UNIT 13 HOW THINGS WORK

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13.1 INTRODUCTION

It is interesting how we utilize various electric devices either at home or workplace that may be fan, electric kettle, computer, etc. As we switch them on, the fan rotates, bulb produces light, and many such electric devices start functioning. In case of the electric heater, it produces heat. Your learners may ask you why it is so. Why does an electric heater produce heat and an electric bulb light? In this unit, we will discuss the theoretical underpinnings and basic principles of such electric devices. These electric devices work when electric current flows through it. Electric current is the movement of electric charges in a unit time and its flow depends on both potential difference and resistance of the wire through which current flows. Phenomenon like combination of resistors, electric power will also be discussed. When electric current flows through a conductor, it produces magnetic effect and the reverse effect is also possible; changing magnetic field produces current in a conductor. Electric motors and electric generators work based on these principles. These concepts will be discussed in the later portion and finally the manner in which domestic circuits is designed will be described. Unit will discuss the pedagogical methods to transact these curricular contents.
13.2 OBJECTIVES

After reading this unit, you will be able to help your learners in:

• understanding the concept of electric circuit,
• differentiating electric potential and potential difference,
• deriving formula of electric power,
• explaining heating effect of electric current,
• interpreting the principle of electric motors and its working, and
• describing the phenomenon of electromagnetic induction.

13.3 ELECTRIC CURRENT AND ELECTRIC CIRCUIT

The concept of ‘current’ is not at all new to secondary learners. Even then, you may start the class by asking simple questions such as:

• What is required for washing machine to work?
• Why does a bulb glow?
• What do electrical lines carry?
• What is the purpose of constructing Dams? and so on.

You may think of more interesting questions/activities to introduce the concept of current. As learners explore the term current, adequate theoretical explanation can be provided. Electric current represents the flow of electric charges. In other words **electric current is defined as the amount of electric charges flowing through a particular area in a unit time.** Thus, electric current is the rate at which electric charge flows. In circuits/conductors/wires, this charge is carried by moving electrons. The particles that carry charges are called charge carriers.

While stating the definition, learners may have confusions about electric charges, the direction of flow of charges and so on. Thus, you may intervene and clarify the following aspects: electric charges flow through circuits/conductors (conductors are materials that allow electricity/charges to pass through). There are two kinds of electric charges—electrons (negative) and protons (positive) and the flow of these charges constitute electric current. While the phenomenon of electricity was observed, electrons were not identified and hence earlier electric current was assumed to be the flow of positive charges and we call it **conventional current direction.** But later electrons were discovered and actually the flow of electrons was from negative terminal to the positive terminal constitutes electric current. Thus in electric circuits, the direction of electric current is taken as opposite to the direction of electrons.

What is an electric circuit? Electric circuit is a continuous and closed path of an electric current. In an electric circuit various components are represented using convenient symbols. The commonly used symbols in an electric circuit are given below:
In circuits, electric current occurs when negative charges flow. At the same time, equal amount of positive charges also flows in opposite direction. Thus, a convention is required to represent current direction that is independent of charge carriers. The direction of *conventional current* is arbitrarily defined as the same direction as positive charges flow. The consequence of this convention is that electrons, the charge carriers in electric circuits, flow in the opposite direction of conventional current flow in an electrical circuit. Thus, the symbol used to represent electric current “I” shows the flow of positive charges and is called the *reference direction* of current $I$. Thus even though outdated, still it is considered that, the direction of an electric current is by convention the direction in which positive charges move. This concept should be made clear to learners.

**Conventional current** flows through a circuit from the positive (+) side of the cell to the negative (-) but the electrons flow in the opposite direction i.e. from the negative (-) side of the cell to the positive (+).

You have defined electric current. You may continue class by asking the question: since electric current is charge flowing in a unit time, can we deduce a formula to calculate the current flowing through a circuit? Of course!

Why don’t you direct your learners to derive that? After doing so, the formula can be revealed. Suppose, ‘Q’ amount of charge flows through a cross section wire/circuit/conductor in a time ‘t’, then electric current is given by;
Content Based Methodology-I

Current = \frac{Charge}{Time}

or \quad I = \frac{Q}{t}

You may further describe the following (As we did earlier, learners may be asked to deduce the unit of electric current). The unit of electric current is ampere (A), named after the French scientist, Andre-Marie Ampere. Also to denote small quantity of current milliampere (1 mA = 10^{-3} A) or microampere (1 ìA = 10^{-6} A) are used. At this point you may provide learners few questions to compute electric current through circuits.

13.3.1 Electric Potential and Potential Difference

Learners have seen that electric current is the flow of charges. Can we expect from learners a question “Why the charges are flowing? To flow charge, there should be some kind of difference? Isn’t? Yes, such a question is quite natural. Why don’t you convince your learners through the following example? You may show a picture of a boy dropping a ball in a slanted plane or water flowing from a water tank kept on the roof of the house. Encourage learners to find answer for the fall of ball or flow of water. Slowly you may realize learners that, the difference in heights caused ball to fall or water to flow. The same concept is applied in electric currents too. To flow electric charges from one point to another, there should be difference between the ends of wire/conductor/circuit and that difference is called potential difference. Potential difference between two points in an electric circuit is defined as the work done to move unit charge (i.e. one coulomb) from one point to other. Or electrical potential difference is the difference in the amount of potential energy a particle has due to its position between two locations in an electric field. While the electrical potential energy of a unit charge at a point in a circuit is called the electric potential (or potential) at that point.

How does electric potential develop? We know, in gravitational field, every object/material possesses some amount of energy by virtue of its position which we call potential energy. In the same way, charges in conductors also possess energy due to position and that energy is called electric potential and potential varies for each charge in an electric field. Thus a difference in potential is set up across ends of conductor with the aid of cells/batteries. As we connect cell in an electric circuit, a difference in potential is developed at two ends which in turn help charges to move (current flow).

Now you may ask your learners to derive the formula for potential difference. Potential difference is calculated using the formula given below;

You may also convince that;

- S.I unit of electric potential is volt (denoted as ‘V’), named after Alessandro Volta.

- Since electric potential difference is expressed in units of volts, it is sometimes referred to as the voltage.
**Ammeter** is an instrument used to measure electric current in a circuit. Ammeter is always connected in series in a circuit.

**Voltmeter** is an instrument used to measure potential difference (voltage) of a circuit. Voltmeter is always connected parallel to a circuit.

![Diagram of Ammeter and Voltmeter](http://epathshala.nic.in/e-pathshala-4/flipbook/)

**Figure 13.2: Ammeter and Voltmeter**

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**Check Your Progress**

**Note:**
- a) Space is given below to write your answer.
- b) Compare your answer with the one given at the end of this Unit.

1) What is the conventional direction of electric current?

2) Describe potential and potential difference.

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**13.3.2 Ohm’s Law**

In order to teach Ohm’s law, you may ask learners to sit in groups and to each group cells, ammeter, voltmeter, resistor and connecting wires are provided. They may be asked to measure voltmeter and ammeter reading by connecting different number of cells and to fill up the table given below. After that a graph with voltmeter and ammeter reading on Y axis and X axis respectively is plotted. On analysing the graph learners will realise that, the graph is straight line and thus the ratio V/I is a constant.
At this stage you may intervene and conclude that;

- A German physicist George Simon Ohm discovered the relationship between voltage and current flowing through circuit i.e. voltage across ends of a conductor is directly proportional to current flowing through it, keeping temperature constant. This relationship is called Ohm’s law.

So we have \( V=I \) or \( \frac{V}{I}=\text{Constant} \)

On removing constant we get, \( V=RI \) or \( V=IR \)

The constant is called resistance of conductor and is represented by ‘R’. The resistance of a conductor is the obstruction posed by the conductor to the low of electric current. Resistance is defined as the ratio of potential difference across the ends of conductor to the current flowing through it.

i.e. \( R=\frac{V}{I} \).

- The S.I unit of resistance is \( \Omega \) (Greek letter). It is clear from the formula that Resistance is inversely proportional to current i.e. as resistance is increased the current flowing through conductor reduces and vice versa.

- The resistance of a conductor depends on three factors; (i) length of the material, (ii) area of cross section, (iii) nature of material. Thus we get

\[ R=\frac{l}{A} \text{ or } R=\rho \frac{l}{A} \]

Where, ‘\( \rho \)’ (rho) is called the electrical resistivity of the conductor. The S.I unit of resistivity is \( \Omega m \). It is the characteristic property of materials. Conductors have very low resistivity while insulators have high resistivity.
Activity 1
A) How will convince your learners that resistance depends on length, cross section and nature of material? Suggest an activity.
B) Explore the resistivity of different materials and prepare a chart.

13.3.3 Combination of Resistors — Series and Parallel

The material which obstructs the flow of current are called resistors. In electric circuits (or electronic devices), resistors are connected to control the flow of electric current. Generally resistors are connected in series or parallel or the combination of both. Resistor circuits that combine series and parallel resistors networks together are generally known as Resistor Combination or mixed resistor circuits. In such a complex circuit, how do we calculate the equivalent/combined/total resistance, current and voltage? We will discuss it in this section. Before moving further, let us be clear of series and parallel combination of resistors.

A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take. The current is the same through each resistor. To find the equivalent resistance of series circuit, learners may be provided with key, voltmeter (6V), ammeter, resistors of different values (R₁, R₂ and R₃) and a cell. After that, ask learners to assemble circuit as shown in figure 13.4a and to measure ammeter reading by placing at different points.

They will realize that in series circuit, the current flowing across the circuit remains same i.e. same quantity of current flows through each resistor. Then, ask learners to measure voltage by keeping it across various resistors. Then, they will realize that the voltmeter reading is different. Thus the total potential difference across a combination of resistors in series is equal to the sum of the potential differences across each individual resistor.

i.e. \[ V = V₁ + V₂ + V₃ \]

Applying Ohm’s laws we get, \[ V₁ = IR₁, \] \[ V₂ = IR₂ \] and \[ V₃ = IR₃, \] ‘I’ same throughout circuit

Therefore, \[ V = IR₁ + IR₂ + IR₃ \]

Or \[ IR = IR₁ + IR₂ + IR₃ \] (where ‘R’ is the equivalent resistance of the circuit)
Or \( R = R_1 + R_2 + R_3 \);

i.e. the equivalent resistance is the sum of the resistances of individual resistors. Thus, we can conclude that **the equivalent resistance in series circuit is the sum of the resistances of individual resistors.**

Now you may move on to parallel circuits. A parallel circuit is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together. The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again. The voltage across each resistor in parallel is the same. To calculate the equivalent resistance in parallel circuit, you may again ask learners to construct a circuit as shown in Figure 13.5a. Here, also let learners measure the voltmeter and ammeter reading keeping at different places. This will help them to realize that the potential difference across the circuit remains same while current through each resistor vary. If \( I_1 \), \( I_2 \) and \( I_3 \) current flow through \( R_1 \), \( R_2 \) and \( R_3 \) respectively, then the total current flowing through circuit is given by

\[
I = I_1 + I_2 + I_3
\]

Applying Ohm’s laws we get, \( I_1 = \frac{V}{R_1} \), \( I_2 = \frac{V}{R_2} \) and \( I_3 = \frac{V}{R_3} \). ‘\( V \)’ same throughout circuit

Therefore, \( \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \) (where ‘\( R \)’ is the equivalent resistance of the circuit)

Or \( \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \)

i.e. reciprocal of equivalent resistance is the sum of the reciprocals of individual resistances. Thus we may conclude that **the reciprocal of equivalent resistance of resistors in parallel circuit is equal to the sum of reciprocals of individual resistances.**

**13.3.4 Electric Power**

Now let us shift our discussion to another associated concept of electric current i.e. electric power. Being a teacher how will you introduce this concept to your learners? Let us see what Mr. Rajeev has done. Rajiv brought different bulbs to
his class and asked learners to note down the details written on the bulb. Learners found that in all the bulbs the potential difference (voltage) remains the same but there is another additional number and its unit is given in watts. Learners couldn’t identify what it was. Slowly the discussions lead to the concept of electric power. Why don’t you try some other strategies to introduce the concept to your learners? For example, you may identify the most powerful learners of your class (even though, the conventional understanding of power differs from electric power). Or else you may ask learners to bring electricity bills and organise a group discussion based on that.

What is electric power? We know that when electric current flows, energy is transferred from one form to the other (electric energy to light energy in bulbs) or some amount of work is done. We also know that the mechanical power is defined as the work done in unit time (P=W/t). In the case of electric power, it is defined as the rate at which electric energy is dissipated or consumed in an electric circuit. Thus electric power is the rate of consumption of energy i.e. measure of how many joules are used per unit of time. Power is calculated using the formula

\[ P=VI=I^2R \text{ (Power in terms of current)} \]

Or \[ P=VI= V \frac{V}{R} = \frac{V^2}{R} \text{ (Power in terms of voltage)} \]

Thus we can say that \[ P=VI= I^2R= \frac{V^2}{R} \]

There are many different units that can be used to express power, such as horsepower for cars. However, the SI unit of electrical power is watt (W). Since watt is very small, for commercial purpose we use kWh (kilo watt hour). kWh is commonly known as ‘unit’ and is used by electric companies to calculate the energy consumed by houses.

**Check Your Progress**

**Note:**
- Space is given below to write your answer.
- Compare your answer with the one given at the end of this Unit.

3) Explain Ohm’s law.

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4) Discuss the various factors on which resistor of conductor depends.

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13.4 HEATING EFFECTS OF ELECTRIC CURRENT

Learners might have noticed that, when switch is turned on, the bulb glows, refrigerator starts to function, electric iron gets heated up, etc. After sometime when learners touch bulb, refrigerator or electric iron, they also feel heat. Why is it so? You may pose this question to learners and can introduce the concept of heating effect of current. Continue with the explanation of energy. After that explain learners that there are different forms of energy such as mechanical energy, electrical energy, nuclear energy, heat (thermal) energy, etc. Also, discuss about the law of conservation of energy i.e. energy is neither created nor destroyed but is transferred from one form to another and hence the energy of the system remains constant. Now you may try the following activity to teach concept of heating effect of current.

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<thead>
<tr>
<th>Device</th>
<th>Energy Converted from</th>
<th>Energy Converted to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulb</td>
<td></td>
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<tr>
<td>Fan</td>
<td></td>
<td></td>
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<tr>
<td>Electric Iron</td>
<td></td>
<td></td>
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<tr>
<td>Tube Light</td>
<td></td>
<td></td>
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<tr>
<td>Microwave Oven</td>
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</tbody>
</table>

As conclusion, you may explain that in devices electrical energy is converted to other form of energy such as thermal (heat). For instance, chemical energy in cells is converted to develop potential difference (potential energy) across its terminals and when it is connected to a circuit, current flows and bulb glow, fan rotate, electric heater heats up and so on. Thus in bulbs electric energy is converted to light energy, in refrigerator as mechanical energy and in electric heater as heat energy. What happens is when current continuously flow in these gadgets, heat energy is also produced and hence we feel heat on touching these devices. That part of electrical energy is used in doing work and to produce heat. This phenomenon of producing heat (thermal) energy due to the flow of current is called heating effect of electric current. You may also hint that, heating effect is one of the effects of electric current similarly magnetic effect is also produced (will discuss in coming sections).

You may further explain: Suppose a charge ‘Q’ flows in time ‘t’ across a potential difference V and resistor ‘R’, the energy lost in moving the charge or work done (by law of conservation of energy, energy lost is converted to other form i.e. heat) is given by

\[ W = QV = ItV \text{ or } VIt \quad (\text{Since } Q = It) \]

The work done is nothing but heat produced. So we will replace W with H (heat produced). Therefore heat produced is given by

\[ H = VIt = I^2Rt \quad (\text{Substituting Ohm’s law i.e. } V = IR) \]

This is known as Joule’s law of heating or simply Joule’s law. The heat energy produced in a conductor by the flow of electric current is called Joule heating. Joule’s law states that the amount of heat developed in a conductor by the
flow of electric current is directly proportional to (i) square of the current I, (ii) resistance of the conductor R and (iii) the time t for which the current flows.

Now you may discuss the practical applications and the pros and cons of joule heating. The bulb produces light by making use of the principle of joule heating. Similarly, electric irons, electric kettles, electric heater, etc. also work based on joule heating. These are some of the advantages. What are the disadvantages? If the heat produced in bulbs increase continuously, the filament melts and gets fused. To avoid fusing of bulb, filaments are made with metals having high melting point and chamber is filled with nitrogen and argon gases. Another common application is the use of ‘fuse’. Fuse protects overflow of current through a circuit. To achieve this, fuses are made using metals having low melting point. When current overflows, the fuse melts and disconnects the circuit.

Activity 2

A) Ask learners to analyze their house electricity bill of last three months and explore the power consumed each month. Also ask to compare it with any their peers and report the observations.

B) What are metals/alloys by which bulb and fuse filaments are made of? Ask learners to prepare a note of it. Organise a discussion on the properties of these metals/alloys.

Check Your Progress

Note:  
a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

5) How does electric heater generate heat? Discuss the basic principle behind it.

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13.5 MAGNETIC EFFECTS OF ELECTRIC CURRENT

When electric current flows through a conductor heat is produced. Why don’t you ask learners a question now; apart from heat what effect would flowing current will produce? If you fail to get answer from learners (even otherwise too) provide learners cell, key, ammeter, variable resistor, and copper wire. Let them construct the following circuit and keep the compass needle beneath copper wire. Remember to place copper wire straight along north-south direction and compass needle beneath it. Let learners close the key and observe deflection of compass needle. After that, the current direction may be changed and the deflection be again observed. Learners will realize that when current flows through
conductor, compass needle deflects and changes direction when current direction is changed. You may conduct this activity and learners may be asked to submit their observations.

You may conclude the activity by explaining that **when current flows through the conductor, magnetic field is developed around it and the direction of magnetic field depends on the direction of the current. This effect is called as magnetic effect of electric current.** This phenomenon was discovered by Hans Christian Oersted. The unit of magnetic field is 'oersted'. Electric motors work based on the principle of magnetic effect of current.

**13.5.1 Magnetic Field and Magnetic Field Lines**

We have seen current flow generates magnetic field. What is magnetic field? At this point you may relate magnetic field with any perfume. If a person applies perfume, there is a space/area around him where other people can feel its effect. So, that area is considered to be the field area of that particular perfume. Similarly the area around a magnet where its presence is felt is called the magnetic field of that magnet. Magnetic field is defined as the space around a magnet in which magnetic force is exerted. Or magnetic field is the space around a magnet in which the force of attraction or repulsion can be detected.

Magnetic field around a magnet is represented by drawing magnetic field lines (magnetic lines of force or lines of force) around it. ‘Magnetic field lines’ are the imaginary lines representing magnetic field. The concept of magnetic field line was introduced by Michael Faraday. Magnetic field at a point is the force experienced by a hypothetical unit North Pole placed at that point and direction of the force gives the direction of the field. Magnetic field is a vector quantity i.e. it has both direction and magnitude. The direction of magnetic field is taken by convention that the magnetic field lines (lines of force) emerge from North Pole and merge at South Pole. The strength of field can be observed from the closeness of the magnetic field lines.

How can we realize learners the presence of magnetic field lines? Try the following activity. Ask learners to keep bar magnet at the centre of a white sheet of paper fixed over a board and spread iron filings around it. Then gently shake the board and they will see iron filings forming a pattern as shown below. The
lines along which the iron filings arrange represents the ‘magnetic field lines’ and is due to the magnetic field created by the bar magnet.

![Image of magnetic field lines](https://en.wikipedia.org/wiki/magnetic_field/)

**Source:** https://en.wikipedia.org/wiki/magnetic_field/

**Activity 3**

Learners may be provided with a bar magnet and a compass needle. Let them conduct the second method of drawing lines of force. For this, ask them to place bar magnet on a sheet of paper. Then place the compass needle near the N pole of bar magnet and mark the North Pole and South Pole of compass needle. Then change position of compass needle such that the south pole of compass needle touch the previously marked North pole. Continue the process and check the drawing of your learners. Check where they get a picture as shown below.

![Diagram of magnetic field lines](https://en.wikipedia.org/wiki/magnetic_field/)

As learners learn to draw magnetic field lines, you may proceed to the properties of magnetic field lines. Why don’t you elicit the properties through discussion method? Let them sit in group and identify it. Thereafter, you may conclude it. The following points must be discussed;

**Properties of Magnetic Field Lines**

1) Magnetic field line is directed from North Pole to South Pole outside the magnet and from South Pole to North Pole inside the magnet.

2) A magnetic field line is a closed and continuous curve.

3) The magnetic field lines are crowded near the pole where the field is strong and far from the magnet where the field is weak.

4) The magnetic field lines never intersect each other, if they do so there will be two direction of magnetic field at that point, which is impossible.
Check Your Progress

Note:  
   a) Space is given below to write your answer.
   b) Compare your answer with the one given at the end of this Unit.

6) Why do two magnetic field lines never intersect? Give reasons for it.
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13.6 MAGNETIC FIELD DUE TO A CURRENT CARRYING CONDUCTOR

We have seen that current carrying conductor produces magnetic field. Magnetic field has both direction and magnitude. Is the pattern of magnetic field produced dependent upon the shape of the conductor? What is the direction of the magnetic field formed? You may probe learners by asking such questions and try to obtain answers from their side. We will now discuss the magnetic field produced when current flows through, straight conductor, circular loop and solenoid,

13.6.1 Magnetic Field due to Current through a Straight Conductor

To identify the pattern and direction of magnetic around straight conductor, learners may be provided with variable resistance (rheostat), cell (12 V), cardboard, thick copper wire, ammeter (0-5 A), compass needle and key. Let them construct the following circuit, place cardboard in horizontally and thick copper wire normal to the cardboard. Also spread some iron filings over cardboard. Then keeping the rheostat at a particular point, pass current through the circuit and at the same time gently tap on the card board. Then learners will observe that the iron filings will align themselves in concentric circles as shown in figure. To find the direction of magnetic point at a point, say P, place compass needle at that point. The direction of the north pole of the compass needle will give the direction of magnetic field at that point.

Source: http://epathshala.nic.in/e-pathshala-4/flipbook/
The activity may be repeated by reversing the current direction. In such a case, learners will find that the compass needle deflects in the opposite direction i.e. the direction of magnetic field change when the direction of the current through straight conductor change. What about the magnetic field at a farther distance from the straight conductor? You may ask learners to observe it by placing compass needle at farther distance. At further points from the straight conductor, the compass needle slightly deflects or may not deflect at all. This shows as we move away from the conductor the magnetic field also reduces. Now you may ask learners to increase the current flow (by reducing resistance) and they will observe that the deflection of the compass needle increases i.e. when current flow increases the magnetic field also increase. Thus we may conclude that; when current flows through a straight conductor;

- The strength of magnetic field created is directly proportional to current
- The direction of the magnetic field depends on the direction of current
- Strength of magnetic field near conductor is high and reduce at farther points

At this point, you may introduce **Right Hand Thumb Rule**. It is used to determine the direction of magnetic field around straight conductor. According to this rule, if conductor is grasped in the right palm the thumb pointing in the direction of current, the curled fingers give the direction of magnetic field. **Maxwell’s Corkscrew Rule** can also be used to determine direction of magnetic field. It says if a right handed screw is rotated such that it is advancing in the direction of current through a straight conductor, then the direction of rotation of screw gives the direction of magnetic field.

![Thumb points in the current direction](image)

**13.6.2 Magnetic Field due to Current through a Circular Loop**

The magnetic field around a circular loop can be demonstrated by constructing the following circuit. Here a copper circular loop is created and connected with cell and key. Let learners observe the pattern of iron filings formed when the current flows through the circuit. The pattern of iron filings formed represents the magnetic field lines across the circular loop and is shown below. The following points may also be explained;

- Every point of the circular loop generate magnetic field and its strength is maximum near the circular loop. The strength of the magnetic field reduces as distance increases from circular loop.
- The arcs of the circles (magnetic field lines) at the centre of loop appear as straight lines
13.6.3 Magnetic Field due to Current through a Solenoid

Before identifying magnetic field due to solenoid carrying current learners may be exposed to solenoids. A **solenoid is a coil of many circular turns wound on a long straight core**. To find the magnetic field due to a current carrying solenoid connections are made as shown in figure a and the resulting magnetic field is shown in figure b.

The following points may be explained:

- The magnetic field inside solenoid are in the form of parallel straight lines. Thus magnetic field inside is same at all points inside solenoid i.e. the field is uniform inside the solenoid

- The magnetic field lines across a solenoid and bar magnet look similar (see figure). Thus solenoid behaves like a bar magnet having North Pole and South Pole
Now we may move on to discuss the concept of Fleming’s Left Hand Rule. We studied that a current carrying conductor produces magnetic field. Now suppose we place a current carrying conductor in a magnetic field, the current carrying conductor will experience a force (see figure). In such a case there exists a relation between current, magnetic field and force. This relation is directionally determined by Fleming’s Left Hand Rule. The Fleming’s Left Hand Rule states that, if the left hand is stretched in such a way that, forefinger, middle finger and thumb are in mutually perpendicular directions; then forefinger shows the direction of magnetic field, middle finger current and thumb shows the direction of motion or force acting on conductor. John Ambrose Fleming introduced this rule. Fleming’s Left Hand Rule is applicable to electric motors.

![Figure 13.8](http://www.electrical4u.com)

**Check Your Progress**

**Note:**

a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

7) Describe Fleming’s Left Hand Rule? Why it is used?

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8) What is similar between bar magnet and Solenoids?

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13.7 ELECTRIC MOTOR

Electric motors convert electrical energy to mechanical energy. Electric motors are used in refrigerators, electric fans, washing machines, mixers, etc. Let us discuss how electric motors work. It consists of a rectangular copper wire ABCD with its arms AB and CD placed perpendicular to direction of magnetic field. The ends of coil are connected to split rings P and Q. The split rings are connected to brushes X and Y as shown in figure. When the key is closed, current flows through the coil. Current flows from A to B in arm AB and from C to D in arm CD; opposite to each other. Since magnetic field acts perpendicular to the current flow, applying Fleming left Hand Rule, we find the force acting on arm AB is downward. Thus the force pushes arm AB downward while arm CD upward. Hence loop ABCD makes a half rotation. This half rotation make Q to touch X and hence the direction of current reverses and flows along the path DCBA (The device that reverses the direction of flow of current through a circuit is called commutator. Hence the split rings act as commutator). This reverses the force on arm AB and CD and half a more rotation in the same direction is completed. The current reversal causes continuous rotation of coil and axle. Such a rotation is used for doing mechanical work.

Check Your Progress

Note: a) Space is given below to write your answer.
   b) Compare your answer with the one given at the end of this Unit.

9) Explain the working of an electric motor? Why commutator is used in electric motor?

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13.8 ELECTROMAGNETIC INDUCTION

Current carrying produces magnetic field. What about the reverse process? Can current be produced by changing magnetic field around a fixed conductor or moving conductor inside a magnetic field? Yes! A current is produced in a conductor by changing magnetic field around a conductor or by moving conductor.
inside a magnetic field. This phenomenon is called electromagnetic induction. Electromagnetic induction is discovered by Michael Faraday.

The following activity can be demonstrated for electromagnetic induction. Connect a galvanometer (instrument used to detect presence of current) to a coil of wire AB having large number of turns. Now take a strong bar magnet and move its north pole towards B then make a deflection in galvanometer, say to left be noticed. This shows a current is produced in the coil. Now withdraw magnet away from coil, the galvanometer deflects in the opposite direction i.e. right. This again confirms the generation of current in coil but in opposite direction against the first. After this you may fix magnet constant and move the conductor back and forth. This also generates electric current in either directions and can be noticed by the deflection of galvanometer. Thus it is proved that current can be produced in a conductor by changing magnetic field around a conductor or by moving conductor inside a magnetic field i.e. When magnetic field change, induced potential difference is developed across the ends of the conductor and it produces induced current to flow. It is also noticed that, when magnet/coil is stationary, there is no deflection in the galvanometer.

You may provide coils, galvanometer and bar magnet to learners and let them experience electromagnetic induction by performing it.

Now you may demonstrate another experiment. Here, two coils are connected as shown below. In this experiment, learners will see that when current flows through first coil, magnetic field around it will change. These changes magnetic field around coil 2 resulting in the development of potential difference across its ends and hence flow of current (current flow can checked by the deflection of galvanometer). This also establishes the law of electromagnetic induction.

We have seen the changing magnetic field induces current. What about the direction of induced current? It is identified by Fleming’s Right Hand rule. So at this point you may describe the Flemings right Hand Rule. Fleming’s Right Hand Rule states that, if the right hand is stretched in such a way that, forefinger, middle finger and thumb are in mutually perpendicular directions; then forefinger shows the direction of magnetic field, thumb direction of motion of conductor.
Content Based Methodology-I

Check Your Progress

Note:  
a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

10) Changing magnetic field develops current in a conductor. Is this ‘statement’ true or false? Why?
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13.9 ELECTRIC GENERATOR

A practical application of electromagnetic induction is seen in the working of electric generators. Electric generators convert mechanical energy to electrical energy. Let us see how an electric generator is working. It consists of a rectangular loop placed between poles of a magnet, two rings (R₁ and R₂) and two brushes (B₁ and B₂) as shown in figure. The rings are attached to a rotatable axle. When the axle is rotated such that, AB moves up and CD moves down, then by applying Fleming’s Right Hand Rule, induced current is developed in the arms AB and CD and flows in the direction ABCD. Thus, current flows from B₂ to B₁ in the external circuit. After half rotation, the arm CD moves up and AB moves
down thereby reversing flow of induced current in the direction DCBA and from B1 to B2 in the external circuit. Thus the direction of current in arms changes after every half rotation. Such a current which changes direction in equal intervals of time is called alternating current. Or alternating current reverses its direction periodically. Alternating current is abbreviated as AC. Thus this device generates alternating current and we call it as AC generator.

If a split ring type commutator (device that reverse the direction of flow of current in a circuit) is used, then one brush will always be in touch with an arm going down and the other brush with an arm going up. This produces a unidirectional current. Unidirectional current is called direct current. A current which flows only in one direction is called direct current. Direct current is abbreviated as DC. If split commuters are used in electric generators, then such a device is called DC generator.

Let us recapitulate. Electric current which changes direction after equal interval of time is called Alternating Current (AC). Electric current which does not change direction with time is called Direct Current (DC).

13.10 DOMESTIC ELECTRIC CIRCUITS

Electricity generated at the power station reach our home through two insulated wires (supported using electric poles) of aluminum or copper. Among the two wires, the red insulated wire is called live wire (positive) and black insulated wire is called neutral wire (negative). The potential difference between these two wires is 220 V. Therefore we receive alternating current having potential difference 220v and frequency 50 Hz). Both the live wire and neutral wire enters in a box where a main fuse is put on the live wire. Thereafter these wires enter ‘main switch’ through ‘electricity meter’. The electricity meter shows the consumption for power used by that particular house and main switch is used to control current flow in houses (by switching off or on).

Then from the main switch two wires are connected to electric circuits. Usually two circuits are made; one circuit is of 5A rating used to operate appliances consuming low electric power (such as bulb, tube light, fan, etc.) and other circuit is of 15A rating used to operate appliances consuming high electric power (such as air conditioner, refrigerator, electric iron etc.). It should be noted that all the circuits in house are connected in parallel so that switching off one circuit does not affect the other circuit. One more advantage of parallel connection of circuits is that each electric appliance gets equal voltage.
Electric circuits also carry a third wire, green insulated. This is the earth wire and is usually connected to the body of metallic electric appliances. The earth wire sends the current from the body of the appliance to the earth whenever a live wire incidentally touches the body of metallic electric appliances. Thus, the earth wire is a protective measure, which saves us from severe electric shocks. The schematic diagram of common domestic circuit is given below.

![Schematic diagram of common domestic circuit](http://epathshala.nic.in/e-pathshala-4/flipbook/)

**Check Your Progress**

**Note:**

a) Space is given below to write your answer.

b) Compare your answer with the one given at the end of this Unit.

11) Discuss domestic electric circuits?

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**13.11 LET US SUM UP**

Many electric devices work when electric current flows through it. In this unit, we have discussed the various aspects related to electric current. Such as, what is electric current? How is it related to resistance and potential difference? etc. Thereafter we have seen the combination of resistors in circuits, series and parallel connection and derived the formula to calculate combined resistance in such combinations. As electric current flows through a circuit, it produces heating effect (as seen in electric heaters, electric irons, etc) or when the magnetic field across a circuit is changed electric current is induced in it (as seen in electric motors and electric generators). These concepts as well are discussed. In addition, the magnetic field produced when current flows through different materials such as straight conductor, circular loop and solenoid are also discussed. We have ended the unit by discussing the domestic circuits. Throughout the unit, the pedagogical aspects have been taken care off. As you teach your learners, these pedagogical considerations will be of great help.
13.12 UNIT END EXERCISES

1) Suggest two activities to introduce the concept of electric potential difference to children of standard 9.

2) Prepare a write up on the procedures followed by electric companies to calculate the electric power consumed by house.

3) Prepare a list of electric devices and identify the forms of energy supplied to them. Also identify the energy conversion in those devices.

4) Examine the components of an electric fan and prepare a note of it.

5) Observe the electric circuit of your house and draw a circuit diagram

13.13 REFERENCES AND SUGGESTED READINGS


Websites:
http://epathshala.nic.in/e-pathshala-4/flipbook/
https://www.pinterest.com/pin
https://en.wikipedia.org/wiki/Magnetic_field
http://www.electrical4u.com/fleming-left-hand-rule-and-fleming-right-hand-rule/
http://www.learnabout-electronics.org/ac_theory/inductors01.php
http://4mechtech.blogspot.in/2013/12/right-hand-corks-screw-rule.html
https://www.shutterstock.com/image-vector/electromagnetic-induction-221191111

13.14 ANSWERS TO CHECK YOUR PROGRESS

1) Conventional current direction is the direction by which positive charges move in circuits.

2) Electric potential is the energy of a unit charge at a particular point, while potential difference is the work done in moving a unit charge form one point to other.

3) Ohm’s law states that, voltage across the ends of the conductor is directly proportional to the current flowing through it keeping temperature constant.

4) Length, area of cross section and nature of material.

5) Heating effects of electric current.
6) If two lines intersect, it will represent different directions at that particular point. Two directions for a single point is impossible.

7) Refer section 13.6

8) Solenoid behaves like bar magnet having north pole and south pole.

9) Refer section 13.7

10) True

11) Refer section 13.10