in the set-up by keeping the key K_1 closed and the key K_2 open?

(ii) Y decreases the value of resistance S in the set-up, while the key K_2 remains open and then K1 closed?

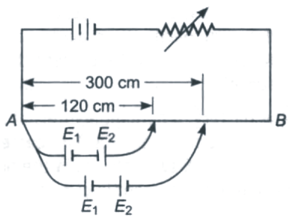
Justify your answer. **[HOTS; Foreign 2012]**

42. State the underlying principle of a potentiometer. Write two factors on which the sensitivity of a potentiometer depends.



In the potentiometer circuit shown in the figure, the balance point is at X. State, giving reason, how the balance point is shifted when (i) resistance R is increased (ii) resistance S is increased, keeping R constant? **[Comp.2013]**

43. In the figure, a long uniform potentiometer wire AB is having a constant potential gradient along its length. The null point for the two primary cells of emfs E_1 and E_2 connected in the manner shown, are obtained at a distance of 120 cm and 300 cm from the end A. **[Delhi 2012]**



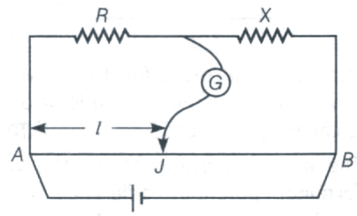
Find (i) E_1/E_2 and (ii) position of null point for the cell E_1. How is the sensitivity of a potentiometer increased?

44. Draw the circuit diagram of a potentiometer which can be used to determine the internal resistance r of a given cell of emf E. Explain briefly how the internal resistance of the cell is determined? **[Delhi 2010, 2008C]**

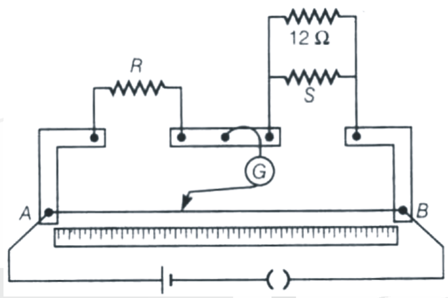
45. In the meter bridge experiment, balance point was observed at J with AJ = l.

(i) The values of R and X were doubled and then interchanged. What would be the new position of balance point?

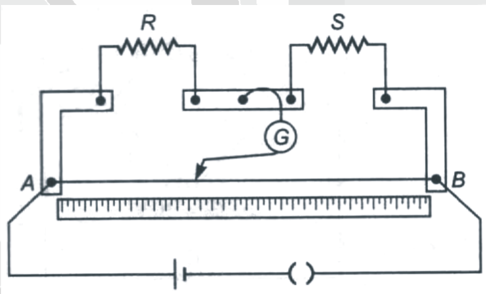
(ii) If the galvanometer and battery are interchanged at the balanced position, how will the balance point get affected? **[All India 2011]**



46. In a meter bridge, the null point is found at a distance of 40 cm from A. If a resistance of 12Ω is connected in parallel with S, the null point occurs at 50.0 cm from A. Determine the values of R and S. **[HOTS; Delhi 2010]**

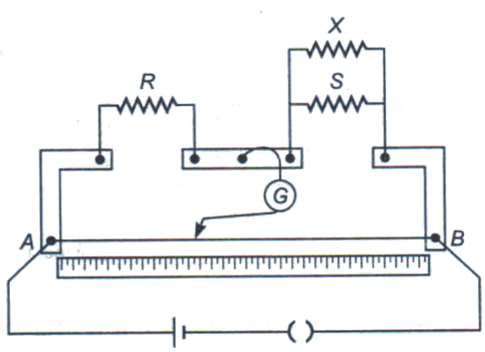


47. In a meter bridge, the null point is found at a distance of 60 cm from A. If a resistance of 5Ω is connected in series with S, the null point occurs at 50.0 cm from A. Determine the values of R and S. **[Delhi 2010]**



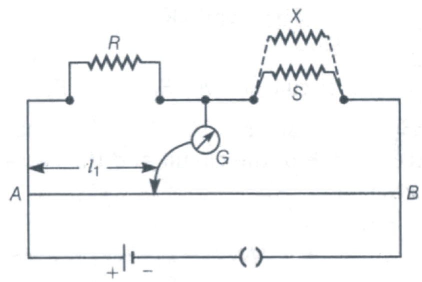
48. In a meter bridge, the null point is found at a distance of l_1 cm from A. If a resistance of X is connected in parallel with S, the null point occurs at a distance l_2 cm from A. Obtain the formula for X in terms of l_1, l_2 and S.

[Delhi 2010]



49. (i) State the principle of working of a meter bridge.

(ii) In a meter bridge balance point is found at a distance l_1 with resistances R and S as shown in the figure. When an unknown resistance X is connected in parallel with the resistance S, the balance point shifts to a distance l_2. Find expressions for X in terms of l_1, l_2 and S. **[All India 2009]**

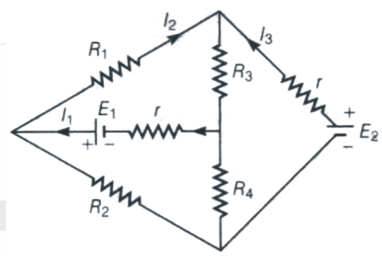


50. Draw a circuit showing a Wheatstone bridge. Use Kirchhoff's rule to obtain the balance condition in terms of the values of the four resistors for the galvanometer to give null deflection. **[Delhi 2008C]**

51. (i) State Kirchhoff's rules for an electric network. Using Kirchhoff's rules, obtain the balance condition in terms of the resistances of four arms of Wheatstone bridge.

(ii) In the meterbridge experimental set up, shown in the figure, the nul point D is obtained at a distance of 40 cm from end A of the meterbridge wire.

If a resistance of 10 Ω is connected in series with R_1, null point is obtained at AD = 60 cm. Calculate the values of R_1 and R_2. **[Delhi 2013]**

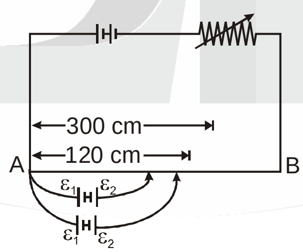


52. a. State the working principle of a potentiometer. With the help of the circuit diagram, explain how a potentiometer is used to compare the emfs of two primary cells. Obtain the required expression used for comparing the emfs.

b. Write two possible causes for one sided deflection in a potentiometer experiment. **[2014]**

53. a. State the principle of potentiometer. Define potential fradient. Obtain an expression for potential gradient in terms of resistivity of the potentiometer wire. **[2014]**

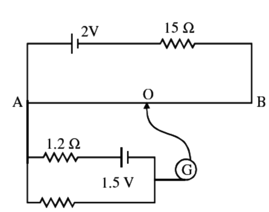
b. Figure shows a long potentiometer wire AB having a constant potential gradient. The null points for the two primary cells of emfs ε_1 and ε_2 connected in the manner shown are obtained at a distance of l_1 = 120 cm and l_2 = 300 cm from the end A. Determine (i) $\varepsilon_1/\varepsilon_2$ and (ii) position of null point for the cell ε_1 only.



54. A potentiometer wire of length 1 m has a resistance of 10 Ω. It is connected to a 6 V bettery in series with a resistance of 5Ω. Determine the emf of the primary cell which gives a balance point at 40. **[2014]**

55. (i) State the principle of working of a potentiometer. **[Delhi 2016]**

(ii) In the following potentiometer circuit AB is a uniform wire of length 1 m and resistance 10 Ω. Calculate the potential gradient along the wire and balance length AO (= l).



TEST YOURSELF

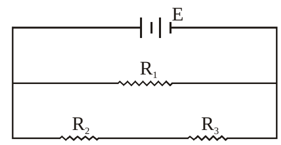
Time: 30 min. **Max. Marks: 25**

Directions: *Attempt all questions.*

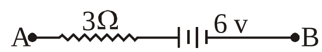
1. What is the effect of heating of a conductor on a drift velocity of free electrons? **1**

2. A carbon resistor is marked in coloured bands of red, black, orange and silver. What is the resistance and tolarence value of the resistor? **1**

3. Three identical resistors R_1, R_2 and R_3 are connected a battery as shown in the following figure. What will be ratio of voltages across R_1 and R_2? **1**

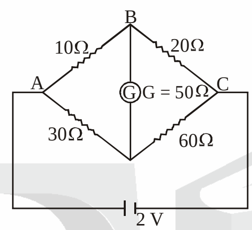


4. What is the potential difference A and B? **1**



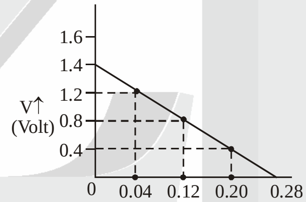
5. Define resistivity and state its S.I. unit. State and explain how the resistivity of a conductor varies with temperature. **1**

6. The given figure shows a network of resistances. Name the circuit so formed. **4**

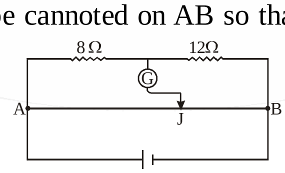


What is the current flowing in the arm BD of this circuit? State the two laws used to find the current in different branches of this circuit?

7. Potential difference across terminals of a cell were measured (in volts) against different currents (in ampere) flowing through the cell. A graph was drawn which was a straight line ABC. Using the data given in the graph, determine: (i) the e.m.f (ii) the internal resistance of the cell **4**



8. Why a volmeter cannot masure emf of a cell? The potentiometre wire AB shown in the figure is 400 m long. Where should the free end of the galvanometer be cannoted on AB so that the galvanometer shows zero deflection? **6**

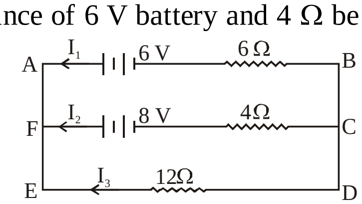


9. a. Obtain the expression $R = \dfrac{ml}{nAe^2\tau}$ where m is the mass of electron, l = length of the wire, n is charge density of the wire, e is charge of on electron, τ is relaxation time and A is the area of cross - section of the wire. **3**

b. In the following network, find the following. **3**

(a) Currents I_1, I_2 & I_3. (b) Terminal potential difference of each battery.

Consider 6 Ω to be the internal resistance of 6 V battery and 4 Ω be the internal resistance of 8 V battery.



EXERCISE ANSWERS

1. Resistivity will remain same **2.** 1 : 2

3. Drift velocity gets doubled **4.** Maganin

5. 60 watt bulb **6.** 1 : 2 **7.** 14 V

8. $V_1 : V_2 = 9 : 8$ **9.** 27.2×10^3s or 27.2 Ks

11. 32 ohm

12. a. V is halved, then E $\rightarrow$ halved, R $\rightarrow$ Remains unchanged

b. L is halved, then E $\rightarrow$ Doubled, R $\rightarrow$ halved

c. D is doubled, then E $\rightarrow$ Remains unchanged, R $\rightarrow$ becomes 1/4 th

13. a. Drift speed becomes 1/3 rd

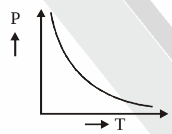
b. Resistance will become 9 times

c. Resistivity remains unchanged

22. a. becomes 1/3rd **b.** becomes 9 times

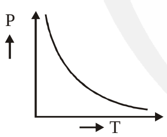
24. In series $\rightarrow$ 3/2 ; In parallel $\rightarrow$ 2/1

25. Metals **26.**

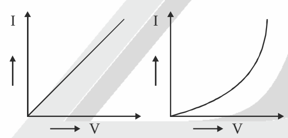


30. 2R **31.** 10.25% **32.** $25 \times 10^4\ \Omega$

33.



34.



Ohmic Materials Non-ohmic Materials

37. Yellow, Violet, Orange and Silver

41. a. Total Resistance R = 6Ω **b.** V_1 2V, V_2 = 4V, V_3=6V

42. 867.2°C **44.** 1027°C **45.** $2.0 \times 10^{-7}\ \Omega$m

46. R = $\sqrt{x.y}$ **47.** 10.25%

48. In series $\rightarrow$ 3/2 ; In parallel $\rightarrow$ 2/1

49. 0.0039° C^{-1} **50.** 25V **52. a.** 24V **b.** 28 V

55. 30A **56.** R = 17Ω , V = 8.5Ω

57. Terminal voltage during charging = 11.5 v

58. 120 A **59. i.** ε = 2V I = 1A

60. In Series Arrangement **63.** 0.33 A

64. b. $I = \dfrac{E'-nE}{R+nr}$ **c.** $V = nE + \underset{\substack{\downarrow \\ \text{Charging Current}}}{I}.(nr)$

65. R = 17Ω ; V = 8.5 V

66. Current = 1.4 A ; Terminal voltage = 11.9 V

67. R = 2.732Ω ; I = 3.71 A.

68. i_1 = 4/17 A $i_1 + i_2$ = 10/17 A ; i_2 = 6/17A $i_1 - i_3$ = 6/17 A ; $i_2 + i_3$ = 4/17A

69. Equivalent Resistance = 2Ω ; Current in AFCEB=0.5A ; Current in AFDEB = 0.5 A

70. Equivalent Resistance = R ; No current flows through CD ; Current in arm ACB = 2.5 A

71. r = 7.5Ω **72.** I_1 = 2.5A $I_2 = I_3$ = 1.875 A

73. 1/3 A **74.** 3.6 A

75. Total current = 0.92 A ; PD = 0.58 v

76. r = 5 ohm

77. i. Current = 1.2 A **ii.** Current through 12Ω coil = 0.2 A

iii. P. D across I battery = 18.8 v. **iv.** P. Dn across II battery = 19.4 v

78. 4Ω, 1A

79. b. I_1 = 1/34 A, I_2 = 9/34 A.

P.D across 5Ω resistor = 25/17 V.

80. Potential difference at the ends of third wire = 92/73 V.

81. I_1 = –1.2 A **82.** I = 1A **83.** B

84. a. X = 8.2 Ω **b.** d_2 = 60.5 cm **85.** ε = 1.247 V

86. X = 11.75 ohm **87.** r = 1.68 ohm

88. 13 : 3 **89.** $X = \dfrac{S}{\dfrac{l_2}{l_1}\left(\dfrac{100-l_1}{100-l_2}\right)-1}$

90. i. Potential gradient K = 0.02V cm^{-1}

ii. Emf of E_1 = 2V

91. i. Potential gradient along AB = 0.008 V cm^{-1}

ii. 37.5 cm