

ELECTRICITY

Electric Current

- Electric current is expressed by the amount of charge flowing through a particular area in unit time.

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

- A continuous and closed path of an electric current is called an electric circuit.
- In electric circuit the direction of electric current is taken as opposite to the direction of the flow of electrons.
- SI unit of electric charge is **coulomb (C)**.
- Coulomb is equivalent to the charge contained in approximately 6×10^{18} **electrons**.
- Unit of electric current is **ampere (A)**.
- One ampere constitutes by the flow of one coulomb of charge per second, i.e., **1 A = 1 C/1 s**.
- 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.

Potential Difference

- Electric potential difference between two points in an electric circuit carrying some current as the work done to move a unit charge from one point to the other.
- SI unit of electric potential difference is **volt (V)**.
- Potential difference is measured by means of an instrument called the voltmeter.
- Voltmeter is always connected in parallel across the points between which the potential difference is to be measured.

Ohm's Law

- The potential difference across the ends of a given metallic wire in an electric circuit is directly proportional to the current flowing through it provided its temperature remains the same. **This is called Ohm's law.**
- $V = IR$
- Its SI unit is ohm.

Resistance

- Resistance is the property of a substance to oppose to the flow of electric current through it, is called resistance.
- The current through a resistor is inversely proportional to its resistance.
- Rheostat is used to change the resistance in the circuit.
- Motion of electrons through a conductor is opposed by its resistance. Component of a given size that offers a low resistance is a good conductor.
- A component of identical size that offers a higher resistance is a poor conductor.
- Insulator have a higher resistance.

- Resistance of the conductor depends on its length, on its area of cross-section, and on the nature of its material. Resistance of a uniform metallic conductor is directly proportional to its length (l) and inversely proportional to the area of cross-section (A).

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

- The resistance and resistivity of a material vary with temperature.
- The metals and alloys have very low resistivity in the range of 10^{-8} ohm to 10^{-6} ohm. They are good conductors of electricity.
- Resistivity of an alloy is generally higher than that of its constituent metals.
- Tungsten is used almost exclusively for filaments of electric bulbs.
- Copper and Aluminium are used in electrical transmission lines.
- Silver is good conductor of electricity.

Resistors in Series

- The equivalent resistance of several resistors in series is equal to the sum of their individual resistances.
- The same current flows through all the loads.
- The voltage across each load is proportional to the resistance of the load.
- The sum of the voltages across each load is equal to the applied voltage.
- If resistors in series.

$$I = I_1 = I_2 = \dots$$

$$V = V_1 + V_2 + \dots$$

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

- A series circuit connects the components one after the other to form a 'single loop'. A series circuit has only one loop through which current can pass. If the circuit is interrupted at any point in the loop, no current can pass through the circuit and hence no electric appliances connected in the circuit will work. Series circuits are commonly used in devices such as flashlights.

Resistors in Parallel

- The reciprocal of the equivalent resistance of a group of resistances joined in parallel is equal to the sum of the reciprocals of the individual resistances.
- The current flowing through each load depends upon the resistance of the load.
- The voltage across each load is the same and is equal to the voltage applied to the circuit.
- The total resistance of a parallel connection is always smaller than the smallest resistance in the circuit.
- If resistors in parallel

$$I = I_1 + I_2 + \dots$$

$$V = V_1 = V_2 = \dots$$

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

- A parallel circuit has two or more loops through which current can pass. If the circuit is disconnected in one of the loops, the current can still pass through the other loop(s). The wiring in a house consists of parallel circuits.

Conductance

- Conductance of a material is the property of a material to aid the flow of charges and hence, the passage of current in it. The conductance of a material is mathematically defined as the reciprocal of its resistance (R).

Electrical Power

- Electric power is defined as the rate at which electric energy is dissipated or consumed in an electric circuit

$$P = VI$$

- SI unit of electric power is **watt (W)**. One watt of power is consumed when 1 A of current flows at a potential difference of 1 V.

$$1 \text{ W} = 1 \text{ volt} \times 1 \text{ ampere} = 1 \text{ V A}$$

- The unit 'watt' is very small. Therefore, in actual practice we use a much larger unit called 'kilowatt'. It is equal to 1000 watts. Since electrical energy is the product of power and time, the unit of electric energy is, therefore, watt hour (W h). One watt hour is the energy consumed when 1 watt of power is used for 1 hour.

- The commercial unit of electric energy is kilowatt hour

$$1 \text{ KWH} = 3.6 \times 10^6 \text{ J}$$

- One horse power is equal to 746 watts.

Chemical Effects of Electric Current

- Most of the liquids that conduct electricity belong to solutions of acids, bases and salts.
- Some liquids are good conductors and some are poor conductors of electricity.
- The passage of an electric current through a conducting liquid normally causes chemical reactions and the resulting effects of this reaction are known as **chemical effects of currents**.
- The process of depositing a layer of any desired metal on another material by means of electricity is known as **electroplating**.
- Electroplating is commonly used in industry for coating metal objects with a thin layer of a different metal.
- Coating of zinc is applied on iron to protect it from the corrosion and formation of rust.

Heating Effect of Current

- A source of electrical energy can develop a potential difference across a resistor, which is connected to that source. This potential difference constitutes a current through the resistor. For continuous drawing of current, the source has to continuously spend its energy. A part of the energy from the source can be converted into useful work and the rest will be converted into heat energy. Thus, the passage of electric current through a wire, results in the

production of heat. This phenomenon is called **heating effect of current**.

- The heat produced depends on the amount of resistance offered by the wire.
- Copper wire offers very little resistance and does not get heated up quickly. On the other hand, thin wire of tungsten or nichrome which are used in bulbs offer high resistance and gets heated up quickly. This is the reason why tungsten wire is used in the filaments of the bulbs and nichrome wire is used as a heating element in household heating appliances.
- Heating effect of electric current can be seen in many devices. Some of them are given below:
 - Electric laundry iron
 - Electric toaster
 - Electric oven
 - Electric kettle
 - Electric heater

Joule's Law of Heating

- Joule's law of heating: $H = I^2 R t$
- Joule's law of heating states that the heat produced in any resistor is:
 - Directly proportional to the square of the current passing through the resistor.
 - Directly proportional to the resistance of the resistor.
 - Directly proportional to the time for which the current is passing through the resistor.

Applications of Heating Effect

Electric Heating Device

- The heating effect of electric current is used in many home appliances such as electric iron, electric toaster, electric oven, electric heater, geyser, etc.
- In these appliances **Nichrome**, which is an alloy of **Nickel and Chromium** is used as the heating element because:
 - It has high resistivity;
 - It has a high melting point;
 - It is not easily oxidized.

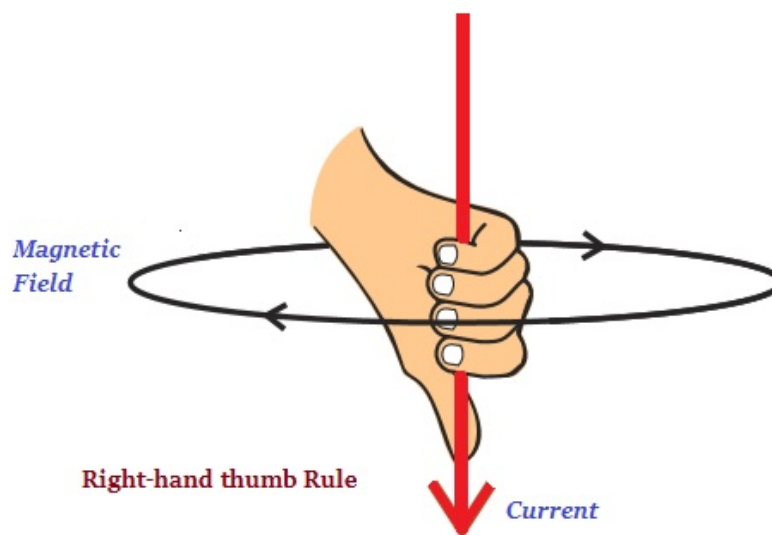
Fuse

- Fuse is the most important safety device used for protecting the circuits due to short circuiting or overloading of the circuits.
- The Joule heating that takes place in the fuse melts it to break the electric circuit.
- Fuse is a strip of alloy wire which is made up of lead and tin with a very low melting point. This can be connected to the circuit. The fuse is usually designed to take specific amount of current. When current passing through the wire exceeds the maximum limit, it gets heated up. Due to low melting point, it melts quickly disconnecting the circuit. This prevents damage to the appliances.

- The fuse wire is usually encased in a cartridge of porcelain or similar material with metal ends.
- The fuse wire is fitted in a porcelain casing because porcelain is an insulator of electricity.
- The fuse wire is connected in series in an electric circuit.
- The fuses used for domestic purposes are rated as 1 A, 2 A, 3 A, 5 A, 10 A, etc.

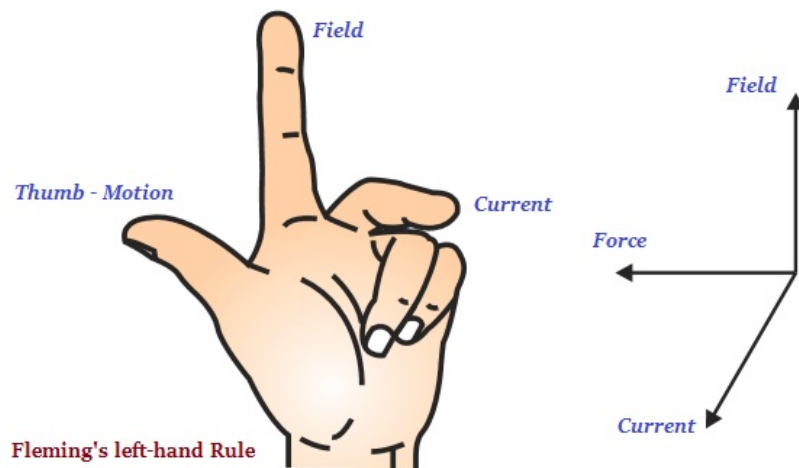
Magnetic Effects of Electric Current

- A wire or a conductor carrying current develops a magnetic field perpendicular to the direction of the flow of current. This is called **magnetic effect of current**.
- Electric current carrying wire behaves like a magnet.
- The region surrounding a magnet in which the force of the magnet can be detected is said to have a magnetic field.
- Magnetic field is a quantity that has both direction and magnitude. Magnetic field lines are closed curves.
- The pattern of the magnetic field around a conductor due to an electric current flowing through it depends on the shape of the conductor. The magnetic field of a solenoid carrying a current is similar to that of a bar magnet.
- An electromagnet consists of a core of soft iron wrapped around with a coil of insulated copper wire.
- **Right-Hand Thumb Rule:** Also known as Maxwell's corkscrew rule, right-hand thumb rule illustrates direction of the magnetic field associated with a current-carrying conductor. It states that *"Imagine that you are holding a current-carrying straight conductor in your right hand such that the thumb points towards the direction of current. Then your fingers will wrap around the conductor in the direction of the field lines of the magnetic field."*

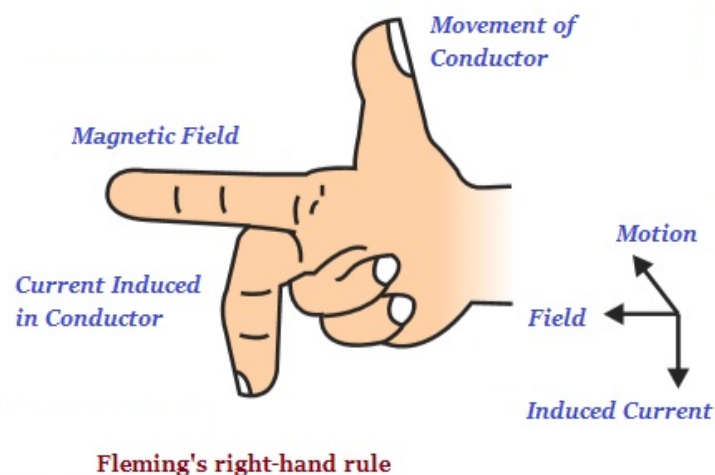


- Human body also produces magnetic field; however, it is very weak and about one-billionth of the earth's magnetic field.
- Heart and brain are the two main organs in the human body where the magnetic field has been produced.

- The magnetic field inside the human body forms the basis of getting the images of different parts of the body.
- The technique used to get the image of body part is known as the Magnetic Resonance Imaging MRI.
- A current carrying conductor when placed in a magnetic field experiences a force. If the direction of the field and that of the current are mutually perpendicular to each other, then the force acting on the conductor will be perpendicular to both and will be given by **Fleming's left hand rule**. This is the basis of an electric motor. An electric motor is a device that converts electric energy into mechanical energy.



- Stretch the thumb, fore finger and middle finger of your right hand mutually perpendicular to each other. If the fore finger indicates the direction of magnetic field and the thumb indicates the direction of motion of the conductor, then the middle finger will indicate the direction of induced current. **Fleming's Right hand rule is also called 'generator rule'.**



- A generator converts mechanical energy into electrical energy. It works on the basis of electromagnetic induction.
- Transformer is a device used for converting low voltage into high voltage and high voltage

into low voltage. It works on the principle of **electromagnetic induction**.

Domestic Electric Circuit

- The electricity produced in power stations is distributed to all the domestic and industrial consumers through overhead and underground cables.
- In India, domestic circuits are supplied with an alternating current of potential 220/230V and frequency 50 Hz.
- The electricity is brought to houses by two insulated wires. Out of these two wires, one wire has a red insulation and is called the '**live wire**' (or **positive**). The other wire has a **black insulation** and is called the '**neutral wire**' (or **negative**).
- The potential difference between the two is 220 V.
- It should be noted that all the circuits in a house are connected in parallel, so that the disconnection of one circuit does not affect the other circuit. One more advantage of the parallel connection of circuits is that each electric appliance gets an equal voltage.
- In domestic circuits, a third wire called the earth wire having a **green insulation** is usually connected to the body of the metallic electric appliance. The other end of the earth wire is connected to a metal tube or a metal electrode, which is buried into the Earth. This wire provides a low resistance path to the electric current. The earth wire sends the current from the body of the appliance to the Earth, whenever a live wire accidentally touches the body of the metallic electric appliance. Thus, the earth wire serves as a protective conductor, which saves us from electric shocks.