# Physics · Class X
# Chapter -12 (Electricity)

## Introduction

- Electricity is an important source of energy in the modern times.
- Electricity is used in our homes, in industry and in transport.
- We will discuss following in this chapter:
  - electric potential
  - electric current
  - electric power
  - heating effect of electric current.

## What is electric charge

Electric charge, basic property of matter carried by some elementary particles (electrons, proton and other subatomic particles).
There are two types of electric charges: positive and negative charge.
Electrons are negatively charged while protons are positively charged.
Opposite charges (unlike charges) attract each other.
Similar charges (like charges) repel each other.

## SI unit of electric charge

The SI unit of electric charge is coulomb (C).
"One coulomb is that quantity of electric charge which exerts a force of $9 \times 10^9$ N on an equal charge placed at a distance of 1 metre from it".
A proton possesses a positive charge of $1.6 \times 10^{-19}$ C whereas an electron possesses a negative charge of $1.6 \times 10^{-19}$ C.

Q) Calculate the number of electrons constituting one coulomb of charge.

Ans: Charge of an electron $= 1.6 \times 10^{-19}$ C.

$\therefore \quad 1.6 \times 10^{-19} C = 1$ electron.

$$1C = \frac{1}{1.6 \times 10^{-19}} \text{ electrons} = 6.25 \times 10^{18} \text{ electron}.$$

Thus, 1 C (Coulomb) is equivalent to the charge contained in $6.25 \times 10^{18}$ electrons.

## Electric Current and Circuit

Flow of electric charges is called electricity (Electric Current).

Those substances through which electricity can flow are called conductors. Examples: Silver, copper and aluminium etc.

Those substances through which electricity cannot flow are called insulators. Examples: Glass, rubber, plastics, paper, wood etc.

Electric current is expressed by the amount of charge flowing through a particular area in unit time. Electric current is the rate of flow of electric charges.

All the conductors (like metals) have some electrons which are loosely held by the nuclei of their atoms. These electrons are called "free electrons" and can move from one atom to another atom throughout the conductor.

If a net charge Q, flows across any cross-section of a conductor in time t, then the current I, through the cross-section is $\boxed{I = \frac{Q}{t}}$

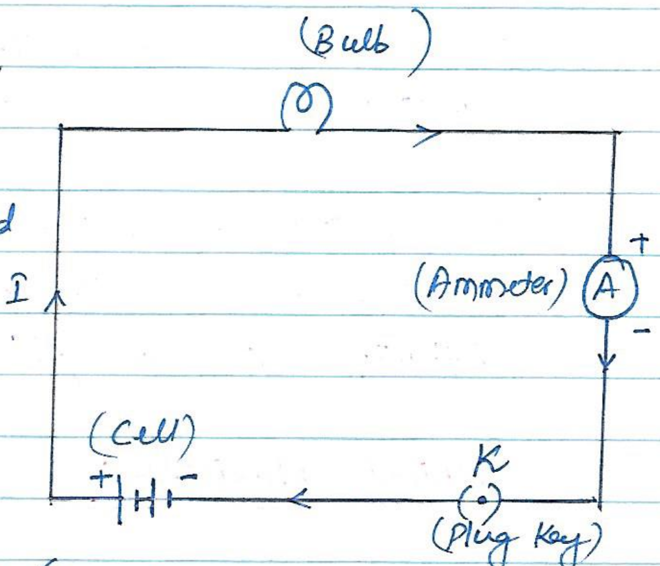
The SI unit of electric charge (Q) is Coulomb (C) which is equivalent to the charge contained in nearly $6 \times 10^{18}$ electron.

The electric current is expressed by a unit called Ampere (A). One ampere is constituted by the flow of one coulomb of charge per second.
that is $1\,A = \frac{1\,C}{1\,s}$  $1\,mA = 10^{-3}\,A$  $1\,\mu A = 10^{-6}\,A$

## Electric Circuit

A closed conducting path through which electric current may flow is called an electric circuit.

An instrument called ammeter measures electric current in a circuit. It is always connected in series in a circuit through which the current is to be measured.




(A schematic diagram of an electric circuit.)

Electric current flows in the circuit from the positive terminal of the cell to the negative terminal of the cell through the bulb and ammeter.

Q) A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge flows through the circuit.

Ans) Given: $I = 0.5\,A$, $t = 10\,min = 600\,sec$

Using equation $I = \frac{Q}{t}$, $Q = It$

$\therefore Q = 0.5 \times 600\,C$

$Q = 300\,C$

"It is the potential difference between the ends of the wire which makes the electric charges (or current) to flow in the wire." The electric current is the flow of charges (called electrons) in a conductor such as a metal wire.

$$I = \frac{Q}{t}$$

## Electric Potential

The electric potential (or potential) at a point in an electric field is defined as the work done in moving a unit positive charge from infinity to that point.
Potential is denoted by the symbol V and its unit is Volt.

A potential of 1 volt at a point means that 1 joule of work is done in moving 1 unit positive charge from infinity to that point.

## Potential Difference:

The difference in electric potential between two points is known as potential difference.
The potential difference between two points in an electric circuit is defined as the amount of work done in moving a unit charge from one point to the other point.

$$\text{Potential Difference}(V) = \frac{\text{Work Done }(W)}{\text{Quantity of charge moved }(Q)}$$

SI unit is Volt (V)

$$\text{Therefore, } 1V = \frac{1 \text{ Joule}}{1 \text{ coulomb}}, \quad 1V = 1\,JC^{-1}$$

The potential difference is measured by means of an instrument called the Voltmeter which always connected in parallel.

Voltage is the other name for potential difference.

Q.) A device that helps to maintain a potential difference across a conductor. Ans) A cell or a battery.

Q) How much work is done in moving a charge of 2 C across two points having a potential difference 12 V?

ANS) Potential Difference $V = 12\ V$
Amount of charge $Q = 2C$.

The amount of work done $W = VQ$
$= 12 \times 2\ J$
$= 24\ J$

Q) How much work is done in moving a charge of 2 coulombs from a point at 118 volts to a points at 128 volts?

ANS) Potential Difference $V = 128 - 118\ V$
$= 10$ volts
Charge moved $Q = 2$ coulombs
Work done $W = V \times Q$ $\left(\because V = \frac{W}{Q}\right)$
$= 10 \times 2$
$W = 20$ Joules.

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

ANS) charge $Q = 1\ C$ (each coulomb)
Potential Differene $V = 6\ V$ (6 V Battery)

The energy will be equal to the work done.

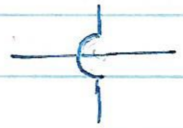
$\therefore$ Work Done, $W = 6 \times 1\ J$
$= 6\ J$
Here, the energy given to each coulomb of charge is 6 J.

# Circuit Diagram

It is often convenient to draw a schematic diagram, in which different components of the circuit are represented by the symbols conveniently used. Conventional symbols used to represent some of the most commonly used electrical components are given below.

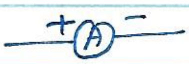
(1) Cell :   (2) Battery of two cells : 

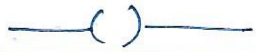
(3) Connecting wire :   (4) A wire join : 

(5) Wires crossing without joining :   6) Bulb : 

(7) Resistor : 
(Fixed resistance)

8) Variable Resistance :  or 
(or Rheostat)

9) Ammeter :   10) Voltmeter 

11) Plug key or switch (open) : 

12) Plug key or switch (closed) : 

# OHM'S LAW

Ohm's law gives a relationship between current and potential difference. According to Ohm's law :
"At constant temperature, the current flowing through a conductor is directly proportional to the potential difference across its ends."

If $I$ is the current flowing through a conductor and $V$ is the potential difference (or voltage) across its ends, then according to Ohm's law:

$$I \propto V \quad \text{(at constant temperature)}$$

$$V \propto I$$

$$\text{(or)} \quad V = R \times I \quad \text{or} \quad V = IR$$

Where $R$ is a constant called "resistance" of the conductor.

We can say $\frac{V}{I} = R$ (constant) called resistance.

$$\frac{\text{Potential Difference}}{\text{Current}} = \text{constant (called resistance)}.$$

$$\text{Also} \quad I = \frac{V}{R}, \quad I \propto V, \quad I \propto \frac{1}{R}$$

(i) The current is directly proportional to potential difference
(ii) The current is inversely proportional to resistance.

## Resistance of a Conductor

The property of a conductor due to which it opposes the flow of current through it is called resistance.

$$R = \frac{V}{I}$$

The resistance of a conductor depends on length, thickness, nature of material and temperature of conductor.
SI unit is ohm ($\Omega$)

1 ohm is the resistance of a conductor such that when a potential difference of 1 volt is applied to its ends, a current of 1 ampere flows through it.

The current through a resistor is inversely proportional to its resistance. If the resistance is doubled the current gets halved.
A component used to regulate current without changing the voltage source is called variable resistance. A device called rheostat is often used to change the resistance in the circuit.

> Motion of electrons in an electric circuit constitutes an electric current. The motion of electrons through a conductor is retarded by its resistance.
> A component of a given size that offers a low resistance is a good conductor.
> A conductor having some appreciable resistance is called resistor.
> A component of identical size that offers a higher resistance is a poor conductor. An insulator of the same size offers even higher resistance.

## Factors affecting the Resistance of a conductor

**(1) Length of the conductor :**

The Resistance of a conductor is directly proportional to its length. $R \propto l$. When the length of a wire is doubled, its resistance also gets doubled, and if the length of a wire is halved, then its resistance also gets halved. Thus, a long wire has more resistance and a short wire has less resistance.

**(2) Area of Cross-Section of the Conductor :**

The Resistance of a conductor is inversely proportional to its area of cross section. $R \propto \frac{1}{A}$. Thus, when the area of cross section of wire is doubled, its resistance gets halved, and if the the area of cross section of wire is halved, then its resistance will get doubled. A thick wire has less resistance and a thin wire has more resistance.

**(3) Nature of Material of the Conductor :**

Some materials have low resistance and others have high resistance. We find that nichrome wire is about 60 times more resistance than copper wire of same length.

**(4) Temperature :**

The resistance of all pure metals increases on raising the temperature; and decreasing on lowering the temperature.

**Resistivity :** $R \propto l$, $R \propto \frac{1}{A}$, $R \propto \frac{l}{A}$, $R = \rho \times \frac{l}{A}$

$\rho$ (rho) is constant known as resistivity. $\rho = \frac{R \times A}{l}$ $\Omega \cdot m$

## Questions

(1) Potential difference between two points of a wire carrying 2A current is 0·1 V. Calculate the resistance between these points.

ANS) Given: $I = 2\,A$ $V = 0{\cdot}1$

Using Ohm's law $V = IR$ $\therefore R = \frac{V}{I} = \frac{0{\cdot}1}{2} = 0{\cdot}05$

Resistance $R = 0{\cdot}05\ \Omega$ (ohm).

(2) A simple electric circuit has a 24 V battery and a resistor of 60 ohms. What will be the current in the circuit?

Given: Potential difference $V = 24$ volt.

Resistance $R = 60$ ohm.

Using ohms law $V = IR$, $I = \frac{V}{R} = \frac{24}{60} = 0{\cdot}4\,A$

$\therefore$ Current $I = 0{\cdot}4\ A$

(3) An electric iron draws a current of 3·4 A from the 220 V supply line. What current will this electric iron draw when connected to 110 V supply line?

ANS) Given: Current $I = 3{\cdot}4\,A$

Potential Difference $V = 220\,V$

Using ohms law $V = IR$ $R = \frac{V}{I} = \frac{220}{3{\cdot}4} = 64{\cdot}7\ \Omega$

Now, Potential Difference $V = 110\,V$

Resistance $R = 64{\cdot}7\ \Omega$

Current $I = \frac{V}{R} = \frac{110}{64{\cdot}7} = 1{\cdot}7\,A$

$\therefore$ Current will be $\underline{1{\cdot}7\ A}$ Ans

(4) A copper wire of length 2 m and area of cross-section $1.7 \times 10^{-6}$ $m^2$ has a resistance of $2 \times 10^{-2}$ $\Omega$. Calculate the resistivity of copper.

ANS) Resistivity, $\rho = \frac{R \times A}{l}$

Given $l = 2m$ $\quad A = 1.7 \times 10^{-6}\ m^2$ $\quad R = 2 \times 10^{-2}\ \Omega$

$$\therefore \rho = \frac{\cancel{2} \times 10^{-2} \times 1.7 \times 10^{-6}}{\cancel{2}} = 1.7 \times 10^{-8}\ \Omega \cdot m$$

$\therefore$ Resistivity $\rho = 1.7 \times 10^{-8}\ \Omega \cdot m$.

(5) A copper wire has a diameter of 0.5 mm and resistivity of $1.6 \times 10^{-8}$ $\Omega \cdot m$.

(a) What will be the length of this wire to make its resistance $10\Omega$.

(b) How much does the resistance change if the diameter is doubled?

ANS) (a) dia of wire = 0.5 m, radius $= \frac{d}{2} = \frac{0.5}{2} = 0.25$ mm

Radius $r = 0.25 \times 10^{-3}$ m

Area of cross-section $A = \pi r^2 = 3.14 \times 0.25 \times 0.25 \times 10^{-6}$

$A = 0.1964 \times 10^{-6}\ m^2$

Resistivity, $\rho = 1.6 \times 10^{-8}\ \Omega m$

Resistance $R = 10\Omega$

length, $l = ?$ $\quad \rho = \frac{R \times A}{l} \Rightarrow l = \frac{R \times A}{\rho}$

$$\text{length}, l = \frac{10 \times 0.1964 \times 10^{-6}}{1.6 \times 10^{-8}} = \frac{1964}{16} = 122.7\ m$$

$\therefore l = 122.7m$

(b) Resistance of wire is inversely proportional to square of diameter.

$R \propto \frac{1}{A}$, $R \propto \frac{1}{d^2}$. $\therefore$ When diameter is doubled.

Resistance will be $\left(\frac{1}{2}\right)^2$ or $\left(\frac{1}{4}\right)^{th}$ one fourth.

(6) A 6 Ω resistance wire is doubled up by folding. Calculate the new resistance of the wire.

Soln) Given : Resistance $R = 6\Omega$

$$R = \frac{\rho \times l}{A} \Rightarrow \frac{\rho \times l}{A} = 6$$

When wire is doubled by folding length will be halved and area will be doubled: $l' = \frac{l}{2}$ $A' = 2A$

$$R' = \frac{\rho \times l'}{A'} = \frac{\rho \times l}{2 \times 2A} = \frac{6}{4} = 1.5\ \Omega$$

$\therefore$ New Resistance $R' = 1.5\ \Omega$.

(7) How much current will an electric bulb draw from a source of 220 V, if the resistance of the bulb filament is 1200 Ω? (b) How much current will an electric heater coil draw from a 220 V source, if the resistance of the heater coil is 100 Ω?

Ans) Given $V = 220\ V$ $R = 1200\ \Omega$ (Bulb)
Using ohm's law $V = IR$ $\therefore I = \frac{V}{R} = \frac{220}{1200} = 0.18A$

$\therefore I = 0.18A$

(b) $V = 220\ V$ $R = 100\ \Omega$ $I = \frac{V}{R} = \frac{220}{100} = 2.2\ A$.
(Heater)

(8) The potential difference between the terminal of an electric heater is 60 V when it draws a current of 4 A from the source. What current the heater draw if the potential difference is increased to 120V?

Ans) $V = 60V$ $I = 4A$ $R = \frac{V}{I} = \frac{60}{4} = 15\Omega$

Now $I = \frac{V}{R} = \frac{120}{15} = 8A$ Ans.

(9) Resistance of a metal wire of length 1 m is 26 Ω at 20°C. If the diameter of the wire is 0.3 mm, what will be resistivity of the metal at that temperature?

Ans) $R = 26\,\Omega$  $l = 1\,m$  dia, $d = 0.3\,mm = 0.3 \times 10^{-3}\,m$

$$A = \frac{\pi d^2}{4} = \frac{3.14 \times 3 \times 3 \times 10^{-8}\,m^2}{4} = \frac{28.26 \times 10^{-8}\,m^2}{4}$$

$$\text{Resistivity } \rho = \frac{R \times A}{l} = \frac{26 \times 7.065 \times 10^{-8}}{1}$$

$$\rho = 183.65 \times 10^{-8}\,\Omega \cdot m$$
$$= 1.84 \times 10^{-6}\,\Omega \cdot m. \text{ Ans.}$$

(from table 12.2, this is the resistivity of manganese)

(10) A 4 Ω resistance wire is doubled on it. Calculate the new resistance of the wire.

Ans) Given $R = 4\,\Omega$

When wire is doubled on it. length would become half. Area of cross section is doubled

$\therefore l' = \frac{l}{2}$  $A' = 2A$

$$R = \rho \frac{l}{A} \Rightarrow R' = \rho \frac{l'}{A'} = \rho \frac{l}{2 \times 2A} = \frac{\rho l}{4A}$$

$$R' = \frac{R}{4} = \frac{4}{4} = 1\,\Omega.$$

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

ANS) The resistance of a conductor depends :

(i) on its length $R \propto l$

(ii) on its area of cross section $R \propto \frac{1}{A}$

(iii) On the nature of its material

(iv) on the temperature of the conductor.

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

ANS) Resistance, $R \propto \frac{1}{A}$. A thick wire has greater area of cross-section whereas a thin wire has smaller area of cross-section. Thus, a thick wire has less resistance and a thin wire has more resistance. Therefore, current will flow more easily through a thick wire.

(13) Let the resistance of an electrical component remain constant while the potential difference across the two ends of the component decreases to half of its former value. What change will occur in the current through it?

ANS) Ohm's law $I = \frac{V}{R}$ $V' = \frac{V}{2}$

$$I' = \frac{V'}{R} = \frac{V}{2R} = \frac{I}{2}$$

If potential difference is halved, the current also get halved.

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

ANS) Because (i) the resistivity of an alloy is much higher than that of pure metal

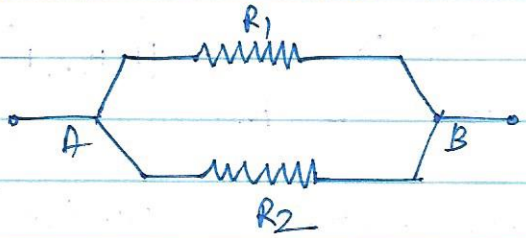
(ii) an alloy does not go under oxidation easily even at high temperature.

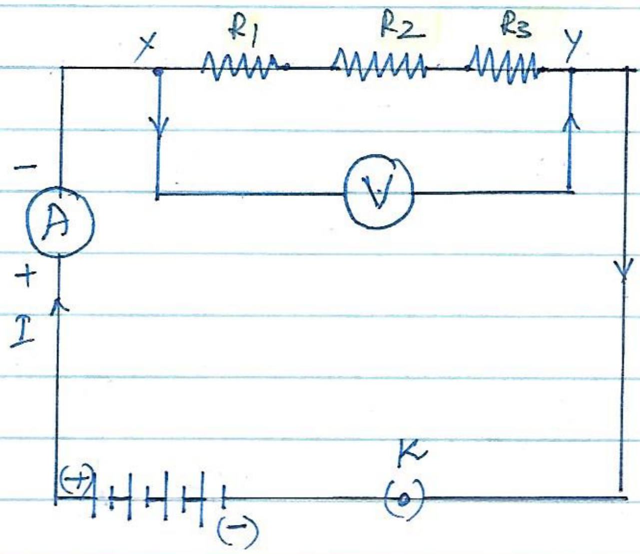
## Combination of Resistances (Resistance of a system of Resistors)

The resistances can be combined in two ways:
(i) in series and (ii) in parallel.

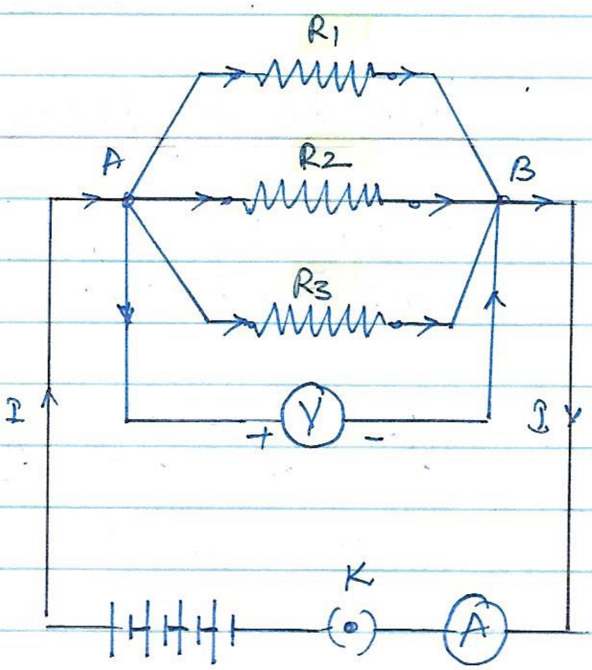
When two (or more) resistances are connected end to end consecutively, they are said to be connected in series.


When two (or more) resistances are connected between the same two points, they are said to be connected in parallel (because they become parallel to one another).



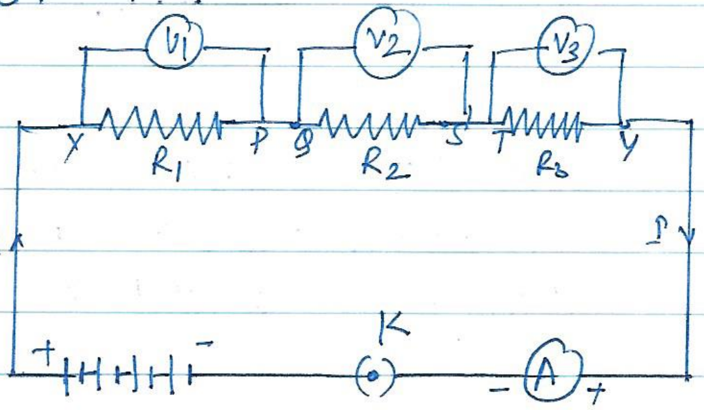

(Resistors in Series.)




(Resistors in parallel.)

## Resistors in Series

According to the law of combination of resistances in series:
The combined resistance of any number of resistances connected in series is equal to the sum of the individual resistances.
Examples, if a number of resistances $R_1, R_2, R_3, \dots$ etc are connected in series, then their combined resistance $R$ is given by: $R = R_1 + R_2 + R_3 + \dots$

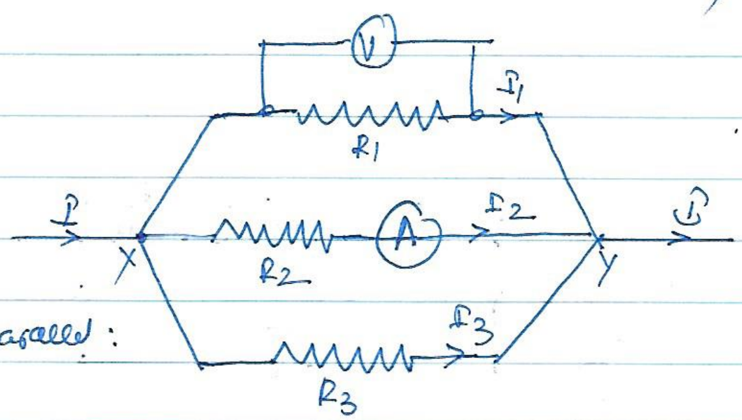



Total potential,
$V = V_1 + V_2 + V_3$

Using ohm's law $V = IR$
$V_1 = IR_1 \quad V_2 = IR_2 \quad V_3 = IR_3$

$IR = IR_1 + IR_2 + IR_3$ (Combined resistance is more)
or $R = R_1 + R_2 + R_3$

## Resistors in Parallel




According to the law of combination of resistors in parallel:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

$I_1 = \frac{V}{R_1} \quad I_2 = \frac{V}{R_2}$

Total current $I = I_1 + I_2 + I_3 + \dots$

$I_3 = \frac{V}{R_3}$

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

$$\therefore \frac{1}{R} = \frac{1}{R_2} + \frac{1}{R_2} + \frac{1}{R_3}$$ (Combined resistance is less.)

Note :

(1) In a series circuit the current is constant throughout the circuit. Thus it is impractical to connect an electric bulb and an electric heater in series, because they needs currents of widely different values.

(2) Another major disadvantages of a series circuit is that when one component fails the circuit is broken and none of the component works.

(3) On the other hand, a parallel circuit divides the current through the electrical gadgets.

(4) The total resistance in a parallel circuit is decreased. This is helpful when each gadget has different resistance and requires different current to operate properly.

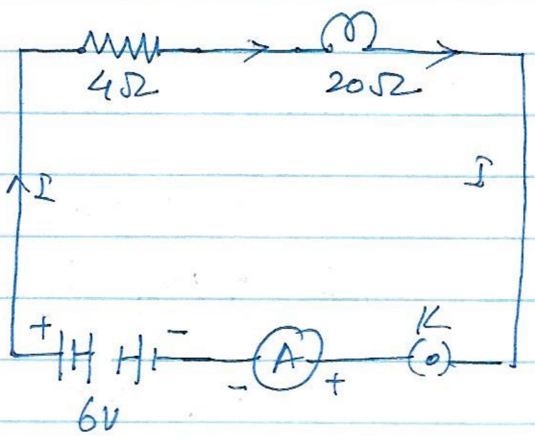
Q) An electric lamp, whose resistance is 20 Ω and a conductor of 4 Ω resistance are connected to a 6V Battery. Calculate :
(a) the total resistance of the circuit
(b) the current through the circuit
(c) the potential difference across the electric lamp and conductor

Ans) (a) Resistance of lamp $R_1 = 20\ \Omega$

Resistance of conductor in series $R_2 = 4\ \Omega$

Total resistance in series,

$R = R_1 + R_2 = 20 + 4 = 24\ \Omega$




(b) Total potential difference $V = 6V$

Current $I = ?$

Using ohm's law $I = \frac{V}{R} = \frac{6}{24} = 0.25\ A$

(c) $V_1$, potential difference across lamp $= 20 \times 0.25 = 5\ V$

$V_2$ potential difference across conductor $= 4 \times 0.25 = 1\ V$.

$V = V_1 + V_2 = 5 + 1 = 6\ V$. (?)

Q) (i) Which among iron and mercury is a better conductor?
(ii) Which material is the best conductor?

Ans) (i) Resistivity of iron $= 10 \times 10^{-8}\ \Omega \cdot m$ $\qquad \rho = \frac{R \times A}{l}$

Resistivity of mercury $= 94 \times 10^{-8}\ \Omega \cdot m$

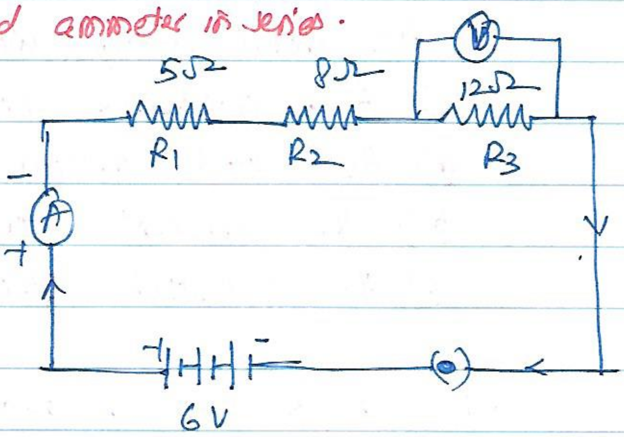
Iron is better conductor.

(ii) We know that a good conductor of electricity should have a low resistivity and a poor conductor of electricity will have a high resistivity. Silver has the lowest resistivity of $1.6 \times 10^{-8}\ \Omega \cdot m$. So, silver is the best conductor.

Q) Draw a schematic diagram of a circuit consisting of a battery of three cells of 2V each, a 5Ω resistor, an 8Ω resistor and 12Ω resistor and a plug key, all connected in series. Put voltmeter across 12Ω resistor.

Ans) Calculate reading in voltmeter and ammeter in series.

Total potential differ $= 3 \times 2V$
$= 6V$.




(i) Reading in ammeter

$R_1 = 5\Omega \quad R_2 = 8\Omega \quad R_3 = 12\Omega$

Total $R = R_1 + R_2 + R_3$

$R = 5 + 8 + 12 = 25\ \Omega$

$V = 6V \qquad I = \frac{V}{R} = \frac{6}{25} = \underline{\underline{0.24\ A}}$

$\therefore$ Ammeter will show reading of 0.24 A.

(ii) Reading in Voltmeter

$I = 0.24V \qquad R = 12\ \Omega \qquad V = IR = 0.24 \times 12 = 2.88V$

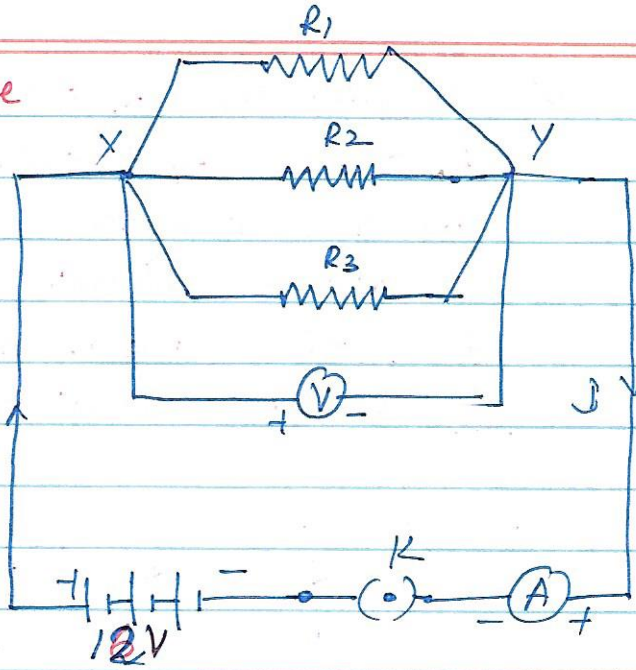
$\therefore$ Voltmeter reading is 2.88 V.

Q.) In given circuit diagram, suppose $R_1 = 5\,\Omega$ $R_2 = 10\,\Omega$ $R_3 = 30\,\Omega$. which are connected to battery 12 V. Calculate :

(a) Current through each resistor.

(b) Total current in the circuit

(c) the total circuit resistance.




Ans) (a) Using ohm's law $V = IR$

Given : $R_1 = 5\,\Omega$ $R_2 = 10\,\Omega$

$R_3 = 30\,\Omega$ $\quad V = 12\,V$ which is same across each resistor in parallel.

$$I = \frac{V}{R}, \quad I_1 = \frac{V}{R_1} = \frac{12}{5} = 2.4\,A$$

$$I_2 = \frac{12}{10} = 1.2\,A \qquad I_3 = \frac{12}{30} = 0.4\,A$$

(b) Total current in series $I = I_1 + I_2 + I_3$

$$= 2.4 + 1.2 + 0.4$$

$$= 4\,A$$

(c) Total resistance in parallel $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

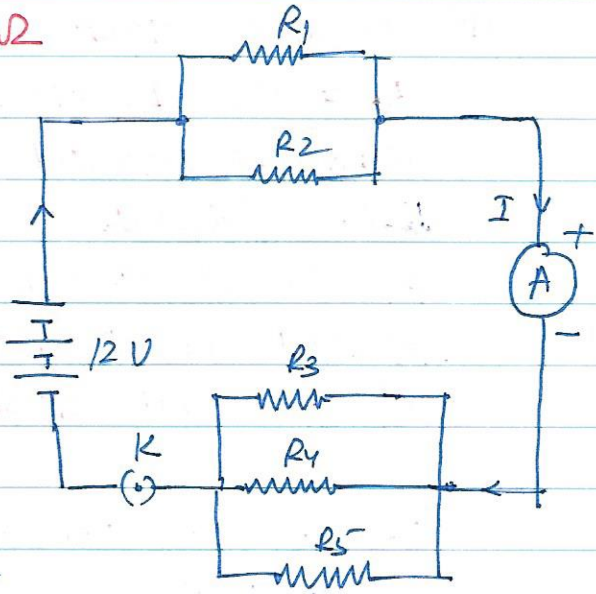
$$\frac{1}{R} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30} = 0.2 + 0.1 + 0.03 = 0.333$$

$$\frac{1}{R} = 0.333 \quad R = \frac{1}{0.333} \Rightarrow \underline{R = 3\,\Omega} \text{ Ans}$$

Q.) In given fig $R_1 = 10\Omega$ $R_2 = 40\Omega$ $R_3 = 30\Omega$ $R_4 = 20\Omega$ $R_5 = 60\Omega$ and a 12 V battery is connected as shown. Calculate :

(a) Total resistance in the circuit

(b) the total current flowing in circuit




Ans) (a) $\frac{1}{R'} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{10} + \frac{1}{40}$

$\frac{1}{R'} = 0.1 + 0.025 = 0.125$

$R' = \frac{1}{0.125} = 8\Omega$

Similarly $\frac{1}{R''} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60}$

$\frac{1}{R''} = 0.03 + 0.05 + 0.0167 = 0.1$

$R'' = \frac{1}{0.1} = 10\Omega$

Total resistance in circuit $R = R' + R'' = 8 + 10 = \underline{18\Omega}$ Ans.

(b) Using ohms law $V = IR$, $I = \frac{V}{R} = \frac{12}{18} = \underline{0.67A}$ Ans

**Q.** **Judge the equivalent resistance when the following are connected in parallel (*i*) 1 Ω and $10^6$ Ω (*ii*) 1 Ω and $10^3$ Ω and $10^6$ Ω.**

**Ans.** (*i*) When a number of resistance are connected in parallel, then their combined resistance is less than the smallest individual resistance. Therefore, equivalent resistance will be less than 1 Ω.

(*ii*) In this case, also the equivalent resistance will be less than 1 Ω.

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

**Ans.** Here, $R_1 = 100\ \Omega$, $R_2 = 50\ \Omega$, $R_3 = 500\ \Omega$

Equivalent resistance = $R$

Resistors are connected in parallel.

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

$$\frac{1}{R} = \frac{1}{100} + \frac{1}{50} + \frac{1}{500} \quad \Rightarrow \quad \frac{1}{R} = \frac{5 + 10 + 1}{500}$$

$$\frac{1}{R} = \frac{16}{500} = \frac{4}{125} \quad \Rightarrow \quad R = \frac{125}{4}\Omega$$

Current through all the three appliances, $I = \dfrac{V}{R} = \dfrac{220 \times 4}{125} = 7.04 \text{ A}$

Since the electric iron connected to the same source that takes as much current as all the three appliances. So

Resistance of the electric iron $= \dfrac{125}{4}\ \Omega = 31.25\ \Omega$

Current through the electric iron = **7.04 A**

**Q.** **What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?**

**Ans.** (*i*) In parallel circuit, if one electrical appliance stops working due to some defect, then all other appliances keep working normally. In series circuit, if one electrical appliance stops working due to some defect, then all other appliances also stop working.

(*ii*) In parallel circuits, each electrical appliance gets the same voltage as that of the power supply line. In series circuit, appliances do not get the same voltage as that of the power supply line.

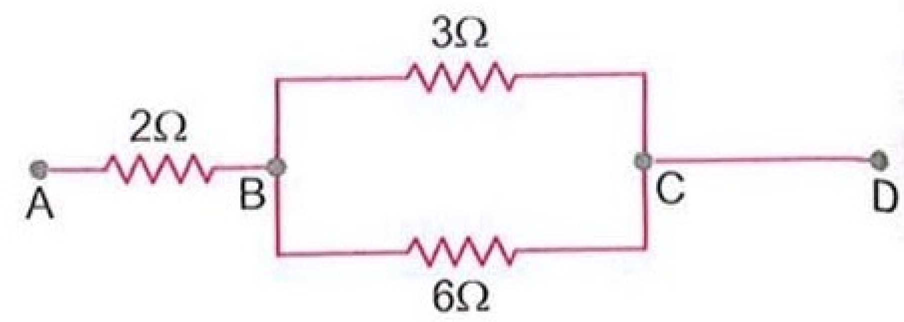
(*iii*) In the parallel connection of electrical appliances, the overall resistance of the household circuit is reduced due to which the current from the power supply is high. In the series connection, the overall resistance of the circuit increases too much due to which the current from the power supply is low.

**Q.** **How can three resistors of resistance 2 Ω, 3 Ω and 6 Ω be connected to give a total resistance of (*i*) 4 Ω, (*ii*) 1 Ω?**

**Ans.** (*i*) As the total resistance (equivalent resistance) is 4 Ω, the 6 Ω resistor cannot be in series. So, it must be in parallel with some other resistors.

In parallel connection, the equivalent resistance (4 Ω) has to be less than all the resistances.

So, the resistors of 2 Ω and 3 Ω cannot be in parallel at one time with 6 Ω.




So, the resistors have to be in a mixed combination. Let us consider the combination shown in the figure.

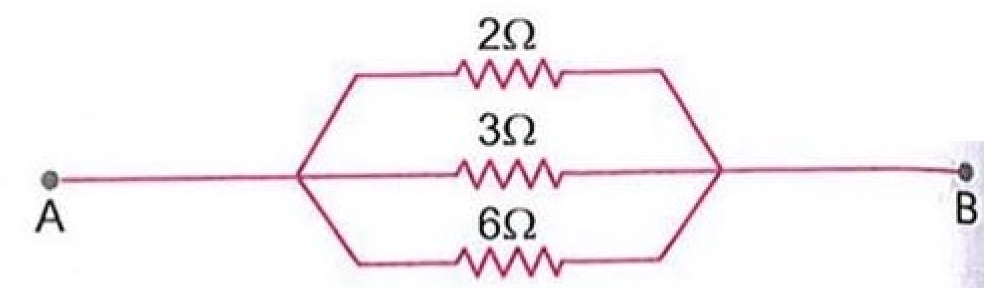
The equivalent resistance between B and C (which are in parallel)

$$= \frac{3\Omega \times 6\Omega}{3\Omega + 6\Omega} = \frac{18\Omega}{9\Omega} = 2\Omega$$

The resistance between A and D = 2 Ω + 2 Ω = 4 Ω.

So, the combination shown in the figure is true.

(*ii*) Here, $R_1 = 2\Omega$, $R_2 = 3\Omega$, $R_3 = 6\Omega$ and $R = 1\Omega$




Since the equivalent resistance of the combination is of lesser value than any of the resistors of the combination, it is clear that the resistors should be connected in parallel. It can be further confirmed by using the formula

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = \frac{3+2+1}{6} = \frac{6}{6} = 1$$

*i.e.*, $R = 1$ ohm.

Therefore, resistors should be connected in parallel.

**Q.** **What is (*i*) the highest, (*ii*) the lowest total resistance that can be secured by combinations of four coils of resistance 4 Ω, 8 Ω, 12 Ω, 24 Ω?**

**Ans.** (*i*) The highest can be secured by series combination and is equal to

$$R = 4\ \Omega + 8\ \Omega + 12\ \Omega + 24\ \Omega = \mathbf{48\ \Omega}$$

(*ii*) The lowest total resistance can be secured by parallel combination, which is given by

$$\frac{1}{R} = \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{24} \Rightarrow \frac{1}{R} = \frac{6+3+2+1}{24}$$

$$\Rightarrow \frac{1}{R} = \frac{12}{24} = \frac{1}{2} \qquad \therefore \quad R = 2\ \Omega$$

## Heating Effect of Current

When an electric current is passed through a high resistance wire, like nichrome wire, the resistance wire become very hot and produces heat. This is called the heating effect of current. The heating effect is obtained by the transformation of electrical energy into heat energy.

The role of 'resistance' in electrical circuits is similar to the role of 'friction' in mechanics.

When an electric charge Q moves against a potential difference V, the amount of work done is given by:

$$W = Q \times V \quad \text{——} (1)$$

We know $Q = I \times t$ —— (2)

Using ohm's law $V = IR$ —— (3)

$$\therefore \ W = I \times t \times I \times R$$

$$W = I^2 \times R \times t \quad J$$

Assuming electrical work done is converted into heat energy

Heat produced, $H = I^2 \times R \times t$ Joule.

This is known as "Joule's law of heating".

According to Joule's law of heating ($H = I^2 \times R \times t$), heat produced in a wire is directly proportional to:

(i) square of current ($I^2$), $H \propto I^2$

(ii) Resistance of wire ($R$), $H \propto R$

(iii) time ($t$), for which current is passed. $H \propto t$

## Applications of the Heating Effect of Current:

(1) The heating effect of current is utilised in the working of electrical heating appliances such as electric iron, electric kettle, electric toaster, electric oven, room heaters, water heaters (geysers) etc.
All these heating appliances contain coils of high resistance wire made of nichrome alloy.

(2) The heating effect of electric current is utilised in electric bulb (electric lamps) for producing light. When electric current passes through a very thin, high resistance tungsten filament of an electric bulb, the filament becomes white-hot and emits light.
Tungsten metal is used for making the filaments of electric bulbs because it has a very high melting point (of 3380°C)

(3) The heating effect of electric current is utilised in electric fuse for protecting household wiring and electrical appliances. A fuse is a short length of a thin tin-plated copper wire having low melting point.
When the current in a household electric circuit rises too much due to some reason, then fuse wire gets heated too much, melts and breaks the circuit.
Thus, an electric fuse is a very important application of the heating effect of current.

## Electric Power

When an electric current flows through a conductor, electric energy is used up and we say that the current is doing work. We know that the rate of doing work is called power. So electric power is the electrical work done per unit time.

$$\text{Electric Power} = \frac{\text{Electric work done}}{\text{Time taken}}$$

$$P = \frac{W}{t}$$

Unit of Power is Watt $\qquad 1 \text{ watt} = \frac{1\,J}{1\,sec}$

1 KW = 1000 watts.

Electric power is the rate at which electrical energy is consumed.
Electric power is the electrical energy consumed per second.

### Formula for Calculating Electric Power.

$$\text{Power} = \frac{\text{Work Done}}{\text{Time Taken}} \qquad P = \frac{W}{t}$$

Work done $\quad W = V \times I \times t$ Joule.

$$P = \frac{W}{t} = \frac{V \times I \times \cancel{t}}{\cancel{t}} = V \times I$$

$$\therefore P = V \times I$$

$V$ = Potential Difference

$I$ = Current in amperes.

$\boxed{\text{Electrical power} = \text{Voltage} \times \text{Current}}$.

(i) $V = IR \quad \therefore \quad P = IR \times I, \quad P = I^2 R$

(ii) $V = IR \qquad P = V \times \frac{V}{R} \Rightarrow P = \frac{V^2}{R}$

1 watt = 1 volt × 1 Ampere = 1 VA

## Commercial unit of electrical energy : Kilowatt Hour.

"One kilowatt - hour is the amount of electrical energy consumed when an electrical appliance having a power rating of 1 kilowatt is used for 1 hour".

1 kw = 1000 watt

1 kwh = 1 kilowatt for 1 hour

= 1000 watts for 1 hour

= $1000 \times 3600$ watt · second

= $3.6 \times 10^6$ watt · second.

1 kwh = $3.6 \times 10^6$ Joule (J) $\left[ \because 1 \text{ watt} = \frac{1 \text{ Joule}}{1 \text{ second}} \right]$

(Questions)

(1) A potential difference of 250 volts is applied across a resistance of 500 $\Omega$ in an electric iron. Calculate (i) current (ii) heat energy produced in joule in 10 seconds.

Ans) (i) $V = 250\,V$ $\quad R = 500\,\Omega$

Using ohm's law $\quad V = IR \quad I = \frac{V}{R} = \frac{250}{500} = 0.5\,A$

$\therefore$ Current $I = 0.5\,A$

(ii) Heat Energy $= I^2Rt$

$= 0.5 \times 0.5 \times 500 \times 10$

$= \frac{25}{\cancel{100}} \times \cancel{500} \times 10$

$H = 1250$ Joule.

(2) Calculate the heat produced when 96,000 coulombs of charge is transferred in 1 hour through a potential difference of 50 volts.

Ans) $Q = 96,000\,C \quad t = 60 \times 60$ sec $\quad (1\,h = 60 \times 60$ sec$)$

Current $\quad I = \frac{Q}{t} = \frac{960\cancel{00}}{6\cancel{0} \times 6\cancel{0}} = \frac{80}{3} = 26.67\,A$

$\therefore I = 26.67\,A$.

Using Ohm's law $\quad V = IR \quad R = \frac{V}{I} = \frac{50}{26.67}$

$R = 1.87\,\Omega \qquad R = 50 \div \frac{80}{3} = 50 \times \frac{3}{80} = \frac{15}{8}$

Heat produced $\quad H = I^2Rt$

$= 26.67 \times 26.67 \times 1.87 \times 60 \times 60$

$= 4788400\,J$

$= 4788.4\,kJ$

$H = I^2Rt = \frac{80}{3} \times \frac{80}{3} \times \frac{15}{8} \times 60 \times 60 = 4800\,kJ$

(3) Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then in parallel in a circuit across the same potential difference. What would be the ratio of heat produced in series and parallel combinations.

Ans) Let the resistance of each one of the two wires be $x$.

(i) When the two resistance wires, each having a resistance $x$, are connected in series, then:

Combined resistance, $R_1 = 2x$.

Let $V$ be the potential difference

then using Ohm's law $V = IR$ $\quad I_1 = \frac{V}{R} = \frac{V}{2x}$

Heat produced $H_1 = I^2Rt = \frac{V^2}{4x^2} \times 2x \times t$

$$H_1 = \frac{V^2 \times t}{2x} \quad \text{———} (1)$$

(ii) When connected in parallel, then

$$\frac{1}{R_2} = \frac{1}{x} + \frac{1}{x} = \frac{2}{x} \Rightarrow R_2 = \frac{2}{x}$$

$$R_2 = \frac{x}{2} \qquad I_2 = \frac{V}{R_2} = \frac{2V}{x}$$

Heat produced $H_2 = I_2^2 \times R_2 \times t = \left(\frac{2V}{x}\right)^2 \times \frac{x}{2} \times t$

$$= \frac{4V^2 \times x \times t}{x^2 \times 2}$$

$$H_2 = \frac{2V^2 \times t}{x} \quad \text{———} (2)$$

$$\frac{H_1}{H_2} = \frac{V^2 \times t}{2x} \div \frac{2V^2 \times t}{x} = \frac{V^2 \times t}{2x} \times \frac{x}{2V^2 \times t} = \frac{1}{4}$$

$H_1 : H_2 = 1 : 4$

(4) An electric iron consumes energy at a rate of 840 W when heating is at the maximum rate and 360 W when the heating is at the minimum. The voltage is 220 V. What are the current and the resistance in each case?

ANS) (a) Power $P = 840$ W $V = 220$ V

Power $= VI$ $\therefore I = \frac{P}{V} = \frac{840}{220} = 3.82$ A

$V = IR$ $\therefore R = \frac{V}{I} = \frac{220}{3.82} = 57.6\,\Omega$

$\therefore I = 3.82$ A

$R = 57.6\,\Omega$

(b) Power $P = 360$ W $V = 220$ V

$I = \frac{P}{V} = \frac{360}{220} = 1.64$ A

$R = \frac{V}{I} = \frac{220}{1.64} = 134.15\,\Omega$

(5) 100 J of heat are produced each second in a $4\,\Omega$ resistance. Find the potential difference across the resistor.

ANS) $H = 100$ J $R = 4\,\Omega$ $V = ?$

$H = \frac{V^2}{R}$ $V^2 = H \times R = 100 \times 4 = 400$

$V = \sqrt{400}$

$V = 20$ V

(6) Why does the cord of an electric heater not glow while the heating element does?

ANS) The cord of the electric heater is made of copper. It does not glow because negligible heat is produced in it by the passing current due to its extremely low resistance.

The heating element of an electric heater is made of nichrome. It glows because large amount of heat is produced in it by the passing electric current due to its high resistance.

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

Ans) $R = 20\ \Omega$ $I = 5A$ $t = 30$ sec

$$H = I^2 Rt = 5 \times 5 \times 20 \times 30$$

$$H = 15000\ J = 15\ kJ.$$

(8) An electric bulb is rated 220 V and 100 W. When it is operated on 110 V, Calculate the power.

Ans) $P = \frac{V^2}{R}$ , $R = \frac{V^2}{P} = \frac{22\cancel{0} \times 22\cancel{0}}{1\cancel{00}} = 22 \times 22$

$$P' = \frac{V^2}{R} = \frac{\cancel{11}0 \times \cancel{11}0}{\cancel{22} \times \cancel{22}} = \frac{100}{4} = \underline{\underline{25\ W}}$$

$P' = \underline{\underline{25\ W}}$ Ans.

(9) A refrigerator having a power of 350 W operates for 10 hours a day. Calculate the cost of electrical energy to operate it for a month of 30 days. The rate of electrical energy is Rs. 3.40 per kWh.

Ans)

Electrical Energy, $E = P \times t$

$P = 350W$   Time, $t = 10 \times 30 = 300\ h$

$$P = \frac{350}{1000} = 0.35\ kW.$$

$$E = P \times t = 0.35 \times 300\ kWh$$

$$E = 105\ kWh$$

Cost of 1 kWh of electricity = Rs. 3.40

Cost of 105 kWh of electricity = Rs. $3.40 \times 105$

= Rs. 357.

(10) A bulb is rated at 200V - 100W. What is its resistance? Five such bulbs burn for 4 hours. What is the electrical energy consumed? Calculate the cost if the rate is Rs. 4.60 per unit.

Ans) (a) Calculation of Resistance   $P = \frac{V^2}{R}$, $R = \frac{V^2}{P}$

$$\therefore R = \frac{200 \times 2\cancel{00}}{1\cancel{00}} = 400\ \Omega$$

(b) Energy consumed :   $E = P \times t$, $E = \frac{100 \times kW}{1000}$

$\therefore E = 0.1\ kW$

Energy consumed by one bulb $= 0.1 \times 4$

$= 0.4\ kWh$

Energy consumed by 5 bulb $= 0.4 \times 5$

$= 2\ kWh$

(c) Cost of electrical energy:

Cost of 1 units = Rs. 4.60

Cost of 2 units = 4.60 × 2

= Rs. 9.20

(11) An electric heater draws a current of 10 A from a 220 V supply. What is the cost of using the heater for 5 hours everyday for 30 days if the cost of 1 unit (1 kWh) is Rs. 5.20?

Ans) $I = 10\,A$ $\quad V = 220\,V$

Power $P = VI = 220 \times 10 = 2200\,W$

$P = 2.20\,kW$ ——— (1)

Energy consumed, $E = P \times t$

$= 2.2 \times 5\,kWh$

Energy consumed in 1 day = 11 kWh

Energy consumed in 30 days = 11 × 30

= 330 kWh (or 330 units)

Cost of 1 unit = Rs. 5.20

Cost of 330 units = 5.20 × 330

= Rs. 1716

(12) An electric bulb is connected to a 220 V generator. The current is 0·50 A. What is the power of the bulb?

Ans) $P = Vi = 220 \times 0{\cdot}5 = 110 \ J/s = 110 \ W$.

(13) An electric refrigerator rated 400 W operates 8 hour/day. What is the cost of the energy to operate it for 30 days at Rs. 3 per kWh?

Ans) $P = 400 \ W$ $\quad t = 8$ hour / day

Energy consumed, $E = P \times t$
$= \frac{400 \times 8}{1000}$ kWh

Energy consumed in 1 day $= 3{\cdot}2$ kWh
Energy consumed in 30 day $= 3{\cdot}2 \times 30$ kWh
$= 96$ kWh (or 96 units)

Cost of 1 unit = Rs. 3
cost of 96 units = $3 \times 96$
= Rs. 288

(14) What determines the rate at which energy is delivered by a current? Ans - Electric Power.

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

Ans) $P = Vi = 220 \times 5 = 1100 \ W = 1{\cdot}1$ kW

Energy consumed $E = P \times t = 1{\cdot}1 \text{ kW} \times 2 \text{ h}$
$= 2{\cdot}2$ kWh.

**Q. 8. 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.**

**Ans.** Potential difference, $V = 12$ V

Current, $I = 2.5 \text{ mA} = 2.5 \times 10^{-3}$ A

We know that $V = IR$

or, $R = \frac{V}{I} = \frac{12}{2.5 \times 10^{-3}} = 4.8 \times 10^{3}\ \Omega = \mathbf{4.8\ k\Omega}$

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

**Ans.** Resistors are connected in series.

So, equivalent resistance

$$R = 0.2\ \Omega + 0.3\ \Omega + 0.4\ \Omega + 0.5\ \Omega + 12\ \Omega = 13.4\ \Omega$$

Potential difference, $V = 9$ V

Current, through the circuit,

$$I = \frac{V}{R} = \frac{9}{13.4} = \mathbf{0.67\ A}$$

**Q. 10. How many 176 Ω resistors (in parallel) are required to carry 5 A on a 220 V line?**

**Ans.** Current, $I = 5$ A

Potential difference, $V = 220$ V

Resistance of parallel circuit, $R = \frac{V}{I} = \frac{220}{5} = 44\ \Omega$

Let no. of resistors $= n$

In parallel, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + n$ times

$$\frac{1}{44} = \frac{1}{176} + \frac{1}{176} + \ldots\ n \text{ times}$$

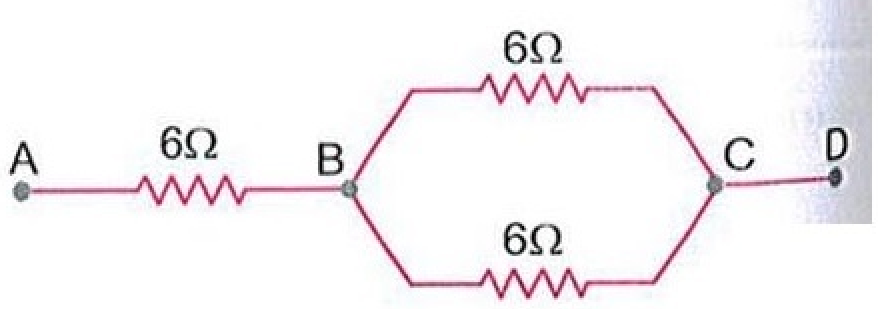
$$\frac{1}{44} = \frac{n}{176}$$

$$n = \frac{176}{44} \text{ or } n = \mathbf{4}$$

Number of required resistors = 4.

**Q. 11. Show how you would connect three resistors, each of resistance 6 Ω, so that the combination has a resistance of (*i*) 9 Ω (*ii*) 4 Ω.**

**Ans.** (*i*) In order to get a resistance of 9 Ω, We connect the given resistors (each of resistance of 6 Ω) in the following way.




Resistance between B and C

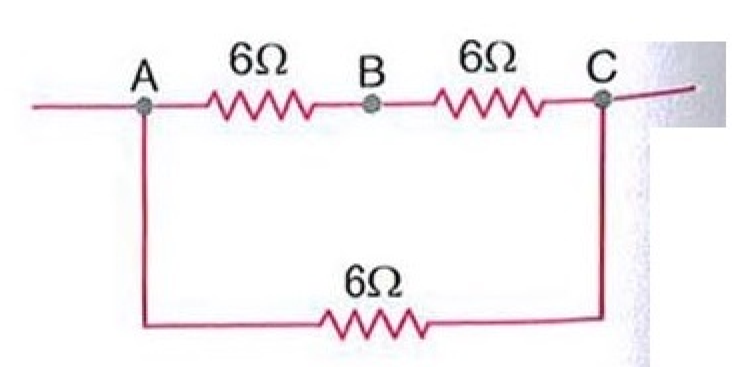
$$\frac{1}{R} = \frac{1}{6} + \frac{1}{6}$$

$$\frac{1}{R} = \frac{2}{6}$$

$$R = 3\ \Omega$$

Resistance of the combination = 6 Ω + 3 Ω = 9 Ω

(*ii*) In order to get a resistance of 4 Ω, we connect two resistors in series and third in parallel as shown in figure.




Resistors AB and BC are in series, therefore,

$$R_S = 6\ \Omega + 6\ \Omega = 12\ \Omega$$

Now, $R_s$ is parallel with the third (6Ω).

∴ Equivalent resistance of combination ($R_p$) is given by

$$\frac{1}{R_p} = \frac{1}{6} + \frac{1}{12} = \frac{2+1}{12}$$

$$\frac{1}{R_p} = \frac{3}{12} = \frac{1}{4}$$

$$R_p = 4\ \Omega$$

**Q. 12. Several electric bulbs designed to be used on a 220 V electric supply line, are rated 10 W. 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.** Potential difference, $V = 220$ V

Power of each bulb, $P = 10$ W

Resistance of each bulb, $\mathrm{R} = \frac{V^2}{P} = \frac{220 \times 220}{10} = 4840\ \Omega$

Total resistance in the circuit,

$$R' = \frac{V}{I} = \frac{220}{5} = 44\ \Omega$$

Let $n$ be the number of bulbs to be connected in parallel to obtain resistance $R'$.

$$\frac{1}{R'} = \frac{1}{R} + \frac{1}{R} + \ldots.\ n \text{ times}$$

$$\frac{1}{R'} = \frac{n}{R}$$

$$n = \frac{R}{R'} = \frac{4840}{44} = \mathbf{110}$$

Required number of bulbs = 110

**Q. 13. A hot plate of an electric oven connected to a 220 V line has two resistance coils A and B, each of 24 Ω resistance, which may be used separately, in series or in parallel. What are the currents in the three cases?**

**Ans.** Potential difference, $V = 220$ V

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

**Case I:** When coils A and B are used separately, current through each coil,

$$I = \frac{V}{R} = \frac{220}{24} = 9.2 \text{ A}$$

**Case II:** When coils A and B are connected in series, the equivalent resistance in the circuit.

$$R_s = 24 + 24 = 48\ \Omega$$

$$\text{Current, } I = \frac{V}{R_S} = \frac{220}{48} = 4.6 \text{ A}$$

**Case III:** When coils A and B are connected in parallel, the equivalent resistance ($R_p$) is given by

$$\frac{1}{R_p} = \frac{1}{24} + \frac{1}{24} = \frac{2}{24}$$

$$R_P = 12\ \Omega$$

$$\text{Current, } I = \frac{V}{R_p} = \frac{220}{12} = \mathbf{18.3\ A}$$

**Q. 14. Compare the power used in the 2 Ω resistor in each of the following circuits: (*i*) a 6 V battery in series with 1 Ω and 2 Ω resistors, and (*ii*) a 4 V battery in parallel with 12Ω and 2 Ω resistors.**

**Ans.** (*i*) Equivalent resistance of 1 Ω and 2 Ω in series, R = 1 Ω + 2 Ω = 3 Ω

Potential difference, $V = 6$ V

Current, $I = \frac{V}{R} = \frac{6}{3} = 2A$

Current in series circuit is same.

∴ Current in 2 Ω resistor = 2 A

Power in 2 Ω resistor, $P = I^2 R = 2^2 \times 2 = 8$ W

(*ii*) Potential difference across 2 Ω resistor = 4 V

$$\text{Power, } P' = \frac{V^2}{R} = \frac{4^2}{2} = 8 \text{ W}$$

$$P : P' = 8 \text{ W} : 8 \text{ W} = \mathbf{1 : 1}$$

**Q. 15. Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to electric mains supply. What current is drawn from the line if the supply voltage is 220 V?**

**Ans.** We know that $P = \frac{V^2}{R}$

∴ $R = \frac{V^2}{P}$

Resistance of 1st lamp,

$$R_1 = \frac{V^2}{P} = \frac{220 \times 220}{100} = 484 \ \Omega$$

Resistance of 2nd lamp,

$$R_2 = \frac{220 \times 220}{60} = \frac{2420}{3} \ \Omega$$

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

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{484} + \frac{3}{2420} = \frac{8}{2420}$$

$$R = \frac{2420}{8} \ \Omega$$

Current drawn from the line

$$I = \frac{V}{R} = \frac{220 \times 8}{2420} = \mathbf{0.73 \ A}$$

**Q. 16. Which uses more energy, a 250 W TV set in 1 h or a 1200 W toaster in 10 minutes?**

**Ans.** Energy used by TV set

$$E_1 = P \times t$$

$$= 250 \text{ W} \times 1\text{h} = 250 \text{ Wh}$$

Energy used by toaster,

$$E_2 = P \times t$$

$$= 1200 \times \frac{10}{60} = 200 \text{ Wh}$$

Thus, TV set in one hour uses more energy than the toaster uses in 10 minutes.

**Q. 17. An electric heater of resistance 8 Ω draws 15 A from the service mains in 2 hours. Calculate the rate at which heat is developed in the heater.**

**Ans.** Here, $R = 8\,\Omega$

$I = 15\text{ A}$

The rate at which heat is developed is power, $P = I^2 R$

$$\text{Power} = \frac{\text{Heat developed } (I^2Rt)}{\text{Time taken } (t)}$$

$= 15 \times 15 \times 8 =$ **1800 J/s.**

**Q. 18. Explain the following:**

**(*i*) Why is the tungsten used almost exclusively for filament of electric lamp?**

**(*ii*) Why are the conductors of electric heating devices, such as bread-toasters and electric irons, made of an alloy rather than a pure metal?**

**(*iii*) Why is the series arrangement not used for domestic circuits?**

**(*iv*) How does the resistance of a wire vary with its area of cross-section?**

**(*v*) Why are copper and aluminium wires usually employed for electricity transmission?**

**Ans.** (*i*) Pure tungsten has a high resistivity and a high melting point (nearly 3000°C). When an electric current is passed through the filament, the electric energy is converted to heat and light energy due to the heating of the filament to a very high temperature. Due to the high melting point of tungsten, the filament does not melt.

(*ii*) The resistivity of an alloy is generally higher than that of its constituent metals. Alloys do not oxidise (burn) readily at higher temperatures. Therefore, conductors of electric heating devices, such as toasters and electric irons, are made of an alloy rather than pure metal.

(*iii*) The series arrangement is not used for domestic circuits because:

(*a*) if connected in series total resistances will increase. Therefore, current flowing through the circuit will be low.

(*b*) if one appliance is switched off or gets damaged than all other appliances will also stop working because their electricity supply will be cut off.

(*iv*) The resistance of a wire is inversely proportional to its cross-sectional area. Thus, a thick wire has less resistance, and a thin wire has more resistance.

(*v*) Copper and aluminium wires are usually employed for electricity transmission because copper and aluminium have very low resistivities.