SCIENCE
CLASS 10
ELECTRICITY

Contents

1. The substances which allow easy flow of electric charges through them are called good conductors or simply conductors, for example : Copper, aluminium etc.
2. The substances which do not allow flow of electric charges through them are called insulators, for example : plastic, rubber, dry wool etc.
3. Electric charge has a usual symbol Q or q and it's unit is coulomb (with symbol C).
4. Electric charge is of two different types i.e. positive charge and negative charge.
5. Elementary charge, i.e. charge on an electron or proton is 1.6×10^{-19} C.
6. 1 C of charge = $(6.25 \times 10^{18})(1.6 \times 10^{-19})$C
   Where 6.25×10^{18} is the number of electrons or protons in 1 C of charge.
7. The positive charge of protons in an atom is equal to the negative charge of electrons in an atom so an atom as a whole is neutral electrically.

1. Electric Current

Electric current is defined as the rate of flow of electric charges through a conductor.

$$\text{Current} = \frac{\text{Charge}}{\text{Time}} \quad \text{i.e., } I = \frac{Q}{t}$$

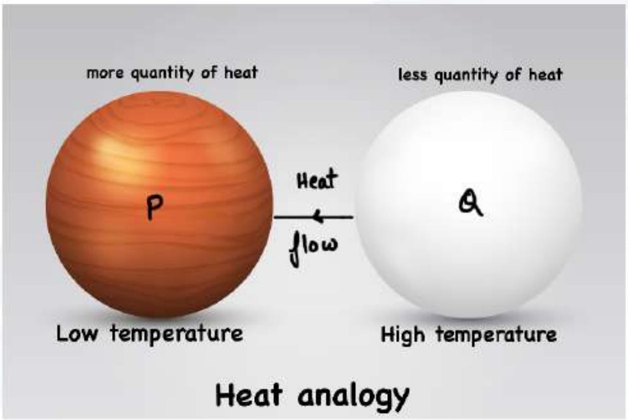
$$\text{Unit of Current} = \frac{\text{unit of charge}}{\text{unit of time}}$$

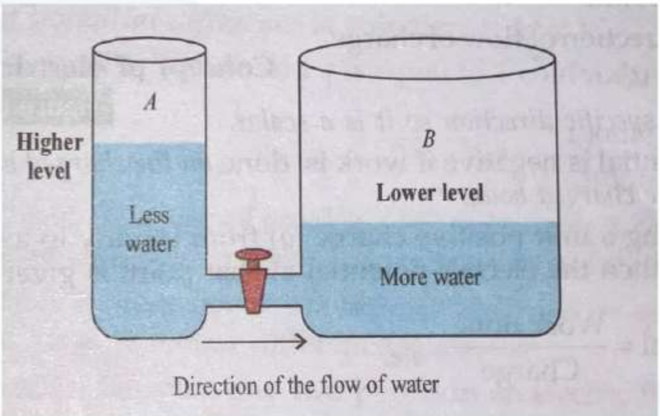
$$= \frac{1 \text{ coulomb}}{1 \text{ second}} = 1\,Cs^{-1}$$

- The SI unit of Current: Ampere (A)
- Definition of Ampere:
  If one coulomb of charge flows through a conductor in one second, then current passing through the conductor is one ampere.
- Current has magnitude but no specified direction. So, current is a scalar.

2. Potential Difference

Charge must flow from a body having more charge to a body having less charge.





It is the temperature difference and not the quantity of heat which decides the direction of flow of heat.

It is the difference between the levels of water and not the quantity of water which decides the direction of the flow of water.

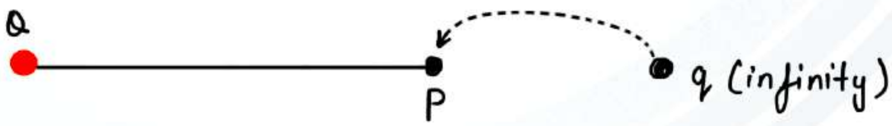
Potential is the level to which a body is charged and not the quantity of charge which decides the direction of the flow of electric charge.

Electric Potential

Electric potential is the electric condition which determine the direction of flow of electric charges from one body to another body.

Or

The electric potential at a point in the field of an electric charge is defined as the work done in bringing a unit positive charge from infinity to that point.



- ★ Potential of a charge body tells the direction of flow of charge.
- ★ Electric potential is denoted by (V)
- ★ It has magnitude and no specific direction so it is scalar.
- ★ Positive potential: work is done by the charged body.
- ★ Negative potential: work is done on the charge body.

If the amount of work done(W) in bringing a unit positive charge(q) from infinity to a point P in electric field of another charge (Q) then the electric potential at that point is given by

$$\text{Potential} = \frac{\text{Work Done}}{\text{Charge}} \quad \text{i.e. } V = \frac{W}{q}$$

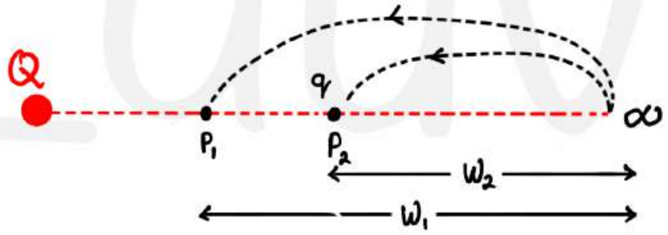
SI unit of electric potential = $\frac{1 \text{ joule}}{1 \text{ coulomb}}$ = 1 JC^{-1} = 1 volt (V)

Definition of volt :

If 1 joule of work is done in bringing a positive charge of 1 coulomb from infinity to a point in an electric field of another charge then the potential at that point is 1 volt.

Potential Difference

The potential difference between two points in an electric field is defined as the amount of work done in bringing a unit positive charge from one point to another in electric field of the other charge.



★ Potential at P_1, $V_1 = \frac{W_1}{q}$

★ Potential at P_2, $V_2 = \frac{W_2}{q}$

Potential Difference between P_1 and P_2 = $V_2 - V_1 = \frac{W_2}{q} - \frac{W_1}{q}$

$$\text{Potential Difference} = \frac{W_2 - W_1}{q}$$

SI unit of potential difference is Volt, denoted by V.

NA 1 Find the work done in moving a charge of 3 coulomb from a point P at 220 volt to a point P at 320 volt.

Sol^n: Potential difference = $\frac{\text{Work done}}{\text{Charge}}$

Potential difference = $P_2 - P_1$
= 320 − 220
= 100 Volt.

Charge = 3 coulomb

work done = P.D × q
= 100 × 3
= 300 Joule //

Source of potential difference

★ **Cell** : It is a source of electricity which **provides potential difference** between its two terminals for a longer duration due to the chemical reaction taking place inside it.

★ A **combination of two or more cells** is called a **battery**.

NA 2 A current of 16 A flows in a metallic wire for 60 minute. Find the net charge passed in this duration.

Sol: Time, t = 60 minute = 60 × 60 sec

Current = $\frac{\text{Charge}}{\text{time}} = \frac{Q}{t}$

$Q = I \times t = 16 \times 60 \times 60 = 57600\ C.$

Potential difference across the terminals of a cell when no current is drawn through it is called **electromotive force** i.e. **e.m.f.**

Electrical Circuits

★ An electrical circuit is a conducting path consisting of electrical components connected across the terminals of a source (a cell or a battery).

★ An electric circuit in which **current flows** is called **closed electric circuit.**

★ An electric circuit in which **no electric current flows** is called **open circuit.**

OHM'S LAW

German physicist George Simon Ohm gave relationship between electric current and potential difference.

According to him, current flowing through a conductor is directly proportional to the potential difference across the conductor when physical conditions like temperature, pressure etc. remain same.

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

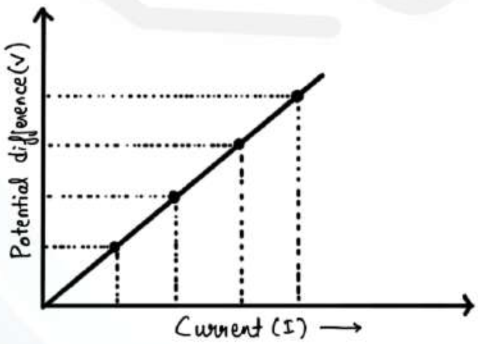
where, R is a constant called the resistance.

from the ohm's law,

$I \propto \frac{1}{R}$ (where V is constant)

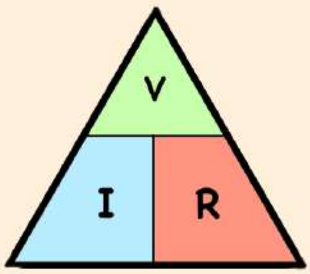
The current is inversely proportional to the resistance of the conductor when the potential difference in the circuit is kept constant.

Graph between V and I



$$\text{Slope} = \frac{\text{change in V}}{\text{change in I}} = \text{resistance R}$$

★ Graph also indicate the current flowing through the resistor is directly proportional to the potential difference across it.



★ $V = IR$

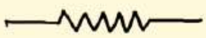
★ $I = \frac{V}{R}$

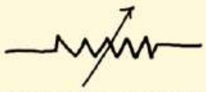
★ $R = \frac{V}{I}$

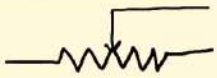
NA 3 A 24V battery feeds a lamp of 480 ohm. Find current in the lamp neglecting the resistance of the connecting wires.

Resistance

- It is the property of a conductor due to which it opposes the flow of electric current through it.
- Symbol of resistors are shown as :


Fixed resistor


Variable resistor

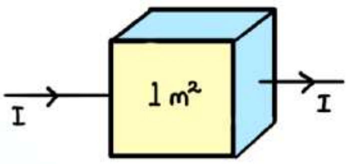

Rheostat

- Resistance is denoted by R
- Resistance has magnitude only so it is Scalar.
- The SI unit of resistance is Ohm (Ω) (omega).

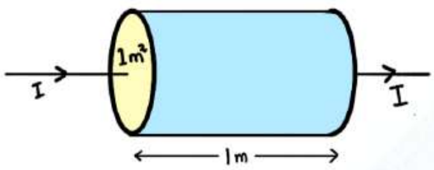
Definition of Ohm :
One ohm is defined as the resistance of a conductor which allows a current of one ampere to flow through it when a potential difference of one volt is applied across it.

Resistivity

- Resistivity of a substance can be defined as the resistance offered by a cube of side 1 meter, when current flows normal to the opposite faces of the cube.



Unit cube



1 m^3 Cylinder

- It is denoted by rho (ρ)
- Resistivity has magnitude only, so it is scalar.
- SI unit of Resistivity is ohm metre.

Very low Resistivity : Conductors
Moderate Resistivity : Resistors
Very high Resistivity : Insulators

Factor on which Resistivity depends:

(i) Nature of material (ii) Temperature of the material

It does not depend upon length or area of cross-section of the material.

FACTOR ON WHICH RESISTANCE OF A CONDUCTOR DEPENDS

1. **Resistance(R)** of a conductor is **directly proportional** to its **length**.

$$R \propto l$$

i.e. longer wire have more resistance than a shorter wire (same material | same area cross section).

2. **Resistance (R)** of a conductor is **inversely proportional** to its **area of cross-section (A)**.

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

i.e. A thin wire has more resistance than a thick wire (same material and same length).

3. The nature of material of the conductor

Different materials of same length, same area of cross-section and same physical conditions may **have different resistances**.

4. Temperature of the conductor

The **resistance** of all pure metals **increases** with a **rise in temperature**.

Conclusion:

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

$$R = \rho \frac{l}{A}$$ (where, ρ is constant called resistivity)

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

Unit of ρ

$$\rho = \frac{\Omega\, m^2}{m}$$

$$\rho = \Omega m$$

Resistance of semiconductor like germanium and silicon decrease with a rise in temperature.

NA 4 Find the resistance of 0.1 km long copper wire. The radius of the wire is 0.5 mm. Take Resistivity of copper of 1.7 X 10^{-8} Ohm-metre.

Sol: $R = \rho \frac{l}{A} = \rho \times \frac{l}{\pi r^2} = \frac{1.7 \times 10^{-8}\,\Omega m \times 100\, m}{3.14 \times (0.5 \times 10^{-3})^2 m^2}$

$R = 2.16\,\Omega$

COMBINATION OF RESISTANCES

The resistance are combined in following ways:

(i) parallel grouping (ii) series grouping (iii) mixed grouping

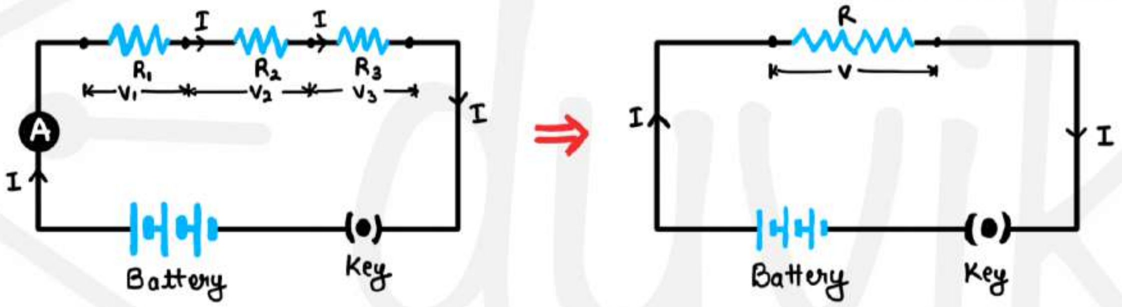
Equivalent Resistor or Resultant Resistor:

It is single resistance which can substitute combination of resistances so that the total current through the circuit remains the same for the same voltage across the combination.

It is denoted by R or R_{eq}

SERIES COMBINATION

When two or more resistors are joined end-to-end so that the same current flows through each one of them, then are said to be in series grouping.



When a number of resistances are connected in series, their equivalent resistance is given by the sum of the individual resistances.

Derivation:

Using Ohm's law

$$V_1 = IR_1, V_2 = IR_2, V_3 = IR_3 \quad — (1)$$

V is the source voltage, where $V = V_1 + V_2 + V_3 \quad — (2)$

Let R be the equivalent resistance of the combination.

$$V = IR$$
$$IR = V$$
$$= V_1 + V_2 + V_3$$
$$= IR_1 + IR_2 + IR_3$$
$$IR = I(R_1 + R_2 + R_3)$$
$$R = R_1 + R_2 + R_3$$

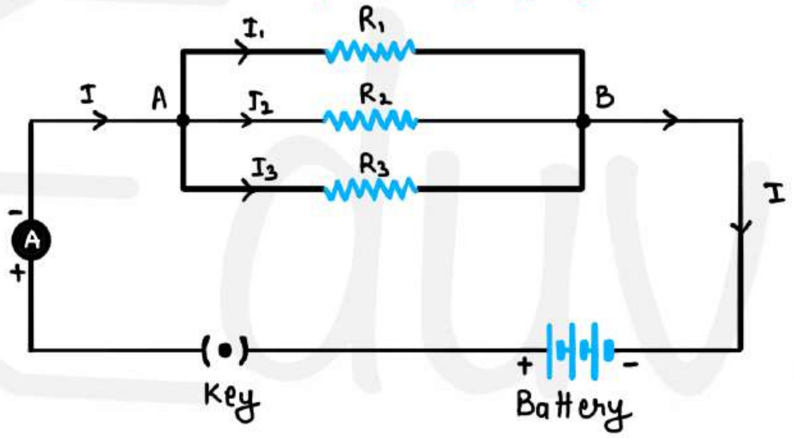
If n resistance are combined in series, then the equivalent resistance (R) is:

$$R = R_1 + R_2 + R_3 + \dots + R_n$$

1. When resistances are connected in series, the equivalent resistance is higher than each individual resistance.
2. In series combination of resistors the total resistance of the combination is equal to the sum of all the individual resistances.
3. In series combination of resistors, the same current flows through each resistor.
4. In series combination of resistors, the voltage of the circuit battery is equal to the sum of the voltage drops across each individual resistors.

PARALLEL COMBINATION

When two or more resistors are connected across each other between two common points such that same potential difference appears across each one of them,they are said to be in parallel grouping.



The combination of resistances in parallel is governed by a rule which states that When two or more resistors are connected in parallel, the reciprocal of the equivalent resistance is equal to the sum of the reciprocals of all the individual resistances.

Derivation

Let V be the potential difference across the two common points A and B.

Using Ohm's law,

Current passing through R i.e. $I_1 = \frac{V}{R_1}$ — (1)

Current passing through R i.e. $I_2 = \frac{V}{R_2}$ — (2)

Current passing through R i.e. $I_3 = \frac{V}{R_3}$ — (3)

The total current flowing through the circuit is :

$$I = \frac{V}{R} \quad — (4)$$

And also $I = I_1 + I_2 + I_3$ — (5)

Using equations (i) to (v), we get $\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$

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

In general, if R ,R_2 ,R_3 …… R_n are connected in parallel, then the equivalent resistance (R) is given by

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

1. The equivalent resistance of parallel combination of resistor is less than the least of individual value of resistances.
2. In parallel combination of resistors, the reciprocal of the equivalent resistance of the combination is equal to the sum of the reciprocals of the individual resistances.
3. In parallel combination, total current flowing through the circuit is equal to the sum of the current flowing through the each resistor.
4. In a parallel combination of resistors, the voltage across each resistor is same and is equal to the applied voltage.

Special Case

1. Let the two resistances R_1 and R_2 be connected in parallel.
   Then equivalent resistance is given by

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

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

2. If $R_1 = R_2$, then $R_{eq} = \frac{R}{2}$

Advantages of Parallel Circuits

All appliances in household, commercial and industrial electric wiring are connected in parallel because

(i) In **parallel system**, **each circuit operates separately**. So, if one of the circuits goes off, the other distribution circuit will remain unaffected.

(ii) **Each Circuit** will have the **same voltage** so that all electrical appliances work under same supply.

(iii) Outage of a **faulty appliance will not affect** the **healthy circuits**.

HEATING EFFECT OF CURRENT

The production of heat in a conductor when electric current flows through it is called **heating effect of current**.

These heating appliances contain coils made of **nichrome alloy**. When electric current is passed through this heating element, a **large amount of heat** is produced in it.(**because it has high resistance**).

Nichrome - Ni (60%) Cr (12%) Fe (26%) Mn (2%)	Constantan - Cu (60%) Ni (40%) Manganin - Cu (84%) Ni (4%)

When electric current flows through a resistor; the work done to overcome the opposition to the flowing charges is converted into heat energy.

He observed that in a conductor carrying current:

(a) **heat** produced is **directly proportional to** the **square of the current** i.e. $H \propto I^2$

(b) heat produced is directly proportional to the resistance of the conductor (resistor) i.e. $H \propto R$.

(c) heat produced is directly proportional to time for which the current flows through the conductor i.e. $H \propto t$.

Combining the above, $H = I^2Rt$

Electric work done, $W = Vq$

$W = VIt \quad (\because I = \frac{q}{t})$

$W = (IR) \times I \times t \quad (\because V = IR)$

$W = I^2Rt$

Here, work done appears in the form of heat.

Heat = Work done = I^2Rt

- ★ SI unit of heat energy is joule(J)
- ★ 1 cal = 4.184 J

Application of the heating effect of current

1. Electric Lamp

It is based on the heating effect of current. Filament of bulb made from a very thin tungsten wire. When current flow through this filament, it get heated and starts emitting light.

Why tungsten is used to make the filament of the bulb?

(i) Although it has comparatively low value of Resistivity yet,very thin and long filament is made to have high resistance. Thus electrical energy is converted into large amount of heat energy.

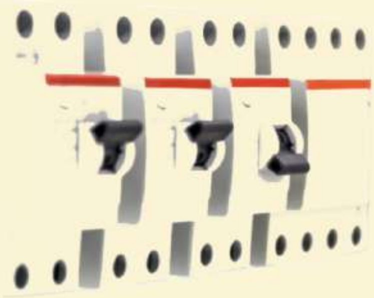
(ii) It has a high melting point (3380°C).

(iii) It is ductile so it can be drawn into thin wires.

2. Electric Fuse

- ★ It is used to protect the appliances against overloading or short circuit.
- ★ Fuse wire is made from a low-melting alloy of tin,copper and lead.
- ★ When current more than the rated fusing current, fuse wire gets heated up and melt away and circuit is broken and further damage is stopped.

- The maximum current which can flow through a fuse without melting, it is called its rating.
- These days, fuses have been replaced by miniature Circuit Breakers (MCBs) to protect the wiring from overloading or short circuit.
- They automatically switch off the circuit in a fraction of a second in case of fault. The MCB can be reset my fault is removed.


Miniature Circuit Breaker

3. Electric heating appliances

Appliances like electric iron, oven, immersion rod, geysers, room heaters etc. have heating elements made of high resistance wire.


Electric iron


Electric oven


Electric geyser

Characteristics of a heating element

(i) It should have high resistance.
(ii) It should have high melting point.
(iii) It should not oxidise at high temperature.
(iv) Thermal expansion of heating element should not be very high.

ELECTRIC POWER

The electric work done per unit time is called electric power.

$$\text{Electric power} = \frac{\text{Electric work done}}{\text{Time taken}} \quad \text{i.e. } P = \frac{W}{t}$$

The electric power also defined as the rate of consumption of electric energy in a circuit.

$$\text{Electric power} = \frac{\text{Energy consumed}}{\text{time taken}} \quad \text{i.e. } P = \frac{E}{t}$$

★ **SI unit** of electric power = $\frac{\text{Joule (J)}}{\text{Second (S)}} = Js^{-1} = \text{watt (W)}$

Definition of watt :

The power is said to be **one watt** when **one joule** of **work is done in one second.**

or

In **term of energy**, the power of an electric appliance **consuming electrical energy at the rate of 1 joule per second** is said to be 1 watt.

Let a current I flow through a conduct under a potential difference of V for time t, then electric work done is given by,

$$\text{Electric work done, } W = VQ = VIt$$

$$\text{Electric power, } P = \frac{W}{t} = \frac{VIt}{t}$$

$$P = VI$$

★ $V = IR$ So, $P = (IR) \times I = I^2R$

★ $I = \frac{V}{R}$ So, $P = V\left(\frac{V}{R}\right) = \frac{V^2}{R}$

ELECTRIC ENERGY

D1 : The **capacity** of an electric device **to carry out electric work.**

D2 : The **electric power P** of a device **used for time t** gives the measure of electric energy

$$E = P \times t$$

$P = VI$ $\therefore E = VIt$

$P = \frac{V^2}{R}$ $\therefore E = \frac{V^2}{R}t$

$P = I^2R$ $\therefore E = I^2Rt$

★ **SI unit** of electric energy **is joule** (**J**).

★ **Commercial unit** is **kilowatt hour** (**kWh**)

★ This unit is also called **Board of Trade Unit** (**BOT**)

★ 1 unit of energy = 1 BOT = 1 kWh = 3.6×10^6 J.

NCERT Intext Questions

1. What does an electric circuit mean? (Page 200)

An electric circuit defined as a conducting path consisting of electrical components like a lamp connected across the terminals of a source (cell or battery).

2. Define the unit of current. (Page 200)

Unit of current is ampere (denoted by A).
If one coulomb of charge flows through a conductor in one second, then the current flowing through the conductor is one ampere.

3. Calculate the number of electrons constituting one coulomb of charge. (Page 200)

Amount of charge on an electron, $e = 1.6 \times 10^{-19} C$

$$Q = ne \Rightarrow n = \frac{Q}{e} = \frac{1}{1.6 \times 10^{-19}}$$

$$n = 6.25 \times 10^{18} \text{ electrons.}$$

4. Name a device that helps to maintain a potential difference across a conductor. A cell or a battery. (Page 202)

5. What is meant by saying that the potential difference between two points is 1V? (Page 202)

If one joule of work is done to take one coulomb of electric charge from one point to another then the potential difference between the two points in one i.e. 1V.

6. How much energy is given to each coulomb of charge passing through a 6V battery? (Page 202)

We know that, 1 coulomb Volt = 1 Joule

1 Coulomb × 6 Volt = 6 Joule

Thus, an energy of 6 J is to be given to each coulomb of charge passing through a 6 V battery.

7. On what factors does the resistance of a conductor depend ? (Page 209)

The resistance of a conductor depends upon:

(i) Nature of the material
(ii) Length of the conductor
(iii) Area of cross-section of the conductor
(iv) Temperature

NCERT Intext Questions

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? (Page 209)

Resistance, $R = \rho \frac{l}{A}$ i.e $R \propto \frac{1}{a}$

A thicker wire has large area of cross-section (a) so it's resistance is lower. So, the current flows more easily through a thick wire.

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

The current flowing through a conductor is given by, (Page 209)

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

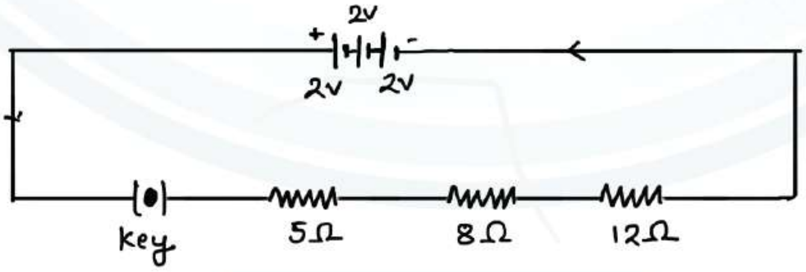
$$\therefore \quad I' = \frac{V}{2} \times \frac{1}{R} = \frac{I}{2}$$

If R is constant and potential difference across the conductor is decreased to half, then the current will also decrease to half of its original value.

10. Why are the coils of electric toaster and electric iron made up of an alloy rather than a pure metal? (Page 209)

Alloys are used for making the coils in electric toaster and iron because
(i) Alloys have higher melting point than pure metals.
(ii) Alloys do not oxidise readily at high temperatures.

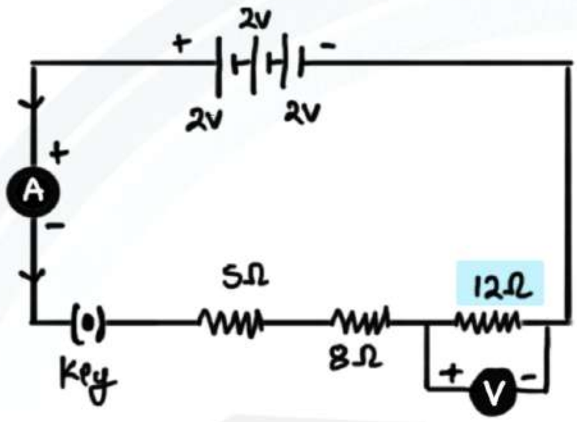
11. Draw a schematic diagram of a circuit consisting of a battery of three cells of 2V each, a 5 Ω Resistor, an 8 Ω Resistor, and a 12 Ω Resistor, and a plug key, all connected in series. (Page 213)



schematic circuit diagram

NCERT Intext Questions

11. Redraw the circuit if Question 10, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the 12 Ω Resistor. What would be the reading in the ammeter and the voltmeter. (Page 213)



Total Resistance = $5\Omega + 8\Omega + 12\Omega = 25\Omega$

Battery voltage = $2V + 2V + 2V = 6V$

$$I = \frac{V}{R} = \frac{6V}{12\Omega} = 0.24A$$

The ammeter will show a reading of 0.24A

$$V = IR = 0.24 \times 12 = 2.88V$$

The voltmeter will show a reading of 2.88 V

12. Judge the equivalent resistance when the following are connected in parallel: (a) 1Ω and $10^6\Omega$, (b) 1Ω and $10^3\Omega$, and $10^6\Omega$. (Page 216)

(a) $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{1\Omega} + \frac{1}{10^6\Omega} = \frac{10^6+1}{10^6\Omega}$$

$$\frac{R}{1} = \frac{10^6}{10^6+1} = 1\Omega$$

(b) $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{1} + \frac{1}{10^3} + \frac{1}{10^6}$$

$$\frac{1}{R} = 1 + 10^{-3} + 10^{-6} = 1 + 0.001 + 0.000001$$

$$\frac{1}{R} = \frac{1.001001}{1}$$

$$\frac{R}{1} = \frac{1}{1.001001} = 0.999\Omega.$$

13. An electric lamp of 100 ohm, a toaster of resistance 50 ohm, and water filter of resistance 500 ohm are connected parallel to a 220 V source. What is the resistance of the electric iron connected to the same source that takes as much current as all the three appliances, and what is the current through it? (Page 216)

NCERT Intext Questions

Here, $\frac{1}{R} = \frac{1}{100} + \frac{1}{50} + \frac{1}{500} = \frac{5+10+1}{500} = \frac{16}{500}$

$R = \frac{500}{16} = 31.25\,\Omega$.

voltage, $V = 220\,V$ (given)

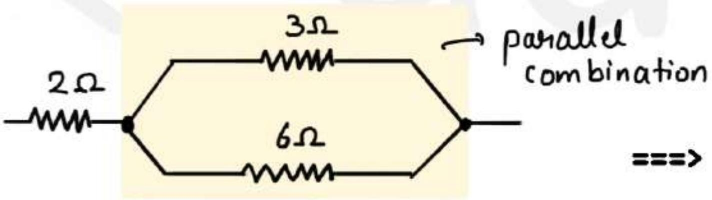
current, $I = \frac{V}{R} = \frac{220}{31.25} = 6.4\,A$.

14. What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series? **(Page 216)**

Refer to the page 12 🙃

15. How can three resistors of resistances 2 ohm, 3 ohm, and 6 ohm be connected to give a total resistance of (a) 4 ohm (b) 1 ohm? **(Page 216)**

(a) Combination of resistances of 3Ω and 6Ω in parallel connected with 2Ω resistance in series.



===>

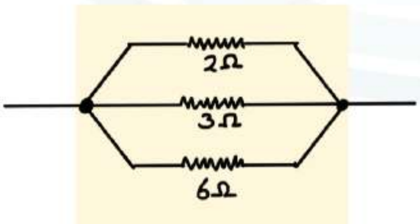
$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{6 \times 3}{6+3}$

$R = \frac{18}{9} = 2\Omega$

$R = R_1 + R_2 = 2 + 2 = 4\Omega$.

(Series combination)

(b) All three resistances in parallel.



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

$\frac{1}{R} = \frac{6}{6} = 1\Omega$ i.e $R = 1\Omega$

NCERT Intext Questions

16. What is (a) the highest, (b) the lowest total resistance that can be secured by combinations of four coils of resistance 4Ω, 8Ω, 12Ω, 24Ω? (Page 216)

(a) Highest resistance = $R_1 + R_2 + R_3 + R_4$ → series combination

$R = 4 + 8 + 12 + 24$

$R = 48\,\Omega$.

(b) lowest resistance, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$ → parallel Combination

$\frac{1}{R} = \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{24}$

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

i.e. $R = 2\,\Omega$.

17. Why does the cord of an electric heater not glow while the heating element does? (Page 218)

The cord of an electric heater is made up of copper. Copper has low resistance, so very little heat is produced when the current flows through the electric cord and it does not glow. Heating coil is made from high Resistivity material, such as nichrome. When electric current flows through it, large heat produce and so it starts glowing.

18. Compute the heat generated while transferring 96000 coulomb of charge in one hour through a potential difference of 50V. (Page 218)

Time, t = 1 hour = 60×60 = 3600 sec.

Heat generated = $Q \times V$ = $96000\,C \times 50\,V$ = $4.8 \times 10^6\,J$ //

19. An electric iron of resistance 20 Ω takes a current of 5A. Calculate the heat generated in 30 sec. (Page 218)

Heat generated = $H = I^2Rt$

$= (5A)^2 \times 20\Omega \times 30\,sec$

$= 25 \times 20 \times 30$ Joule

$= 15000\,J$ //

NCERT Intext Questions

20. What determines the rate at which energy is delivered by a current?
(Page 220)

Rate at which energy is delivered by a current is called electric power.
It is determined by
(i) The potential difference (denoted by V) across the conductor in volt.
(ii) The current (denoted by I) in ampere. i.e. Power, P=VxI

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

Power, $P = V \times I = 220V \times 5A$
$= 1100 \text{ VA}$
$= 1100 \text{ W}$
$= 1.1 \text{ kW}$

Electrical energy consumed
$= P \times t$
$= 1.1 \times 2 \text{ hour}$
$= 2.2 \text{ kWh}$ //

NCERT Exercise Question

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

(a) $\frac{1}{25}$ (b) $\frac{1}{5}$ (c) 5 (d) 25

Resistance of each part of the wire $= R \times \frac{1}{5} = \frac{R}{5}$.

then, equivalent resistance is given by

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

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

$$\frac{1}{R'} = \frac{25}{R}$$

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

$$\frac{R}{R'} = \frac{25}{1}$$ //

NCERT Exercise Question

2. 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

Electrical power in circuit = $VI = I^2R = \frac{V^2}{R}$

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

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

Resistance, $R = \frac{V^2}{P} = \frac{(220)^2}{100} = \frac{48400\,V^2}{100\,W} = 484\,\Omega$.

Power consumed at 110V, $P = \frac{(V)^2}{R} = \frac{(110V)^2}{484} = 25\,W$.

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

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

Heat produced in series combination, $H_s = \frac{V^2 t}{2R}$

Heat produced in parallel combination, $H_p = \frac{2V^2 t}{R}$

$$\frac{H_s}{H_p} = \frac{V^2 t}{2R} \times \frac{R}{2V^2 t} = \frac{1}{4}$$

NCERT Exercise Question

5. How is a voltmeter connected in the circuit to measure the potential difference between two points?

A voltmeter is placed across the two points in parallel.

6. A copper wire has diameter 0.5 mm and Resistivity of $1.6 \times 10^{-8}\Omega m$. What will be the length of this wire to make its resistance 10Ω ? How much does the resistance change if the diameter is doubled?

Area do cross-section of wire, $a = \pi r^2$

$$= \pi\left(\frac{d}{2}\right)^2 = 3.14 \times \left(\frac{0.5 \times 10^{-3} m}{2}\right)^2$$

$$= 3.14 \times (0.25 \times 10^{-3})^2$$

Using the formula, $R = \rho\frac{l}{a}$

$$l = \frac{R}{\rho}a = \frac{10\Omega \times 3.14\,(0.25 \times 10^{-3} m)^2}{1.6 \times 10^{-8}\Omega m}$$

$$l = 122.7\ m$$

If the diameter of copper wire is doubled, then new diameter of wire,

$$d = 2 \times 0.5\,mm = 1mm = 1 \times 10^{-3} m.$$

Hence, area of cross-section, $a = \pi r^2$

$$= 3.14\left(\frac{1 \times 10^{-3}}{2}\right)^2$$

$$= 3.14 \times (0.5 \times 10^{-3})^2$$

Then, resistance of the coil, $R = \rho\frac{l}{a} = \frac{1.6 \times 10^{-8}\Omega m \times 122.7 m}{3.14\,(0.5 \times 10^{-3})^2}$

$$R = 2.5\Omega$$

New resistance of the wire will be one-fourth of its original value.

8. When a 12V 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.

$$\text{Resistance} = \frac{\text{Potential difference}}{\text{Current}} = \frac{12V}{2.5\,mA} = \frac{12V}{2.5 \times 10^{-3} A}$$

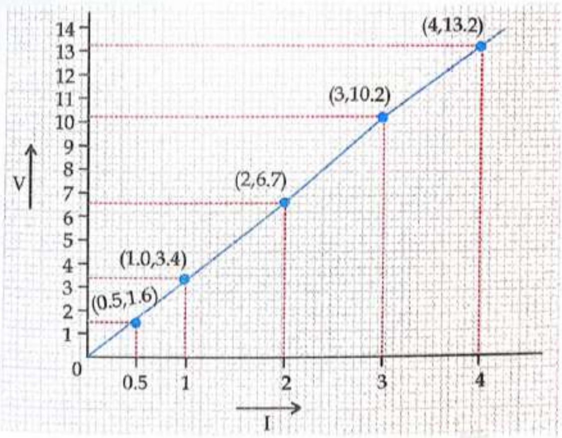
$$= 4.8 \times 10^{3}\Omega = 4800\Omega$$

NCERT Exercise Question

7. The value of current I flowing in a given resistor for the corresponding values of potential 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 that resistor.



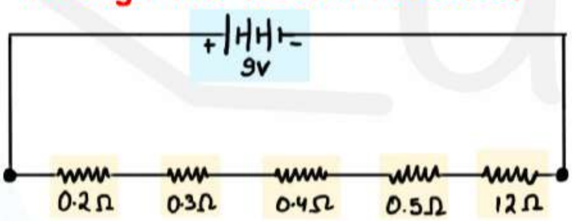
Resistance of the conductor

$$= \text{Slope } \frac{\Delta V}{\Delta I} = \frac{10.2 - 1.6}{3 \times 0.5}$$

$$= \frac{8.6}{2.5}$$

$$= 3.44\,\Omega$$

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



② In Series Combination, same current flows through all Resistors.

So, $\text{Current} = \frac{V}{R} = \frac{9V}{13.4\,\Omega} = 0.67A$

① Total Resistance, $R = 0.2\,\Omega + 0.3\,\Omega + 0.4\,\Omega + 0.5\,\Omega + 12\,\Omega$

$R = 13.4\,\Omega$

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

Let there be n resistors in parallel,then the equivalent resistance is given by

$$R = \frac{176\,\Omega}{n} \quad \text{—①}$$

$$R = \frac{V}{I} = \frac{220V}{5A} = 44\,\Omega \quad \text{—②}$$

from ① and ②

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

$$n = \frac{176}{44} = 4$$

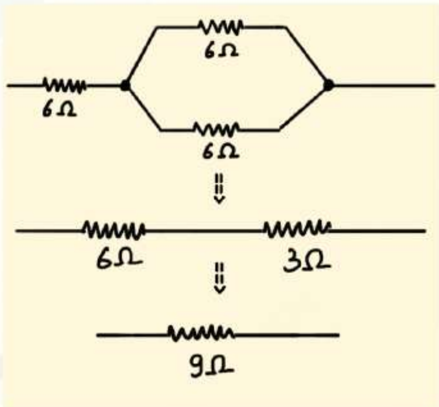
Thus four resistors of 176 ohm each are required.

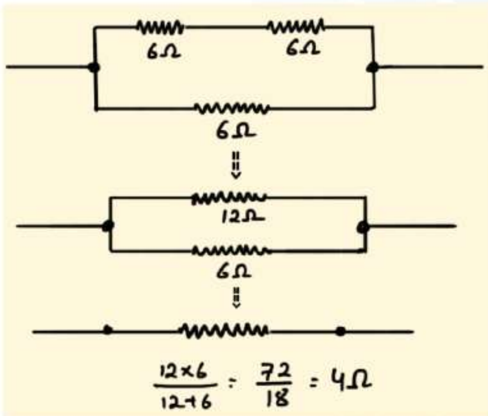
NCERT Exercise Question

11. Show how you would connect three resistors, each of resistance 6 ohm, so that the combination has a resistance of (a) 9 ohm (b) 4 ohm.

(a) We get 9 ohm by connecting 6 ohm and 3 ohm resistors in series. A parallel combination of two 6 ohm resistors gives 3 ohm.

(b) To get a combination of 4 ohm, we may connect two 6 ohm resistors in series and this combination to third 6 ohm resistor in parallel.





12. Several electric bulbs designed to used on a 220 V 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 5A?

Current flowing through each bulb, $I = \frac{P}{V} = \frac{10\,W}{220\,V} = \frac{1}{22}\,A$

The maximum allowable current = 5A

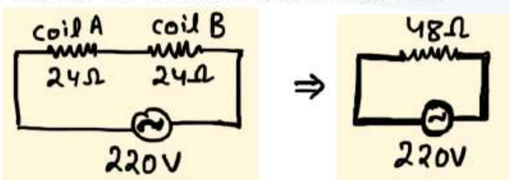
Numbers of bulbs which can be connected $= \frac{5\,A}{1/22\,A} = 22 \times 5 = 110$ //

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

(i) Used separately

Current through each coil $= \frac{220\,V}{24\,\Omega} = 9.17\,A$.

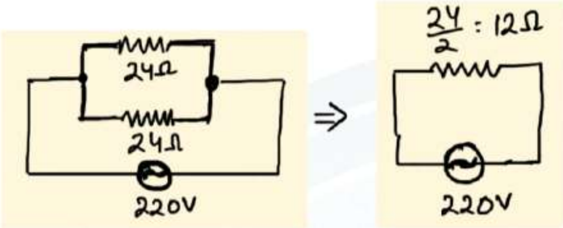
(ii) Used in series combination



Current through each coil $= \frac{220\,V}{48\,\Omega} = 4.58\,A$.

NCERT Exercise Question

(iii) Used in parallel combination



Total resistance = $\frac{24}{2}\ \Omega = 12\ \Omega$

Main Current = $\frac{220V}{12\Omega} = 18.33\ A$

A current of $\frac{18.33}{2} = 9.17\ A$ will flow through each resistor.

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

(a) Resistance in series circuit = $1\Omega + 2\Omega = 3\Omega$

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

Power $= I^2R = (2A)^2 \times 2\Omega = 8W.$

(b) Both the resistance in parallel circuit will have the same voltage across them. So,

Power $= \frac{V^2}{R} = \frac{(4V)^2}{2\Omega} = \frac{16V^2}{2\Omega} = 8W.$

The power used in the 2 ohm resistor in both the circuit is the same.

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

Total wattage, $P = 100 + 60 = 160W$

$\therefore$ Current, $I = \frac{P}{V} = \frac{160}{220} = 7.27\ A.$ //

16. Which uses more energy a 250 W TV set in one hour or a 1200 W toaster in 10 minutes?

Energy (TV Set) = $250W \times 1hr$
$= 250\ Js^{-1} \times 60\times60\ sec$
$= 9,00,000\ J$

Energy (toaster) = $1200W \times 10min$
$= 1200\ Js^{-1} \times 10\times60\ sec$
$= 7,20,000\ J$

Clearly,the T.V set will use more energy.

NCERT Exercise Question

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

Time, $t = 2h = 2 \times 60 \times 60$ sec

Rate of heating $= \frac{I^2Rt}{t} = I^2 \times R = (15A)^2 \times 8\Omega$

$= 225 \times 8 = 1800\ Js^{-1}$ //

18. Explain the following:

(a) Why is the tungsten used almost exclusively for filament of electric lamps?

Tungsten has high melting point of about 3400°C . Resistivity of tungsten is slightly more than that of copper.

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

Alloys have higher Resistivity than pure metals. Their Resistivity changes very little with a rise in temperature. Alloys do not get oxidised readily at high temperature.

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

In series, any outage of an application will open the whole circuit and even healthy appliances will not work then.

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

The resistance of a wire is inversely proportional to the area of cross-section. When the area of cross-section is increased, resistance of the wire is decreased and vice-versa.

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

Both copper and aluminium are very good conductors of electricity. They are ductile i.e. they can be easily drawn into wires. For these reasons copper and aluminium are usually employed for electricity transmission.