CONVEX CLASSES
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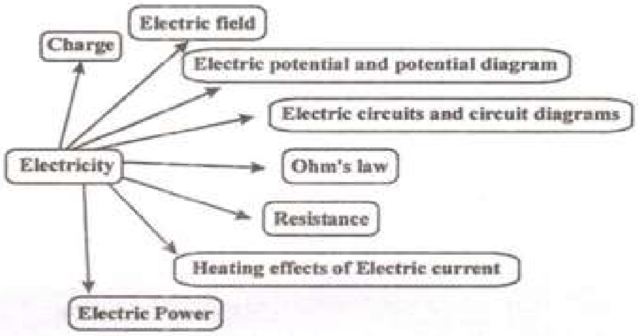
Electricity



INTTODUCTION :

Electricity has grreat importance in the modern society. The modern devices in out to day life require electricity for their operation. The most clean and convenient form of energy in our day to day life is electricity.

CHARGE :

change is defined as the property of matter. When a charge is at rest, it produces electric field only, but when in motion, it also produces magnetic field. Charge can be positive or negative. The smallest stable possible charge is the charge on an electron.

Properties of Electric Charge :

1. Electric charge is of two types viz, positive and negative charge. proton is said to be charged positively and electron is said to be charged negative. The magnitude of elementary positive or negative charge is same and is equal to $1.6\times10^{-19}C$.
2. Like charges repel and unlike charges attract each other. Thus a proton repels a proton and attracts an electron.
3. The force of attraction or repulsion between two charges is given by Coulomb's law.
4. **Charge is conserved :** Charge can neither be created no be destroyed. The charge from one body can be transferred to another body but the total charge of a system remains constant. This is called the law of conservation of charge.
5. **Charge is quantized :** Protons and electrons are elementary charged particles. Thought the charge on them is opposite in nature, the magnetude of charge possessed by them is same i.e., $1.6\times10^{-10}C$. Charge on a body is always an integral multiple of this value. This is called quantization of charge.
   The charge exists in fixed packets i.e., when a body is charged the charge on it is an integral multiple of the charge on an electron.
   Reason for quantisation :
   Since, electrons are indivisible, thus only integral number of electrons can be tranferred from one body to another, on rubbing. Hence, the charge bodies will have charges which are integral multiples of the charge on electron.
6. When a body gains electrons, it becomes negatively charged. When it loses electrons it becomes positively charged. The positive charge being bound firmly in the nucleus does not participate in charging.
7. Charge is invariant
8. Charge resides on the outer surface of the conductor. In insulators it remains where it is placed.
9. The electric charge is additives in nature.

10. Charge cannot exist without mass but mass can exist without charge.
11. Charge is scalar quantity and the SI unit of charge is coulomb, denoted by (C).

Note : The smallest possible charges is the charge on a quark i.e., $\frac{2e}{3}$ and $\frac{-e}{3}$, but it is unstable in nature.

Remember : Mass of an electron $= 9.1\times10^{-31} Kg$ **.**

A body having a charge of $+1C$ **has an electron deficit of** 6.25×10^{18} **electrons.**

The study of electricity is classified into two parts.

1. **Static electricity :** It deals with electric charges at rest and their effects.
2. **Current electricity :** It deals with charges in motion and their effects.

S.No	Positive Charge	Nagative Charge
1.	Glass Rod	Silk
2.	Woolen cloth or fur	Ebonite, Amber, Rubber
3.	Woolen cloth	Plastic
4.	Dry hair	Plastic Comb

This chapter deals with charges in motion i.e., current electricity.

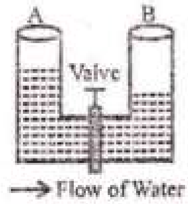
The chapter move only if there is a difference of electric pressure (i.e., the potential difference) along the conductor. This difference of potential may be produced by a battery, consisting of one or more electric ceils.

The potential difference is measured by means of an instrument called the voltmeter.

Note : The voltmeter is always connected in parallel across the points between which the potential difference is to be measured.

Remember : Concept of Electric Potential Difference

To understand the concept of electric potential take a vessel consisting of two arms A and B as shown in Figure. The water level in arm. A is higher than the level in arm B. when value is closed. We know that pressure exerted by a liquid in a vessel at the botton of the vessel is directly proportional to the height of the liquid in the vessel.



Thesefore, pessure exerted by water in arm A is greater than the pressure exerted by water in arm B. It means that there is pres sure difference between the ams A and B. When the value is opened, the water flows from arm A to arm B of the vessel due to pressure difference. This flow of water continues till the water level in both the arms of the vessel be comes equal or there is no pressure difference between the two arms. This activity shows that the water flows from higher pressure to lower pressure. In other words water flow from one region to another region only if there is a pressure difference between the two regions.

Teacher Leaning : The electric potential difference across the ends of a conductor is maintained by a dry cell or a battery. The chemical reaction taking place in a cell makes one electrode of the cell as positive and the other electrode of the cell as negative. When a conductor is connected across these electrodes of the cell, then one end of the conductor is at positive potential and the other end of the conductor is at negative potential. Thus, these exists an electric potential difference across the ends of the conductor. This electric potential difference moves the electrons (negative charges) in the conductor from one end to the other end.

Illustration : Five joule of work is done in moving 12.5×10^{18} electrons from one end to other end of a conductor. What is the potential difference between the two ends of conductor ?

Sol. The charge on 6.25×10^{18} electrons is 1 C.

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$\therefore$ When 12.5×10^{18} electrons move, the net charge transferred is 2 C.

$\therefore$ $Q = 2C$.

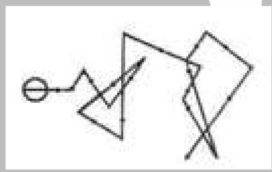
Work done (W) in moving 2C charge $= 5\,J$. (given)

The potential difference (V) between the ends of conductor is

$$V = \frac{\text{Work done}}{\text{Charge}} = \frac{5J}{2C} = 2.5\,JC^{-1}$$

$V = 2.5\,\text{volts}$

Key Concept : Drift velocity



In a conductor or a wire, negatively charged particles called electrons have random or zig-zag motion as show in figure. Therefore, the net flow of electrons (or net flow of charge) across any cross-section of the conductor is zero. This is because number of electrons flowing though he given cross section of the conductor is zero. This is because number of electrons flowing through the given cross section to the right side is equal to the number of electrons flowing to the left side through the given cross section.

Hence, there is no electric current in the conductor. However, when the ends of the conductor are connected across a dry cell there is a potential diffeence across the conductor. Now, the electrons move from one end to another end of the conductor. But the motion from one end to another end of the conductor. But the motion of these electrons is not in straight lines. These electrons collide with the ions of the conductor while moving from one end to another end of the conductor. As a result of these collision, electrons drift from one end to another end with an average speed known as drift velocity. The drift velocity of electrons in a conductor is very small.

Typical value of the drift velocity of an electron in a conductor is about $2.22\times10^{-4}\,m\,s^{-1}$.

It means, electrons will take time about 2.5 hours to travel 5 metre long conductor.

Illustration : Electric potential at a point in an electric field is $0.5\,V$ when charges of 3C was brought from infinity to that point. Calculate the work done.

Sol. Electric potential $(V) = 0.5\,\text{volts}$

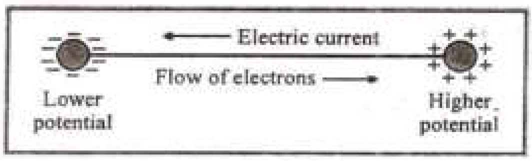
Charge $(Q) = 3C;$ Work done $(W) = ?$

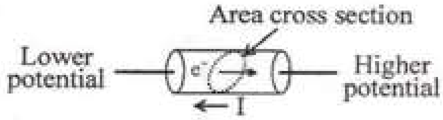
$$V = \frac{W}{Q}$$

$\therefore$ $W = VQ = 0.5V\times3C = 1.5VC = 1.5J$ Ans.

1.5 Flow of Charge (Electric current) :

Electric current is defined as continuous rate of flow of electric charge. Consider flow of charges through a conductor as shown in figure. If ΔQ charge flows in Δt time through the cross section of conductor under consideration then the current over this time interval is defined as $I = \frac{\Delta Q}{\Delta t}$





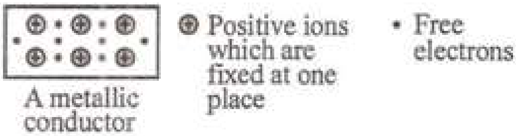
The S.I. unit of current is the ampere symbolically represented as A. Therefore also.

$$Current\,(\mathrm{I}) = \frac{\text{Charge (Q)}}{\text{Times (t)}} = \frac{Q}{t}$$

$$\boxed{1\,mA = 10^{-3}\,A,\ I\,\mu A = 10^{-6}\,A}$$

Knowledge Enhancer :

In a metallic conductor, when an atom loses one or more electrons, then atom be comes a positive ion, which remains fixed at one place in the conductor. The electrons detached from an atom become free and capable of moving from one part to another part of the conductor, The electric current in a metallic conductor is due to the flow of electrons (i.e., negative charge carriers).



Note : 1 A of current is equivalent to one coulomb of charge passing through conductor in 1 second.

Conventionally, we define the direction of the current in the direction of flow of negative charge. Whereas, the direction of current is considered opposite to the direction of flow of electrons.

An instrument called ammeter measures electric current in a circuit. It is always connected in series in a circuit.

Remember : A conductor or a wire carrying current is neutral. That is, it has net charge on it equal to zero.

Types of electrical Materrials :

(1) Insulators (2) Semiconductors (3) Conductors

Charge flow or conduction of electric current takes place only if free charge carriers are present. Since protons are bounded and present in the nucleus so the conduction takes place only due to electrons.

(1) Insulators do not conduct electricity because of the absence of free electrons in them, Rubber is an excellent insulator.

(2) Conductors conduct electricity due to presence of free electrons in them for example wire made of Cu, Al. are good conductors.

(3) Semiconductors begave as insulators at low temperrature whereas they behave as conductors at high temperatures.

Symbols of some commonly used components in circuit diagrams.

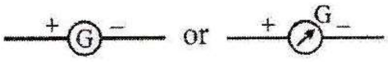
(1) An electric cell 

(2) A battery or a combination of cells 

(3) Plug key or switch (open) 

(4) Plug key or switch (closed) 

(5) A wire joint or junction 

(6) Galvanometer 

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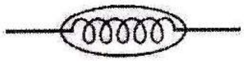
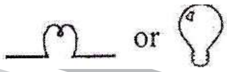
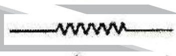
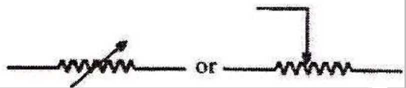
(7) Wires crossing without joining 

(8) Heater 

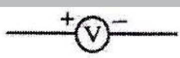
(9) Electric bulb 

(10) A resistor of resistance 

(11) Tapping key 

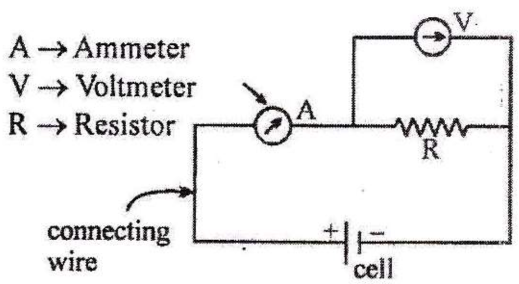
(12) Variable resistance or rheostat 

(13) Ammeter 

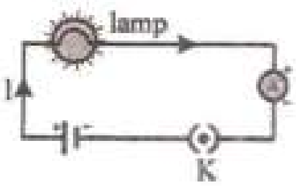
(14) Voltmeter 

Electic Resistance

Electric Circuit : An electric circuit is a closed conducting path containing a source of eloectric energy (i.e., a cell or a battery) and a device or element or load utilizing the electric energy. For example, an electric bulb or lamp connected with a cell with the help of connecting wires form simple electric circuit. In this circuit a cell is a source of electric energy and an electric lamp is the load.



In fact, electric current is a means of transferring electric energy from the source to the load. Thus, "a closed conducting path containing the source of electric energy and the load through whihc electric current flows is known as electric circuit".
A simple electric circuit is shown in figure.



open and Closed Electric Circuits

Open electric circuit : An electric circuit through which no electric current flows is known as open electric circuit.
The electric circuit shown in figure will be open circuit if the plug of the key is taken out or if the connecting wire breaks from any point.

Closed circuit : An electric circuit through which electric current flows continuously is known as closed circuit.

(1) **Electric Cell :** An electric cell is a device which maintains a contimuous flow of charge in a circuit. The Cell changes chemical energy into electrical energy.

(2) **Electro Motive Force (E.M.F.) of a cell :** The work done by the cell in forcing unit positive charge to flow in the whole circuit once, is called the electromotive force (e.m.f.) of the cell.

$$E = \frac{w}{q}\left(J/C\right)$$

The unit of emf is called '**volt'(V).** If in the flow of 1C of charge in a circuit the energy given by the cell 1J, then the emf of the cell is 1V.

(3) **Internal Resistance of a cell :** When we connect the plates of a cell by a wire, an electric current flows in the wire from the positive plate of the cell towards the negative plates, and in the electrolyte (inside the cell) it flows from the negative plates towards the positive plate. The resistance offered by the electrolyte of the cell to the flow of current (ions) through it is called the 'internal Resistance' of th cell.

(4) **Terminal Potential Difference :** The potential difference across the terminals of a cell or battery when the cell is in charging or discharging mode is called terminal potential difference.

Electrical Resistance : In a conductor whenever current flow takes place the motion of electrons takes place. During motion they are opposed to flow and this is known as electrical resistance. **The SI unit of electrical resistance is Ohm denoted by Ω.**

Factors which determine the electric resistance of a conductor :

(1) The resistance of a conductor is directly proportional to its length $R \propto l$

(2) The resistance is inversely proportional to the area of cross section of the conductor

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

(3) The resistance depends upon the nature of the material of the conductor

(4) Removing the propertionality sign we have $R = \rho \frac{l}{A}$

(5) ρ-Resistivity of the conductor.

Resistivity : The resistance of a unit volume of a substance is known as its resistivity. Resistivity is also known specific resistance and its SI unit is ohm m.

(6) **Effect of temperature on resistance :**

The resistance of the conductors increases with increase in temperature. Let the resistance of conductor at 0^0C be R_0.

Let the resistance of the conductor at t^0C be R'.

Then, $R_t = R_0(1+\alpha t)$, where 'α' is known as the **temperature coefficient of resistance.**

Pure metals have positive temperature coefficient of resistance. The resistance of metals in creases with an increasw in temperature.

Alloys have a very less temperature coefficient of resistance. So the resistance of alloy like Manganin and Constantan vary very little with an increase in tempeature. But of this property they are used in making standard resistances.

Semiconductors like germanium, silicon and bad conductors like glass, pure water etc., have negative temperature coefficient. The resistance of these materials de creases with an increase in temperature.

Reason for variation of resistance with temperature :

Resistance offered by a metallic conductor is due to the collisions between drifting electrons, and the ions present in the metallic conductor. When the temperature of the conductors increases, the amplitude ions of vibration of ions in the lattice in creases and hence the collisions between electrons and the ions become more fre quent. therefore, the opposition to the flow of electrons (constituting the electric current) increases. In other words, resistance of the metallic conductor increases or decreases with the increase or decrease of the temperature respectively.

Then, $R_1 = R_0[1+\alpha(t_2 - t_1)]$

Where, α is the temperature coeffecient of the resistance.

$$\alpha = \frac{(R_1 - R_0)}{R_0(t_2 - t_1)}$$

Thus, temperature coefficient of resistance (α) is defined as the change in resis tance per unit original resistance per degree rise in temperature.

S.I unit of α is $\frac{\text{ohm}}{\text{ohm kelvin}}$ or kelvin^{-1} or K^{-1}

α is negative for insulators and semi - conductors i.e., their resistance decreases with the rise of temperature (i.e., $R_1 < R_0$)

α is very - very small for high resistivity alloys like manganin ($\approx 10^{-5}\ {}^0C^{-1}$). i.e., their resistance does not change appreciably with change in temperature. It is for this reason that manganin and constantan are used in making standard resistance coils.

Illustration: the length of copper wire is 100 m and its radius is 1 mm. Calculate its resis tance if resistivity of copper is $1.72 \times 10^{-8} \Omega m$.

Sol. Length of copper wire $(l) = 100m$

Area of cross section (a) = $\pi r^2 = 3.14 \times 10^{-6} m^2$

Resistivity (ρ) of copper = $1.72 \times 10^{-8} \Omega m$

Resitivity offered by a conductor is given by

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

$$= \frac{1.72 \times 10^{-8} \times 100}{3.14 \times 10^{-6}} = 0.55\Omega$$

In this numerical, length of copper wire is 100m. If the length is 1000m i.e., 1 km, the resistance offered by it would be 5.5Ω which is very less. Thus copper is a good con ductor of electricity.

Illustration: The resistance of 1 m of nichrome wire is 6Ω. Claculate its resistance if its length is 70 cm.

Sol. Given

Ist case

Length of nichrome wire (l_1) = 1m = 100cm

Resistance of nichrome wire (R1)= 6Ω

2nd case

$l_2 = 70cm$

$R_2 = ?$

By Ist law of resistance

$$\frac{R_1}{R_2} = \frac{l_1}{l_2}$$

$$\frac{6\Omega}{R_2} = \frac{100\text{cm}}{70\text{cm}}$$

$$\therefore R_2 = 4.2\Omega$$

Illustration: Two wires made of german-silver are taken such that the length and area of cross-section of the second wire are twice and thrice respectively those of the first wire. If the resistance of the second wire is 12r, find the resistance of the first wire.

Remember: Silver is the best conductor of electricity.

Sol. **Ist case**

$l_1 =$ length of German silver wire.

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a_1 = area of cross section;

R_1 = resistance

$R_1 = \rho \frac{l_1}{a_1}$ ....(i)

IInd case

l_2 = length of wire $= 2l_1$ a_2 = area of cross section of wire $3a_1$.

R_2 = resistance of wire $= 12\Omega$

$R_2 = \rho \frac{l_2}{a_2}$

$\therefore$ $12 = \rho \frac{2l_1}{3a_1}$ ....(ii)

dividing (i) by (ii)

$\frac{R_1}{12} = \frac{pl}{a_1} \times \frac{3a_1}{\rho(2l_1)} = \frac{3}{2}$ $\therefore$ $R_1 = 18\Omega$

Knowledge Enhancer

1. The connecting wires in an electric circuit are made of copper and aluminium. The resistivity of pure metals is very low, so. electric current passes easily through them. Out of metals, silver is the best conductor of electricity because its resistivity is the lowest among all metals. Thus, connecting wires in an electric circuit must be made of silver. However, the silver metal is costly as compared to other metals like aluminium and copper. The resistivity of copper and aluminium are also low and these metals are cheaper than silver. Therefore, connecting wires are made of copper and aluminium metals.

2. Filament of an electric bulb is made of tungsten metal. Tungsten being a metal has high resistivity. Moreover, it does not burn (or oxidise) even at higher temperatures. The melting point of tungsten is very high i.e., about $3380^0 C$. For these reasons, filament of an electric bulb (incandescent lamp) is made of tungsten.

3. Heating elements of electrical appliances like electric iron, electric heater, electric toaster, room heater, immerrsion rod are made of nichrome (an alloy of nickel, iron, chromium and manganese). Nichrome is an alloy of metals. The resistivity of nichrome is more than the resistivity of the metals used to make it. Moreover, nichrome does not burm (or oxidise) even at higher temperature. The melting point of nichrome is $1500^0 C$. That is why, heating elements of electical appliances are made of nichrome i.e., an alloy.

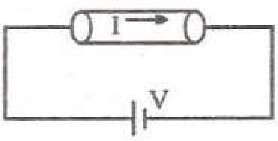
4. Insulators are used to protect ourselves from the severe shock of electric current.

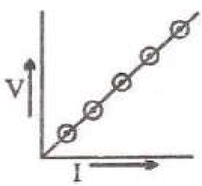
OHM'S Law

"When physical conditions (temperature, length, cross section) remains the same, the current flowing through a conductor is diectly proportional to the potential difference across the ends of a conductor."

i.e., $I \propto V$

So we can also write





So we can also write

$\therefore \quad V \propto I$

$$\boxed{V = IR}$$

$R = \frac{V}{I} =$ Constant, provided length cress section and temperatue of the conductor remains same.

Remember : Bigger units of resistance.

1 kilp ohm $1(K\Omega) = 10^3\Omega$

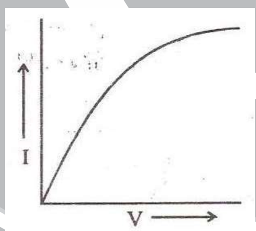
Mega ohm $(M\Omega) = 10^6\Omega$

$$\boxed{\Rightarrow \quad 1\,ohm = \frac{1\text{Volt}}{1\text{Ampere}}}$$

1 ohm is the resistance of a conductor is defined as when 1 V of potential difference is applied across the conductor and then a current of 1 A flows through it.

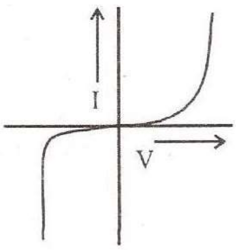
Exception of Ohm's law - In general almost all metal conductors obey the Ohm's law $V = 1R$ For which graph between V and I is a straight line as shown in figure. The conductors (or device) obeying the ohm's law are called ohmic. Howeve, there are some exceptions such as vacuum tube, semiconductor diode, transistor, liquid electrolytes etc. in which relation

$V = IR$



(a)

Figure (b) shows $V - I$ curve for a semiconductor device such as diode or transistor. Again this graph is not fitted in the form of standard Ohm's law. Hence such devices are non ohmic.



(b)

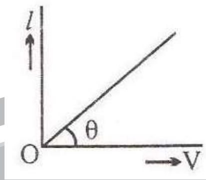
Knowledge Enhancer

The reciprocal of resistanc eis called conductance $G = 1/R$.

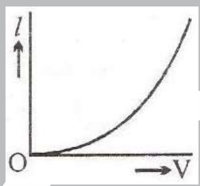
Its SI unit is ohm^{-1} or mho or siemen(s).

The substances which obey Ohm's law are called Ohmic or linear conductors. The resistance of such conductors is independent of magnetude and polarity of applied potential difference. Here the graph between 1 and V is a straight line passing through the origin. The reciprocal of slope of straight line gives resistance

$$R = \frac{V}{I} = \frac{1}{\tan\theta} = \text{constant}$$



Examples silver, copper, mercury, carbon, mica etc.
The substances which do not obey Ohm's law are called non-ohmic or non linear conductors. The $I-V$ curve is not a straight line. i.e., $p-n$ diode, transistor, themionic valves, rectifiers etc.



Check Point

(a) Alloys of metals usally have (greater/less) resistivity than that of their constiotuent metals.
(b) Alloys usally have much (lower/higher) temperature coefficients of restance than pure metals.
(c) The resistance of graphite and most non-metals increases/decreases with in crease in temperature.
(d) The resistivity of a semiconductor increases/decreases repidly with increasing temperature.
(e) The resistivity of the alloy manganin is nearly indepent of/increases rapidly with increases of temperatures.
(f) The resistivity of a typical insulator (e.g,amber) is greater than that of a metal by a factor of the order of $\left(10^{22}/10^{23}\right)$.

Solution

(a) Alloys of metals usally have greater resistivity than that of their constiotuent metals.
(b) Alloys usally have much lower temperature coefficients of restance than pure metals.
(c) The resistance of graphite and most non-metals decreases with increase in tem perature.
(d) The resistivity of a semiconductor decreases repidly with increasing temperature.
(e) The resistivity of the alloy manganin is nearly indepent of increasing temperature.
(f) The resistivity of a typical insulator (e.g,amber) is greater than that of a metal by factor of the order of 10^{22}.

Important Terms:

Resistor : A compc circuit which offers resistance (i.e. opposition) to the flow of electrons constituting electric current is know as a resistor. For example, a metallic wire or a conductor used in an electric circuit is known as resistor.

Variable resisistance : In an electric circuit, sometimes current has to be increased or decreased.

A component used in an electric circuit to change the current without changing the potenial difference across the circuit is called variable resistance.

Rheostat : is a device used in an electric circuit to change the resistance and hence current in the circuit. It means, rheostat acts as a variable resistance of known value in the circuit.

COMBINATION OF RESISTANCES (OR RESISTORS) :

Series Combination :

In this combination, the resistances are joined end .
In series combination the current across each resistance is same but the potential difference across each R_1, R_2 and R_3 , V_1, V_2 and V_3. To replace R_1, R_2 and R_3 by an equivalent resistance the potential difference across equivalent should be equal to the sum of the potential difference across the three resistances.

$V_1 = IR_1$
$V_2 = IR_2$
$V_3 = IR_3$
$E = V_1 + V_2 + V_3$
$IR_{eq} = IR_1 + IR_2 + IR_3$

$$\boxed{R_{eq} = R_1 + R_2 + R_3}$$

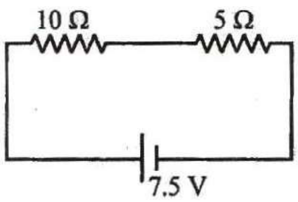
Characteristics of series circuit :

(i) Same current is flowing through all the resistances.
(ii) The effective resistance is the sum of the individual resistances. Effective resistance $R_{eff} = R_1 + R_2 + R_3$.
(iii) The applied voltage $V = V_1 + V_2 + V_3$.
(iv) The maximum power is consumed by resistor having the highest resistance, or the voltage drop is maximum across the highest resistance.

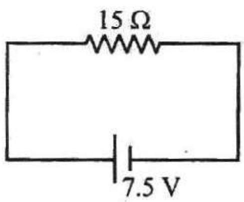
Disadvantage of series arrangement of resistors :

(i) Suppose all electric appliances like bulbs and electric tubes are connected in series in a circuit. If any one of them fuses (i.e., breaks), then all the other appliances will also not work. This is because series arrangment is not used in do mestic electric circuit.

IIlustration : Calculate (a) the equivalent resistance, (b) The electric current, and (c) The potential difference across each resistor in the circuit shown in figure.
Sol.



(a)



(b)

(a) Any current that passes through the resistor of 10Ω also passes through the resistor of 5Ω. So the 10Ω and 5Ω resistors are connected in series. Their equivalent resistance is $R = 10\Omega + 5\Omega = 15\Omega$.

(b) The circuit is equivalent to that shown in figure (b). The current is $i = \frac{V}{R} = \frac{7.5V}{15\Omega} = 0.5A$.
This is the current through both the resistors.

(c) The potential difference across the 10Ω resistor is

$$V_1 = iR_1 = (0.5A)\times(10\Omega) = 5V$$

The potential difference across the 5Ω resistor is.

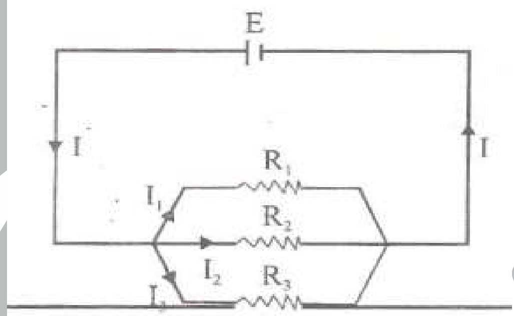
$$V_2 = iR_2 = (0.5A)\times(5\Omega) = 2.5\ V$$

Parallel Combination :

When two or more resistances are combined in such a way their first ends are connected to one point and the second ends to another point then combination is in parallel. In this combination the potential difference between the ends of all the resistances is same but the current in different resistances are different.

$$I = I_1 + I_2 + I_3$$

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



$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\Rightarrow \boxed{\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}}$$

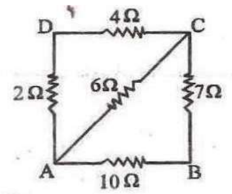
The reciprocal of the equivalent resistance of the resistances connected in parallel is equal to the sum of the reciprocal of those resistances.

Addvantage of connecting electrical devices in parallel :

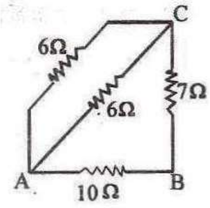
1. In a series circuit the current is constant throughout the electric circuit. Thus it is obviously impracticable to connect an electric bulb and an electric heater in series, because they need currencs or windely different values to operate properly.
2. Another major disadvantage of a series circuit is that when one component fails the circuit is broken and none of the components works.
3. On the other hand, a parallel circuit divides the current through the electrical gadgets. The total resistance in a parallel circuit is decreased. This is helpful particularly when each gadget has different resistance and requires different current to operate properly.

If 'n number of resistors each of same value connected in parallel, then the equivalant resistance of the parallel combination of 'n' resistors is given by $R_{eq} = \frac{R}{n}$

IIlustration : Determine the equivalent resistance between points A nad B in the following circuits.



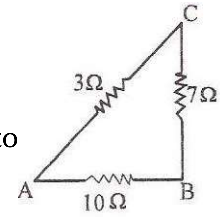
Solution



1Ω and 2Ω in series $R_{eq_1} = 4 + 2 = 6\Omega$

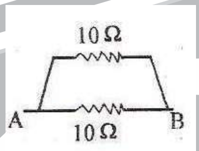
CLASS (X)

6Ω and 6Ω in parallel reduces to



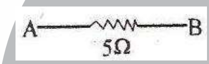
$$\frac{1}{R_{eq_2}} = \frac{1}{6} + \frac{1}{6} = 3\Omega$$

3Ω and 7Ω in series



$$R_{eq_3} = 3 + 10\Omega$$

10Ω and 10Ω in parallel



$$\frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{10} = 5\Omega$$

Check Point

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

Solution

(i) For maximum effective resistance , all the resitors should be joined in series.

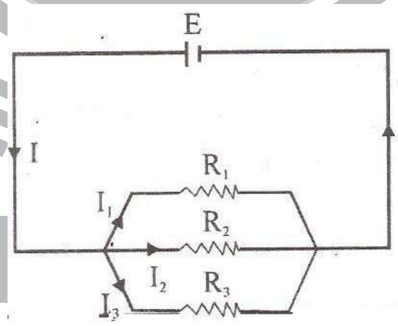
$$R_{\max} = R + R + R + ...n \text{ or } R_{\max} = nR$$

(ii) For maximum effective resistance , all the resitors should be joined in parallel.

$$\frac{1}{R_{\min}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} + ...n \text{ or } \frac{1}{R_{\min}} = \frac{n}{R} \quad \text{So, } \frac{1}{R_{\min}} = \frac{n}{R} \quad \text{Now, } \frac{R_{\max}}{R_{\min}} = n^2.$$

Try yourself :

1. Determine the value of current in the 2Ω resistance and the potential difference between A and B in the circuit diagram given



2. Find the equivalent resistance between the points A and B of the adjoining circuit diagram.

Destribution of Current in Two Resistors in Parallel :

Consider the circuit in Fingure. The resistance R_1 and R_2 are connected in parallel. The current i gets distributed in the two resistors.

We have $i = i_1 + i_2$ ....(i)

Applying Ohm's law to the resistor R_1

$V_A - V_B = R_1 i_1$ .... (ii)

And Applying Ohm's law to the resistor R_2

$V_A - V_B = R_2 i_2$ .... (iii)

C L A S S (X)

Form (ii) and (iii), $R_1 i_1 = R_2 i_2 \; or \; i_2 = \frac{R_1}{R_2} i_1$

Substituting for i_2 in (i), we have

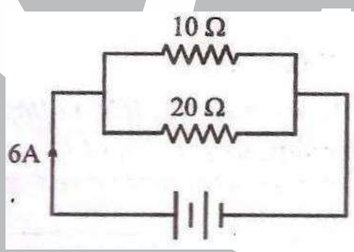
$$i = i_1 + \frac{R_1}{R_2} i_1 \left(1 + \frac{R_1}{R_2}\right) = i_1 = \frac{R_1}{R_2} R_2 \qquad \text{or} \qquad \boxed{i_1 + \frac{R_2}{R_1 + R_2} i}$$

Similarly, $\boxed{i_2 + \frac{R_2}{R_1 + R_2} i}$

Thus, $\frac{i_1}{i_2} + \frac{R_2}{R_1}$.

The current through each branch in a parallel combination of resistors is inversely proportional resistance.

IIlustration : Two resistors of resistance 10Ω and 20Ω are connected in parallel. A battery supplies 6A of current to the combination, as shown in figure. Calculate the current in each resistor.



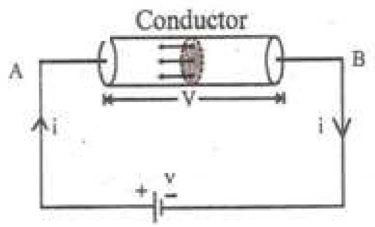
Sol. The current in the 10Ω resistors is :

$$i_1 = \frac{R_2}{R_1 + R_2} i = \frac{(20\Omega)\times(6A)}{(10\Omega)+(20\Omega)} = 4A.$$

HEATING EFFECT OF ELECTRIC CURRENT :

When conductor is connected to a source of electricity like cell or batteries, an electric field is developed across its ends due to this field free electrons of the conductor get moving in a definite direction. During their motion these free electrons experience the resistance due to the collisions with the ions atoms already present in that conductor. Therefore, some energy of the electrons gets lost in this process which appears in the form of heat energy.This effect of electric current is known as heating effect of electric current. The electric appliance like electric kettle, heater, press etc. operate their functioning based on the heating effect of electric current.

Passing of an electric current of strength 'i' through a conductor of resistance 'R' for time- interval Δt produces a potential difference 'V' across its ends then the total charge passing through the conductor in time-intervel Δt will be q = Strength of Current $\times$ time -interval or $i \times \Delta t$.



In this process the work done in carrying q coulomb of charge from one end to the other at potential difference V will be.

W = q.V or W = $(i \times \Delta t) \times \Delta t \times (i \times R) = i^2 \times R \Delta t$

If this entire work is converted into heat then heat produced is :

CLASS (X)

$$H = \frac{W}{J} = \frac{Vi\Delta t}{J}$$

Here J is a conversion constant and known as the **Mechanical quivalent of heat**. Its value is 4.18 joule/calorie (1 cal = 4.18 J)

Hence the heat produced due to flow of current through a conductor.

$$H = \frac{Vi.\Delta t}{4.18} = 0.239 Vi.\Delta t = 0.239\, i^2 R\Delta t \quad \text{(In calorie)}$$

The production of heat in a conductor due to flow of electric current through it is called heating effect current.

JOULE'S LAW :

These are as follows :-

(i) The amount of heat (H) produced in a conductor in a define time interval Δt is directly proportional to the square of the strength of current passing through it.

Hence $H \propto I^2$

It is also known as law of current.

(ii) If the current of definite strength i passes through a conductor of resistance R for a definite time interval Δt then the amount of heat (H) produced in the conductor is directly proportional to its resistance R.

Hence $H \propto R$

It is also known as the law of resistance.

(iii) If the current of definite strength i passes through a conductor of resistance R then the amount of heat (H) produced in the conductor is directly proportional to the time interval Δt for which the current flows in it.

Hence $H \propto \Delta t$

It is also known as the law of time.

Therefore the amount of heat produced (H) when a current of strength i passes through a conductor of resistance R for a time interval Δt is given by .

$H \propto I^2 R \Delta t$

H = $I^2 Rt\, Joule$

Or $$\boxed{H = \frac{1}{J} I^2 R\Delta t = 0.239 I^2 \ R\Delta t \ calorie}$$

This equations is a mathematical expression of Joule's law.

Chack Point

Specimen Numerical :- An electric heater of resistance 500 ohm is connected to a main supply for 30 minutes. If 5 A current flows through the heater, calculate the heat energy produced in the heater.

Solution: Here, I = 5 A : R = 500 ohm

t = 30 minute = $30 \times 60 s = 1800 s$

Using: H = $I^2 Rt$, we get

H = $(5)^2 \times 500 \times 1800 = 22500000 J = 2.25 \times 10^7 J$

Thus, heat energy produced = $2.25 \times 10^7 J$

PARACTICAL APPLICATION OF HEATING OF ELECTRIC CURRENT

Electric heater, electric iron anmd water heater etc. work on the heating effect of current.

When electric appliance like electric heater, electric iron and water heater etc. are connected to the main supply of electricity, these applyance become hot but the connecting wires remain cold. The element of elevtric heater is made of nichrome. Nichrome has high value of resistivity of the and hence high resistence. We know, heat produced is directly proportional to the resistance of the material through which current flows. Since, resistance of nichrome is high, so a large amount of heat is produced in the element of the electric heater. Thus , filament of electric heater becomes red hot. On the other hand, connecting wires are made of copper or alu minium is very small, so a very small heat is produced in the connecting wires made of copper or aluminium.

Rlectric bulb glows when electric current flows through the filament of the bulb.

Filament of an electric bulb is made of a thin wire of tungsten. The melting point of filament is high i.e. about 3380^0C. The filament of the bulb is enclosed in a glass envelope fixed over an insulted support. The glass envelop of electric bulb is filled with inactive gases like nitrogen and argon. Since resistance of thin filament is very high, so a large heat is produced as the electric current flows through the filament of the bulb becomes white hot. Hence, the filament of the bulb emits light and heat.

Electric fuse in the electric circuit melts when large when current flows in the circuit.

Electric fuse is a safety device connected in series with the circuit. Electric fuse is a wire made of a material whose melting point is very low. Examples of the materials for making fuse wire are copper or tin-lead alloy. When large current flows through a circuit and hence through a fuse wire a large amount of heat is produced. Due to this large amount of heat, the fuse wire melts and the circuit is broken so that current stops flowing in the circuit. This saves the electric circuit from burning.

Electric fues used in electrical circuits are rated as 1A , 2A , 3A , 5A , 10A etc. When we say, electric fuse is rated as 1A , it means the maximum current that can flow through the fuse wire without melting it is 1A. If an electric current flows through the electric circuit is more than 1A, then the fuse rated as 1A will melt and the circuit breaks. For such electric circuit, fuse as 2A is used.

ELECTRTIC POWER :

The rate of doing work, in an electric device due to flow of current in it , is defined as the power of that electric device.

If, an a circuit with an electric source. the potential V is developed across the two ends of a conductor of resistance R as current of strength i passes through it for a time-interval Δt then the work done in carrying a charge q through a potential difference V in the circuit will be -

$W = q \times V = i \times \Delta t \times V$

So the rate of work done, i.e. Power of the electric device (P);

$$P = \frac{W}{\Delta t} = \frac{i \times \Delta t \times V}{\Delta t} = i \times V \quad \text{Or} \quad P = V \times i = \frac{V^2}{R} = i^2 R$$

P = VI, when either V or I or both V and I change.

P = I^2R is applied when current I is consistant in the electric circuit.

P = $\frac{V^2}{R}$ is applied when potential difference is constant in the difference circuit.

1 VA = 1 W

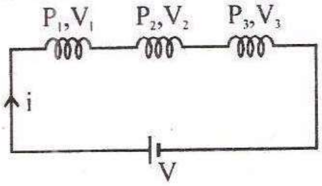
1 kVA = 10^3 W

1 h.p = 746 W

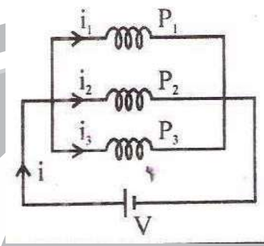
* Equivalent power in series and parallel combination.

In series combination

$\frac{i}{P_{eq}} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3}$



In parallel combination



$P_{eq} = P_1 + P_2 + P_3$

The S.I. unit of electric power is watt. Therefore in an electric circuit if 1 ampere current flows for a time-interval of 1 secound through a potential of 1 Volt then the power of the electric device is general as 1 watt.

In general kilowatt & Megawatt are used for measurement of electric power, Hence -

1 Kilowatt = 1000 watt = 10^3 watt

and 1 Megawatt = 1000 kilowatt = 10^6 watt

In practice, Hence Power (H.P) is also used for the mesurement of electric power. The value of 1 Hourase Power is 746 Watt.

ELECTRIC ENERGY :

The work done in moving an electric charge through a circuit is electric energy.

The work done by an electric source for the flow of current for a certian time interval is known as electric energy of circuit. If electric power P is given foe a small for a small time Δt in a electric circuit then electric energy of the circuit will be W = P×Δt so the energy of the electric circuit is-

W = P×Δt = Vi $\Delta t = i^2 R \Delta t$

The unit for the measured of electric energy is **watt** $\times$ **sec** or **joule.** In practice kilo-watt hour is used for the measured of Electric Energy. It is also know as Board of Trade Unit (B . O . T . U .) or simply Electric Unit i.e.,

1 Electric Unit = 1 k.w.h = 1 kilo watt $\times$ 1hour = 1000 watt $\times$ 3600 second

or 1 Electric Unit = 3.6 $\times 10^6$ watt $\times$ second or joule. The rate of doing work, in an electric device due to flow of current in it, is defined as the power of that.

How to calculate electricity bill ?

Suppose electric appliances of a house have consumed 100 kWh of electric energy in a month and the cost of one unit is 50 paise. Then the bill for month = $100 \times 50 = 5000$ **paise = R.s. 50.00. Here 1 kWh = 1 unit.**

LET US RECAPITULATE

- Electric current : An electric current is defined as the amount of charge flowing through any cross-section of a per unit time, $I = \frac{Q}{t}$. Electric current is a scalar quantity.
- Electric current in terms of number of electrons (n) in a conductor , $I = \frac{ne}{t}$, e = charge on an electron = $-1.6 \times 10^{-19} C$.

C L A S S (X)

- In a metallic wire or conductor, the flow of electric current is due to flow of electrons from one end to the other end of the wire.
- Charge carrier in a metallic wire are conduction elements.
- 6.25×10^{18} electrons make one coulomb of charge.
- S.I unit of electric current is ampere (A).
- Ampere (A) : Electric current through a conductor is said to be 1 ampere if one coulomb charge flows through any cross-section of the conductor in one second.
- Ammeter is used to measure electric current.
- Ammeter is always connected in series in an electric circuit.
- IElectric potential is defined as work done per unit charge.

$$V=\frac{W}{q}$$

- Electric potential is a scalar quanitity.
- Electric potentital difference is defined as the work done in moving a unit positive charge from one point to another point.

$$dV=\frac{W}{q}$$

- SI unit of electric potential is Volt (V).
- Voltmeter is used to measure the potential difference between two points in an electric circuit.
- Voltmeter is always connected in parallel in an electric circuit.
- **Ohm's Law :** This law states that, '' the electric current flowing in a conductor is directly proportional to the potential difference across the ends of conductor, provided the temperature and other physical conditions of the conductor remain the same''.
- **Resistance (R) :** Resistance of a conductor is the ability of the conductor to oppose the flow of charge through it.
- Unit of resistance is ohm.
- 1 Ohm : Resistance of a conductor is said to be 1 ohm if a potential difference of 1 volt across the ends of the conductor produces a current of 1 ampere through it.
- Resistor is a component (say a metallic wire) in an electric circuit which offers resistance to the flow of electrons constituting the electric current in the electric circuit .
- Law od Resistance :
  (i) Resistance of a conductor depends upon the nature of the conductor.
  (ii) Resistance of a conductor is directly proportional to the length of the conductor.
  (iii) Resistance of a conductor is inversely proportional to the each of cross-section of the conductor.
  (iv) Resistance of a metallic conductor increases with the increases of temperature and decreases with the decreases of the temperature.
- $R=\frac{p1}{A}$
- Resistivity or Speccific Resistance (p) : Resitivity is defined as resistance of the conductor of unit length and area of cross-section.
- Unit of Resistivity :
  In CGS system, unit if resistivity is ohm-cm.
  In SI system, unit of resistivity is ohm-metre.
- Two or more resistore are said to be connected in series if same amount of current flows through there resistors.
- The effective resistance are said to be combination of resistors is the algebraic sum of the individual resistances of the resistors in the combination.
- An electric bulb or a heater or a metallic wire acts as a resistor.

- If one fact of the electric bulbs connected in parallel if the potential difference across each resistor is equal to the applied potential difference across the combination of the resistors.
- The effective resistance of the resistors connected in parallel is less then the minimum resistance of a resistor in the combination.
- Resistors are connected in series if the resistance of the electric circuit is to be increased.
- Resistors are connected in parallel if the resistance of the electric circuit is to be decreased.
- Joule's Law of Heating :
  The amount of heat produced in a conductor is
  (i) Directly proprional to the square of the electric current flowing through it.
  (ii) Directly proportional to the resistance of the conductor.
  (iii) Direcctly proportional to the time for wich the electric current flows through the conductor.

$$H = I^2Rt \quad \text{(joule)}$$

- Electric fuse is a safety device used to save the electric appliances from burning.
- Electric fuse is a wire made of a material having low melting point.
- Electric fuse wire is made of copper or tin - lead alloy.
- Electric energy: The work done by a source of elctricity to maintain a current in an electric circuit is known as electric energy

$$E = VIt$$

- Electric power : Electric power is defined as the amount of electric work done in one second.

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

- SI unit of power is watt.
- Practical unit of power is horse power (h.p.)

$$1\text{h.p.} = 746\text{W}$$

- Electric energy = Electric power × time
- Commercial unit of Energy : kilowatt - hour (kWh)
- 1kWh=3.6×10h6J

Remember

Remember	Electric Current	$i = \frac{Q}{t}$
	Ohm's Law	$V = iR$
		$R = \rho\frac{l}{A}$
	Resistors in series	$R_{eq} = R_1 + R_2 + R_3 + ...$
	Resistors in parallel	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$
	Heat produced by electric current	$u = i^2Rt = \frac{V^2}{R}t = Vit$
	Electric power	$P = \frac{U}{t} = i^2R = \frac{V^2}{R} = Vi$

Concept Application (NCERT Questions)

Q1 A piece of wire of resistance R is cut into five parts. These parts are then connected in parallel. If the equivalent resistance of this combination is R', then the ratio R/R' is :

(a) 1/25 (b) 1/5 (c) 5 (d) 25

Ans Resistance of each one of the five parts = $\frac{R}{5}$

$$\frac{1}{R}=\frac{1}{R/5}+\frac{1}{R/5}+\frac{1}{R/5}+\frac{1}{R/5}+\frac{1}{R/5}$$

or $$\frac{1}{R'}=\frac{5}{R}+\frac{5}{R}+\frac{5}{R}+\frac{5}{R}+\frac{5}{R}+\frac{5}{R}+\frac{25}{R}$$

or $$\frac{R}{R'}=25$$

Thus,(D) is the correct answer.

Q2 Which of the following terms does not represent electrical power in a circuit :

(a) I^2R (b) IR^2 (c) VI (d) V^2/R

Ans Electrical power,

$$P=VI=(IR)R=I^2R=V\left(\frac{V}{R}\right)=\frac{V^2}{R}$$

Obviously, IR^2 does not represent eletric power in a circuit.

Thus, (B) is the current an answer.

Q3 An electric bulb is rated 220V and 100W. When it is operated on 110 V, the power consumed will be

(a) 100W (b) 75W (c) 50W (d) 25W

Ans Resistance of the electric bulbs,

$$R=\frac{V^2}{P} \quad (P=V^2/R)$$

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

power consumed by the bulb when it is operated at 110 V is given by

$$P'=\frac{V^2}{R}=\frac{(110)^2}{484}=\frac{110\times110}{484}=25W$$

(V'=110V)

Thus, (D) is the correct answer.

Q4 Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then in parallel in circuit. The ratio of the heat produced in series and parallel combinations would be :

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

Ans Since both the wires are made of the same material and have equal lengths and equal diameters, these have the same resistance. let it be R

When connected in series, their equivalent resistance is given by

$$R_s=R+R=2R$$

When connected i parallel, their equivalent resistance is given by

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

Further, electrical power is given by $P=\frac{V^2}{R}$

Power (or heat produced) is series, $P^s = \frac{V^2}{R_s}$

Power (or heat produced) is parallel, $P_P = \frac{V^2}{R_P}$

thus, $\frac{P_s}{P_s} = \frac{V^2/R_s}{V^2/R_P} = \frac{R_P}{R_s} = \frac{R/2}{2R} = \frac{1}{4}$ or $P_s : P_P :: 1:4$

thus, (C) is the correct answer

Q5 How is voltmeter connected in the circuit to measure potential difference between two points ?

Ans A voltmeter is always connected in parallel across the points between which the p.D. is to be determined.

Q6 A copper wire has a diameter of 0.5 mm and a resistivity of 1.6×10^{-6} ohm cm. How much of this wire would be required to make a 10 ohm coil? How much does the resistance change if the diameter is doubled ?

Ans We are given that, Diameter of the wire, D 0.5 mm $= 0.5\times10^{-3}$ m

resistivity of copper (ρ), $=1.6\times10^{-6}$ ohm cm $=1.6\times10^{-8}$ ohm m

required resistance, R = 10 ohm

As $R = \frac{\rho l}{A}, l = \frac{RA}{\rho} = \frac{R(\pi D^2/4)}{\rho} = \frac{\pi R D^2}{4\rho} [A = \pi r^2 = \pi(D/2)^2 = \pi D^2/4]$

or $\ell = \frac{3.14\times10\times(0.5\times10^{-3})^2}{4\times1.6\times10^{-8}}$ m $= 112.7$ m

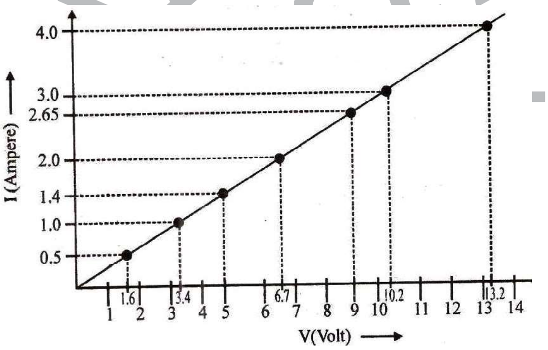
Since, $R = \frac{\rho\ell}{\pi D^2/4} = \frac{4\rho\ell}{\pi D^2}.(R \propto 1/D^2)$. When D is doubled, R becomes $\frac{1}{4}$ times.

Q7 The value of current, I, flowing in a given resistor for the corresponding value of po tential difference, V across the resistor are given below :

I (ampere):	0.5	1.0	2.0	3.0	4.0
V (volt) :	1.6	3.4	6.7	10.2	13.2

Plot a graph between v and I and calculate the resistance of resistor.

Ans The V-I graph is as shown in fig.



For V = 4V (i.e., 9V - 5V), I = 1.25 A (i.e., 2.65A - 1.40 A). Therefore,

$R = \frac{V}{I} = \frac{4V}{1.25A} = 3.2\Omega$

The value of R obtained from the graph depends upon the accuracy with which the graph is plotted.

Q8 When a 12 V battery is connected across an unknown resistor, there is a current of 2.5 mA in the circuit. Find the value of the resistance of the resistor.

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Ans Here, V 12V, I = 2.5 mA = $2.5\times10^{-3}A$

Resistance of the resistor

$$R=\frac{V}{I}=\frac{12V}{2.5\times10^{-3}A}=4800\Omega=4.8k\Omega$$

Q9 A battery of 9 V is connected in series with resistors of 0.2, 0.3, 0.4, 0.5 and 12. How much current would flow through the 12 resistor ?

Ans Since all the resistors are in series, equivalent resistance.

$$R_s = 0.2+0.3+0.4+0.5+12=13.4$$

Current through the circuit,

$$I=\frac{V}{R_s}=\frac{9V}{13.4\Omega}=0.67A$$

In series, same current (I) flows through all the resistors.

Thus, current flowing through 12Ω resistor = 0.67 A

Q10 How many 176Ω resistors (in parallel) are required to carry 5A in 220V line ?

Ans Here, I = 5A, V = 220V.

Resistance required in the circuit, $R=\frac{V}{I}=\frac{220V}{5V}=44\Omega$, resistance of each resistor,

$r=176\Omega$

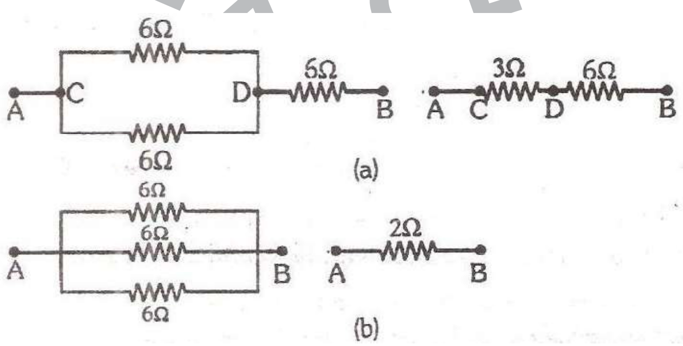
If n resistors, each of resistance r, are connected in parallel to get the required resis tance R,

Then $R=\frac{r}{n}$ or $44=\frac{176}{n}$ or $44=\frac{176}{44}=4$

Q11 Show how you would connect three resistors, each of resistance 6Ω, so that the combination has a resistance of (i) 9Ω (ii) 2Ω

Ans (i) In order to get a resistance of 9Ω from three resistors, each of resistance 6, we connect two resistors in Parallel combination (or resistance 3Ω) in series with the third resistor as shown in fig.

(ii) In order to get a resistance of 2Ω from three resistors, each of resistance 6Ω, we connect all the three resistors in parallel as shown in fig (b) as equivalent resistance in parallel combination, i.e., R_P is given by $R_P=\frac{6\Omega}{3}=2\Omega$



Q12 Several electric bulbs designed to be used on a 220V electric supply line, are rated 10W. how many lamps can be connected in parallel with each other across the two wires of 220 V line if the maximum allowable current is 5 A ?

Ans Resistance of each bulb, $r=\frac{V^2}{p}=\frac{(220)^2}{10}=4840\Omega$

Total resistance in the circuit, $R=\frac{220V}{5A}=44\Omega$

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Let n be the number of bulbs (each of resistance r) to be connected in parallel to obtain a resistance R.

Clearly, $R=\frac{r}{n} or\, n=\frac{r}{R}=\frac{4840\Omega}{44\Omega}=110$

Q13 A hot plate of an electric oven connected to a 220 V line has two resistance coils A and B, each of 24Ω resistance, which may be used seperately, in series, or in paral lel. What are the currents in the three cases ?

Ans Here, potential difference, V = 220 V

Resistance of each coil, $r=24\Omega$

(i) When each of the coils A or B is connected separately, current through each coil,

i.e., $I=\frac{V}{r}=\frac{220V}{24\Omega}=9.2A$

(ii) When coils A and B are connected in series, equivalent resistance in the circuit,

$R_s=r+r=48\Omega$

Current through are series combination, ie.e, $I_s=\frac{V}{R_s}=\frac{220V}{48\Omega}=4.6A$

(iii) When the coils A and b are connected in parallel, equivalent resistance in the circuit,

$R_p=\frac{r}{2}=\frac{24\Omega}{2}=12\Omega$

Current through the parallel combination, i.e, $I_P=\frac{V}{R_p}=\frac{220V}{12\Omega}=18.3A$

Q14 Compare the power used in the 2Ω resistor in each of the following circuits :
(i) a 6V battery in series with 1Ω and 2Ω resistors, and
(ii) a 4V battery in parallel with 12Ω and 2Ω resistors.

Ans (i) Since 6V battery is in series with 1Ω and 2Ω resistors, current in the circuit.

$I=\frac{6V}{1\Omega+2\Omega}=\frac{6V}{3\Omega}=2A$

Power used in 2Ω resistor, $P_1=i^2R=(2A)^2\times 2\Omega=8W$

(ii) Since V battery is in parallel with 12Ω and 2Ω resistors, pd across 2Ω resistor, V = 4V.

Power used in 2Ω resistor, $P_2=\frac{V^2}{R}=\frac{(4V)^2}{(2\Omega)}=8W$

Clearly, $\frac{P_1}{P_2}=\frac{8W}{8W}=1$

Q15 Two lamps, one rated 100W at 220V, and the other 60W at 220V, are connected in parallel to the electric mains supply. What current is drawn from the line if the supply voltage is 220V ?

Ans Resistance of first lamp, $r_1=\frac{V^2}{P}=\frac{(220)^2}{100}=484\Omega$

Resistance of the second lamp, $r_2=\frac{V^2}{P}=\frac{(220)^2}{60}=806.7\Omega$

Since the two lamps are connected in parallel, the equivalent resistance is given by

$\frac{1}{R_P}=\frac{1}{r_1}+\frac{1}{r_2}+\frac{r_2+r_1}{r_1 r_2}$

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or $R_p = \frac{r_2 r_1}{r_1 + r_2} = \frac{484 \times 806.7}{484 + 806.7} = \frac{390442.8}{1290.7} = 302.5\Omega$

Current drawn from the line, i.e., $I = \frac{V}{R_p} = \frac{220V}{302.6\Omega} = 0.73A$

Conceptual Application [NCERT Questions]

(1) What does an electric circuit mean ?

(2) Define the unit of current ?

(3) Calculate the number of electrons consisting ine coulomb of charge ?

(4) Name a device that helps to maximize a potential difference across a conductor ?

(5) What is meant by saying that a potential difference between two points is 1V ?

(6) How much energy is given to each coulomb of charge passing through a 6V battery ?

(7) On what factors does the resistance of a conductor depend ?

(8) Will current flow more easily through a thick wire or a thin wire of the same material, when connected to the same source ? Why ?

(9) Let the resistance of an electrical component remains constant while the potential difference across the ends of the compound decreases to half of its former value. What change will occur with current through it ?

(10) Why are coil of electric toasters and electric irons made of an alloy rather than a pure metal ?

(11) (a) Which among, iron and mercury is better conductor ? (resistivity of iron = $10.0 \times 10^{-8}\Omega m$ and resistivity of mercury = $94 \times 10^{-8}\Omega m$) (b) Which material is the best con ductor ?

(12) Draw a schematic diagram of a circuit consisting of three batteries of 2V each, a 5Ω resistor, 8Ω resistor and a 12Ω resistor and a plug key, all connected in series .

(13) Redraw the circuit of question 12, putting an ammeter to measure the current through the resistor and a voltmeter to measure the potential difference across 12Ω resistor. What would be the reading in the ammeter ?

(14) Judge the equivalent resistance when the following are connected in parallel :
(a) 1Ω and $10^6\Omega$ (b) 1Ω and $10^3\Omega$ and $10^6\Omega$

(15) An electric lamp of 100W, a toaster of resistance 50Ω, and a water filter of resistance 500Ω are connected in parallel to 220V source. What is the resistance of an iron connected to the same source that takes as much current as all three appliances and what in the current through it ?

(16) What is (a) highest (b) lowest resistance that can be secured by combining four coils of resistances $4\Omega, 8\Omega, 12\Omega, 24\Omega$?

(17) Why does the connecting cord of an heater does not glow while the heating element does ?

(18) Compute the heat generated while trasferring 96000 coulomb of charge in one hour through a potential difference of 50V.

(19) An electric iron of resistance 20Ω takes a current of 5A. Calculate the heat developed in 30 seconds.

(20) What are the advantage of connecting electrical devies in parallel with a battery instead of connecting them in series ?

(21) How can three resistors of resistance 2Ω, 3Ω and 6Ω be connected to give a total resistance of (a) 4Ω (b) 1Ω?

(22) What determine the rate at which energy is delivered by an electric current ?

(23) An electric motor takes 5A from a 220V line. Determine the power of the motor and energy consumed in 2h ?

Conceptual problems :

(1) Electrical resistivity of some substances at 20^0C are given below :

Silver	$1.60\times10^{-8}\Omega$-m
Copper	$1.62\times10^{-8}\Omega$-m
Tungsten	$5.2\times10^{-8}\Omega$-m
Iron	$10.0\times10^{-8}\Omega$-m
Mercury	$94.0\times10^{-8}\Omega$-m
Nichrome	$10.0\times10^{-8}\Omega$-m

(2) The length of different metallic wires but of same area of cross - section and made of the same material are given below.

(3) The metallic wires A and B of same material are connected in parallel. Wire A has length 1 and radius r and wire B has length 21 and 2r. Compute the ratio of the resistance of parallel combination and the resistance of wire A.

Section C
Numerical Ability:

(1) How much work will be done in bringing a charge of 5.0 millicoulombs from infinity to a point P at which the potential is 12 V ?

(2) A particle with a charge of 1.5 coilombs is taken from a point A at a potential of 50V to another point b at a potential of 120V. Calculate the work done.

(3) How many electrons are required to get 1C of negative charge ?

(4) Calculate the current in a wire if 900 C of charge passes through it in 10 minutes.

(5) How much current will flow through a resistor of resistance 12Ω if a battery of 18 v is connected across it ?

(6) Calculate the resistance of a copper wire of length 1 m and area of cross section $2mm^2$ Resistivity of copper is $1.7\times10^{-8}\Omega m$.

(7) A copper wire has a resistance of 0.6Ω. nother copper wire of the same mass as the first one is double in length of the first. Find the resistance of the second wire.

(8) In an experiment to verify Ohm's law, the current through a resistor and the potential difference across it are measured. From the values given below, plot a graph of I versus V. Showthat the data confirms Ohm's law and find the resistance of the resis tor.

Current(A)	0.1	0.2	0.3	0.4
Potential difference (V)	1.2	2.4	3.6	4.8

(9) When a potential difference 20V is applied across a resistor, it draws a current of 3A. if 30V is applied across the same resistor, what will be the current?

(10) How will the resistance of a wire change if its diameter (b) is doubled, its length remaining the same ?

(11) Calculate the potential difference across each resistor in the circuit shown in figure.

(12) Three identical bulbs are connected in parallel with a battery. The current drawn from the battery is 6a. If one of the bulb gets fused, what will be the total current drawn from the battery ?

(13) A uniform wire of resistance R is cut into three equal pieces, and these pieces are joined in parallel. What is the resistance of the combination?

(14) Consider the circuit shown in figure. the voltmeter on the left reads 10V and that one the right reads 8V. Find (a) the current through the resistance R, (b) the value of r, and (c) the potential difference across the battery .

(15) Three resistors of resistance 10Ω, 20Ω and 30Ω are connected in parallel with a 6V cell. Find (a) the current through each resistor, (b) the current supplied by the cell, and (c) the equivalent resistance of the circuit.