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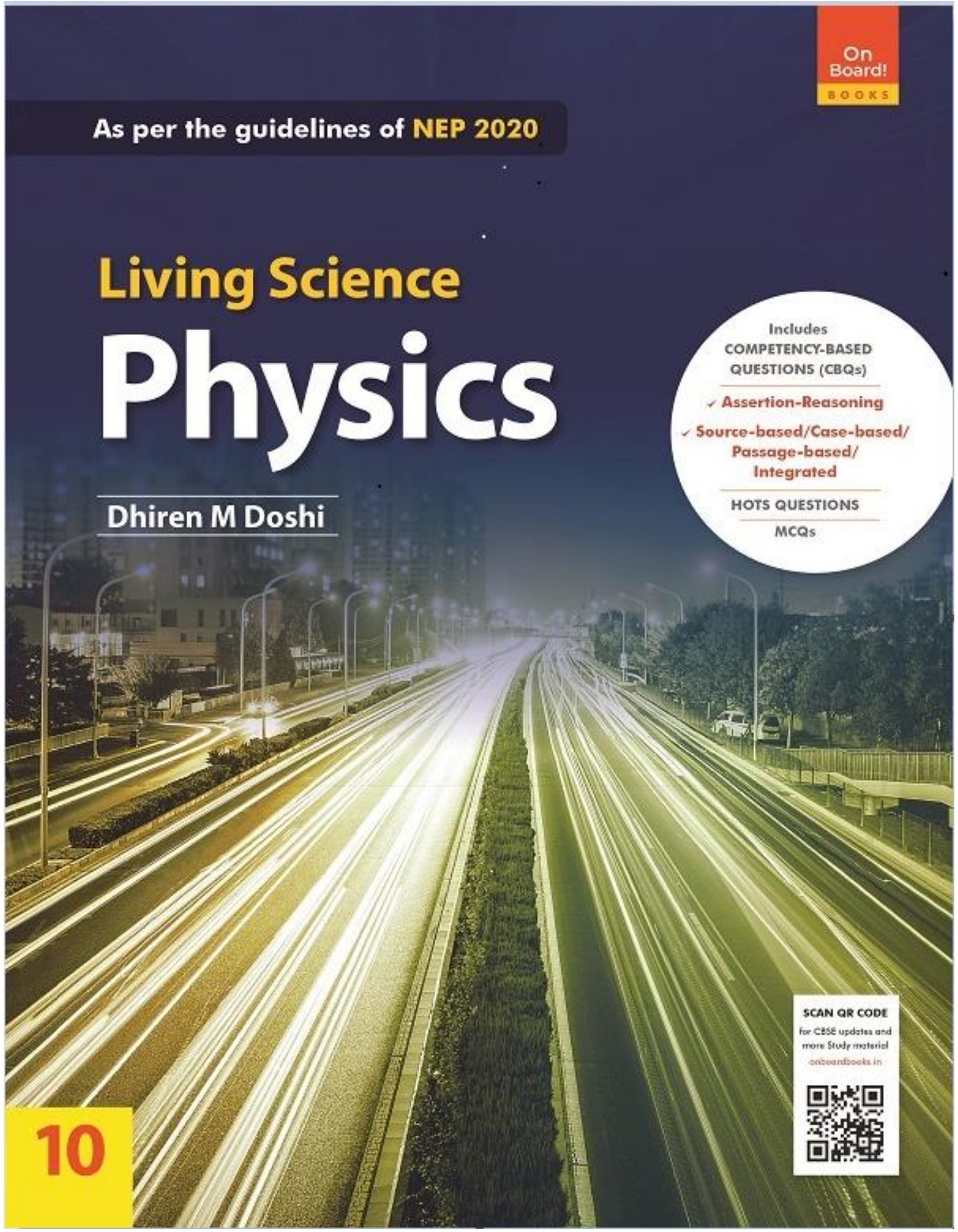


CBSE Living Science Physics

Class 10

Chapter 1: Electricity

LEARNING OBJECTIVES

- ❖ Electric charges
- ❖ Direction of electric current
- ❖ Electric potential
- ❖ Potential difference

Electric Current

- ❖ Continuous flow of electric current

Basic Components of an Electric Circuit and Their Symbols

- ❖ Circuit diagram

Ohm's Law

- ❖ Electrical Resistance
- ❖ Conductors, resistors and insulators

Combination or Grouping of Resistors

- ❖ Series combination of resistors
- ❖ Parallel combination of resistors

Heating Effect of Electric current

- ❖ Applications of heating effect of electric current

Electric Power

Types of Charges

All objects around us are made up of tiny particles called atoms. Every atom contains two types of charged particles – protons and electrons. Protons carry a positive (+) charge whereas electrons carry a negative (–) charge. A body gets positively charged if it loses electrons and negatively charged if it gains electrons.

Properties of electric charges

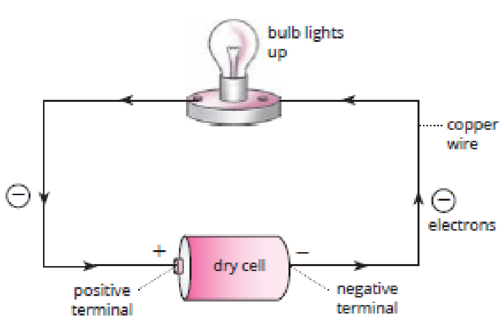
1. Unlike (or opposite) charges attract each other. For example, a positive charge attracts a negative charge.

2. Like (or similar) charges repel each other. For example, a positive charge repels a positive charge and a negative charge repels a negative charge.

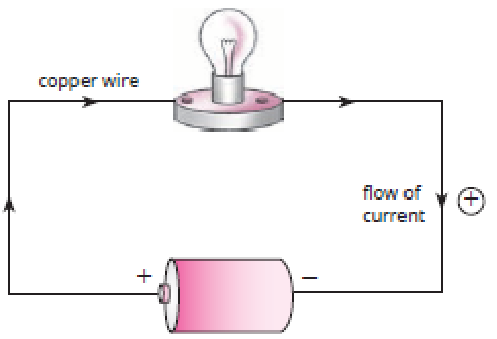
Nature and direction of electric current

The flow of electrons in a definite direction in a conductor constitutes an electric current.

Electric current was considered to be the flow of positive charges and the direction of flow of positive charges was taken to be the direction of electric current. Thus, the conventional direction of electric current is from the positive terminal of the source of electric current (cell or battery) to its negative terminal.



The flow of electrons in a wire is electric current.

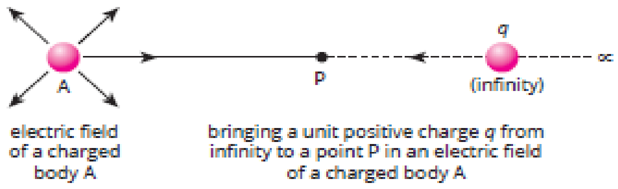


The arrows show the direction of current.

Potential difference and electric current

Electric potential

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

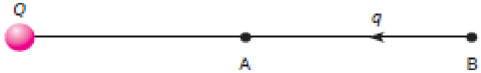


Electric potential at a point P

Electric potential (*V*) = Work done/ Charge = *W*/*q*
The SI unit of work is joule (symbol J) and that of electric charge is coulomb (symbol C). The SI unit of electric potential is volt.

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.



Potential difference is the amount of work done in moving a unit charge *q* from point B to point A in an electric field created by the charge *Q*.

Potential difference (*V*) = Work done (*W*)/ Charge (*Q*)
$V = W/Q$ 1 volt = 1 joule/1 coulomb , The SI unit of potential difference is volt (V). One volt is the potential difference between two points in a current-carrying conductor when 1 joule of work is done to move one coulomb of electric charge from one point to the other.

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

Electric Current

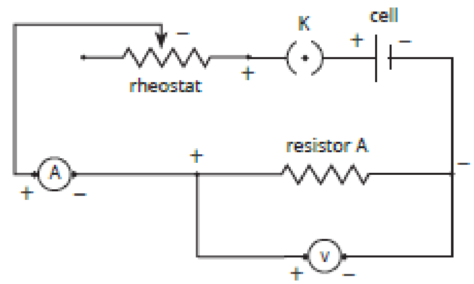
Electric current is expressed by the amount of electric charge flowing through a particular area per second. If *Q* is the net charge which is flowing through any cross section of a conductor in time *t*, then Current *I* = *Q*(Charge flow) /*t* (Time)
The SI unit of current is ampere. Thus, when 1 coulomb of charge flows through a conductor in 1 second, then the current flowing through it is said to be 1 ampere. The electric current in a circuit is measured by means of an instrument called **ammeter**.

Basic Components of an Electric Circuit and Their Symbols

A continuous conducting path consisting of wires, resistances and a switch between the two terminals of a battery or cell through which an electric current flows, is called a **circuit**.
A continuous and closed path along which an electric current flows is called an **electric circuit**. The circuit in which electric current flows is called a **closed circuit**. The bulb in this activity glows because the circuit is complete. It is said to be a closed circuit. The circuit in which electrical contact at any point is broken (or the switch of the torch is turned off) and hence no current flows is called an **open circuit**.

Circuit diagram

A diagram which shows the arrangement of various electrical components used in an electric circuit with the help of their electrical symbols is called a **circuit diagram**.



Ohm's Law

According to Ohm's law, 'The electric current (*I*) flowing through a conductor is directly proportional to the potential difference (*V*) across its ends, provided the temperature and other physical conditions of the conductor remain the same,'

i.e. $I \propto V$ Or, V/I = Constant, R

So, Current, $I = V/R$

Unit of resistance

The SI unit of resistance is ohm, which is denoted by the symbol Ω (called 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.

Electrical Resistance

The property of a conductor by virtue of which it opposes the flow of electric current through it is called its resistance.

1.Resistance is denoted by the letter *R*.

2. Resistance is a scalar quantity.

Factors affecting the resistance of a conductor

1. Resistance of a conductor is directly proportional to its length, i.e. $R \propto l$

2. The resistance of a conductor is inversely proportional to its area of cross section, i.e. $R \propto 1/A$

3. The resistance of all pure metals increases with increase in temperature and decreases on lowering the temperature.

4.Some materials have low resistance, whereas others have much higher resistance.

- Metals like copper, silver and aluminium have very low resistance.
- Nichrome, constantan, etc. have higher resistance. That is why nichrome is used for making heating elements of heaters, toasters, electric irons, etc.

Resistivity

Resistivity of a material is the resistance offered by 1 m length of a wire of material having an area of cross section of 1 m^2.

Unit of resistivity

$R = \rho l/A$ or, $\rho = (R \times A)/ l$

Now, the unit of resistance *R* is ohm (Ω), the unit of area of cross section *A* is $metre^2$ (m^2) and the unit of length *l* is metre (m).

So, putting these units in the above equation, we get,

Unit of resistivity (ρ) = ohm × (metre)^2 / metre

= ohm × metre (Ωm)

Thus, the SI unit of resistivity is ohm-metre which is written in symbol as Ω m

Conductors, resistors and insulators

Conductors: Those substances which have very low electrical resistivity are called conductors.

Resistors: Those substances which have comparatively higher electrical resistivity are called resistors.

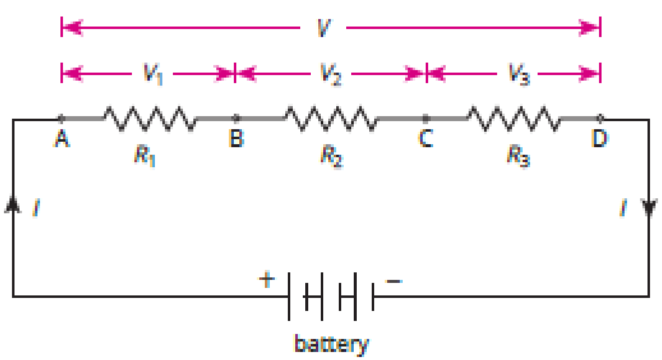
Insulators: Those substances which have infinitely high resistivity are called insulators.

Refer to Table 1.4 for Differences between resistance and resistivity

Combination or Grouping of Resistors

Series combination of resistors

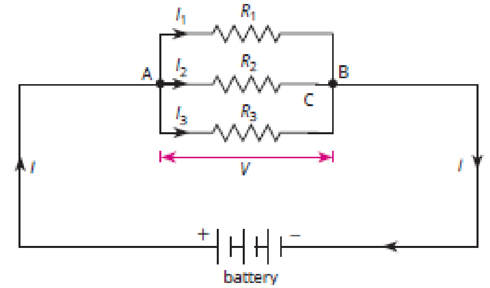
Two or more resistors are said to be connected in series if they are connected end to end consecutively in an electric circuit.



Equivalent resistance of three resistors connected in series: $R_s = R_1 + R_2 + R_3$

Parallel combination of resistors

Two or more resistors are said to be connected in parallel if one end of a resistor is connected to one end of the other resistor and the second end of the first resistor is connected to the second end of the other resistor, such that the potential difference across each resistor is the same.



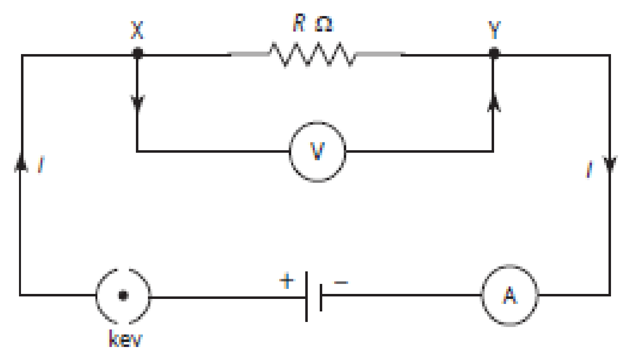
When a number of resistors are connected in parallel, the reciprocal of the equivalent resistance is equal to the sum of the reciprocals of the individual resistances. $1/R_p = 1/R_1 + 1/R_2 + 1/R_3$

Heating Effect of Electric Current

A part of the electrical energy from the source supply is consumed in doing useful work. The rest of the electrical energy is converted into heat energy, which raises the temperature of the gadget.

Heat produced in a conductor by electric current

Consider a conductor XY of resistance *R* ohms. Let a potential difference (in volts) be applied across the ends of XY. Let the steady current (in amperes) that passes from end X to end Y be *I*. If this current flows for *t* seconds, then the amount of electric charge transferred from point X to Y is $Q = I \times t$



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When an electric charge Q moves against a potential difference V, the amount of work done (W) is given by $W = Q \times V$.

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

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

This work done is called **electrical work done**. The electric circuit is **purely resistive.** all the electrical energy consumed is converted into heat energy. Then amount of heat produced

$$W = H = I^2 \times R \times t$$

or $$H = I^2 \times R \times t$$

$H = I^2 \times R \times t$ is known as **Joule's law of heating**.

According to Joule's law of heating

1. Heat produced in a conductor is directly proportional to the square of current (I^2), i.e. $H \propto I^2$

2. Heat produced in a conductor is directly proportional to the resistance (R) of the conductor for a given current and time, i.e. $H \propto R$.

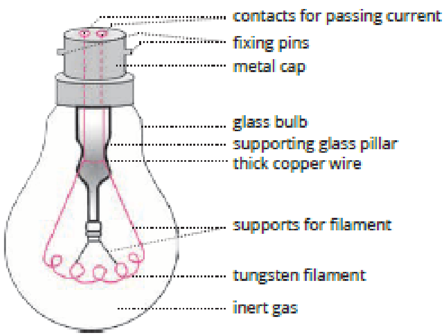
3. Heat produced in a conductor is directly proportional to time (t) for which current flows through the conductor, i.e. $H \propto t$.

Applications of the Heating Effect of Current

The heating effect of electric current has many useful applications.

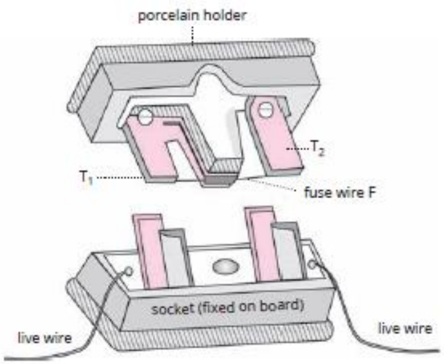
Electric bulb

The heating effect of electric current can be used to produce light, as in the case of electric bulb. An electric bulb consists of a filament made of tungsten wire. Tungsten is used because it has a large value of resistivity and a high melting point.



Electric fuse

Electric fuse is an application of Joule's heating effect of electric current. An electric fuse is a safety device consisting of a piece of thin wire of a material (generally an alloy of tin and copper) having a low melting point and high resistance, which melts and breaks the circuit if the current exceeds a safe value, hence preventing the electrical appliances in the circuit from getting damaged.



Rating of a fuse

The maximum current which can flow through a fuse without melting it, is called its rating. The fuses used for domestic purposes are rated as 1 A, 2 A, 3 A, 5 A, 10 A, etc.

Electric Power

Electric power (P) can be defined as the rate of doing electrical work, or the rate at which electrical energy is consumed in an electric circuit.

i.e. Electric power (P) = Electrical work done /Time taken

or $P = E / T$

or $P = (V \times I \times t) / t$ (since $E = V \times I \times t$)

or $P = V \times I$

So, electric power is also defined as the product of the applied voltage and the current flowing through the circuit.

Other relations for electric power

Electric power in terms of *I* and *R*

We know, $V = I \times R$ (from Ohm's law)

Substituting the value of V in the equation

$$P = V \times I$$

$$P = (I \times R) \times I \qquad \text{(substituting the value of } V\text{)}$$

$$P = I^2 R$$

Electric power in terms of *V* and *R*

We know, $I = V/R$ (from Ohm's law)

Substituting the value of I in $P = V \times I$

we get, $P = V \times V/R$ or $P = V^2 /R$

So, $P = V \times I = I^2R = V^2/R$

Units of electric power

We know, $P = V \times I$

The SI unit of potential difference is 1 volt and that of current is 1 ampere.

So, the SI unit of power = 1 V × 1 A = 1 VA or 1 watt (1 W).

∴ The SI unit of electric power is watt (W).

Thus, electric power is said to be 1 watt if 1 ampere current flows through an electrical circuit when a potential difference of 1 volt is applied.

Power rating of common electrical appliances

All electrical appliances such as electric bulb, electric iron, geyser, toaster, room heater and hair dryer are rated in terms of **voltage** and **electric power** (wattage).

1. **Voltage:** The voltage of an electrical appliance is the potential difference that can be safely applied across its input terminals. In our country, we get domestic electric supply at 220 V, so the voltage of electrical appliances in our country is kept at 220 V.
2. **Electric power (wattage):** The electric power (wattage) of an electrical appliance is the rate at which it consumes electrical energy under the rated voltage.

3. Rating: The value of the voltage and electric power of an electrical appliance taken together is called its rating.

Relationship between electrical energy and electric power

If V is the applied potential difference, I the current flowing in the circuit and t is the time for which current is flowing in the circuit, then we know

$E = V \times I \times t$ and also, $P = V \times I$

∴ From the above two equations, $E = P \times t$

Electrical energy (*E*) = Electric power (*P*) × Time (*t*)

The commercial unit of electrical energy is kilowatt-hour (kWh), i.e.

1 kWh = 1000 Wh 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.

Relationship between SI unit of electrical energy and commercial unit of electrical energy

We know that SI unit of electrical energy is joule, whereas the commercial unit of electrical energy is kWh.

1 kilowatt-hour (1 kWh) = 1 kilowatt × 1 hour

1 kWh = 3.6×10^6 J

Calculation of the cost of electrical energy consumed

The electric meter fixed at the main board in our house measures the electrical energy consumed in kWh.

Kilowatt-hour is the unit of electrical energy. On the basis of the cost of 1 unit of electricity given, we can find out the total cost. Since, electricity is sold in units of kilowatt-hour, so first we should convert the power consumed in watts into kilowatts by dividing the total watts by 1000. The kilowatts are then converted into kilowatt-hour by multiplying the kilowatt by the number of hours for which the appliance has been used. This gives us the total electrical energy consumed in kilowatt-hour or number of 'units'.

∴ Electrical energy consumed (units)

= [Power (in watt) × Time (in hour)] /1000

Now, knowing the cost of 1 unit of electricity, we can find the total cost.

Total cost = Number of units consumed × Cost of 1 unit

SUMMARY

1. Electric current: The flow of electrons in a definite direction in a conductor constitutes an electric current.

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

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

4. Volt: One volt is the potential difference between two points in a current carrying conductor when 1 joule of work is done to move a charge of 1 coulomb from one point to the other.

5. Circuit: The path along which current flows is called a circuit.

6. Ohm's law: According to Ohm's law, the electric current (I) flowing through a conductor is directly proportional to the potential difference (V) across its ends, provided the physical conditions and temperature remain the same.

7. Resistance: The property of a conductor by virtue of which it opposes the flow of electric current through it is called its resistance. It depends on the following factors: **a.** length of the conductor **b.** area of cross section of the conductor **c.** temperature of the conductor **d.** nature of the material of the conductor.

8. Conductors: Those substances which have very low electrical resistivity are called conductors. They allow the electric current to pass through them easily. Silver is the best conductor of electricity.
9. Resistors: Those substances which have comparatively high electrical resistance are called resistors.
10. Insulators: Those substances which have infinitely high electrical resistance are called insulators.
11. Resistivity: The resistivity of a material is the resistance offered by 1 m length of the wire of the material, having area of cross section 1 m^2. The factors affecting the resistivity are **a.** nature of the material **b.** temperature of the material.
12. Series combination of resistances: When a number of resistances are connected in series, the total resistance is equal to the sum of the individual resistances.
13. Parallel combination of resistances: When a number of resistances are connected in parallel, the reciprocal of the equivalent resistance is equal to the sum of the reciprocals of the individual resistances.
14. Electrical power: It can be defined as the rate of doing electric work.
15. Rating of an electrical appliance: The value of the voltage and electric power of an electrical appliance taken together is called its rating.