UNIT 7 ELECTROMAGNETISM

Structure

7.1 INTRODUCTION

Electricity has affected our lives to such an extent that it is difficult to think of any major human activity in which electricity is not used. Applications of principles based on different effects of electricity can be easily noticed in devices used at homes, offices, schools, hospitals, industry and in fact many other spheres of life. Radio. fan, T.V., pump and refrigerator are some of the commonly used devices which work on one or the other principles of electricity. Can you name some other appliance in your house which also works on electricity? On what principle does it work?

The present unit focuses on two major concepts related to electricity and its interaction with magnetic field. These include the force acting on a current carrying conductor kept in a region of magnetic field and generation of electric current from magentic field. The unit intends to explain how best a teacher can make his/her students understand the basic principles involved therein. It includes illustrative explanations of the basic concepts stated above.

The suggested activities will enable you to help the students understand the working of d.c. electric motor and d.c. electric generator. You may try to obtain a toy motor or a cycle dynamo from electric junk or electronics shop and use these for demonstration. The assembled working models of electric motor and electric generator can also be had from service material shop or dealers. These can be easily used as teaching aids and will help the students in better understanding of related concepts.

7.2 OBJECTIVES

At the end of this unit, you will be able to:

- design simple activities to demonstrate magnetic effect of current and the effect of magnetic field on electric current;
- enable you to make the students comprehend the phenomenon of electromagnetic induction with the help of simple demonstrations;

- explain the construction and working of electric motor and electric generator effectively;
- evaluate different concepts related to interaction between magnetic field and electric current;
- help the students relate concepts of electromagnetism to daily life situations; and
- use different methodologies for effective transaction of concepts related to electromagnetism.

7.3 MAGNETIC EFFECT OF CURRENT

7.3.1 Electric Current Flowing through a Metallic Conductor Produces Magnetic Field

Main Teaching Points

- Electric current flowing through a metallic conductor has a magnetic field around it.
- Direction of magnetic field depends upon direction of current flowing through the conductor.

Teaching-Learning Process

In order to demonstrate that magnetic field is associated with a current carrying metallic conductor, the following experiment can be performed:

Take a straight copper wire, a source of direct current, magnetic needle, a rheostat, a key and connecting wires. Set up the experiment as shown in the figure 7.1 and switch on the current in the circuit.

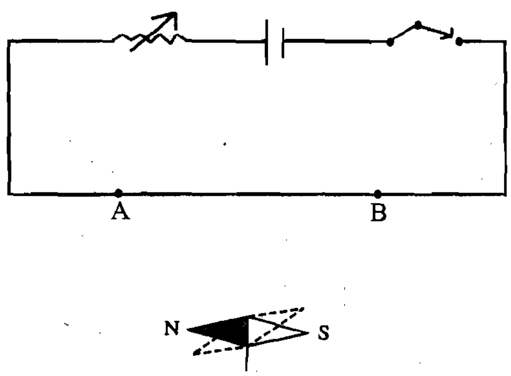

Fig. 7.1

Why does a magnetic needle show deflection when the circuit is switched on? What do you observe when the circuit is switched off ? Now reverse the direction of flow of current through the wire AB by reversing the polarity of the battery. Why does the magnetic needle show deflection in the opposite direction?

The above observations clearly indicate that when current is made to flow through the circuit, there is a magnetic field produced around wire AB and hence the needle deflects. The reflection of the needle in the reverse direction on changing the direction of current indicates that the direction of magnetic field around the conductor AB reverses in the second case. This effect in which a magnetic field is produced by the current flowing through a metallic conductor is called magnetic effect of current. An electromagnet is a simple example of current. An electromagnet is a simple example of this effect in daily life situations.

The following questions may be asked in the class to facilitate interaction (Interactive questions):

Interactive Questions

1. What is magnetic effect of current ?
2. If the electric current flowing through the conductor is very feeble, the magnetic needle may not deflect. Why ?
3. State one factor on which direction of magnetic field due to current flowing through a conductor depends ?
4. What would be your observation, if the direction of magnetic needle is at right angles to the direction of length of the current carrying conductor ?

Methodology used : Discussion-cum-demonstration method has been adopted for clarifying the concepts to the students in this section. Question answer technique has been used to reinforce learning. Similar questions can be designed to make the process more interactive in nature.

Check Your Progress

Notes : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

1. Can the above demonstration be repeated with alternating current?

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2. Suggest any one precaution you will take to ensure that the demonstration does not fail in the classroom.

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3. Does the magnetic field exist even when the electric current is passed through an electrolyte?

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7.3.2 Direction of Magnetic Field Produced Due to Electric Current is Determined by Applying Different Rules

Main Teaching Points

- Direction of magnetic field due to an electric current can be determined by applying specific rules.

Number of different rules can be applied to know the direction of magnetic field produced due to flow of an electric current through a metallic conductor. One such rule is Maxwell's right hand thumb rule. Let us try to understand it with the help of a figure.

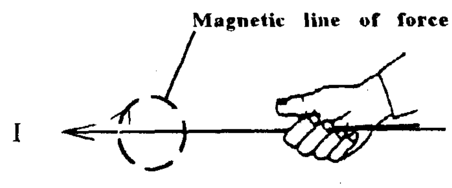

Fig : 7.2 : The Maxwell right-hand grip rule

As shown in the diagram, if we imagine the current carrying linear conductor to be held in the grip of our right hand in such a way that thumb points in the direction of flow of current then the curvature of curling of fingers around the conductor, represents the direction of magnetic lines of force.

Imagine the same linear conductor being held in your right hand but with the direction of current reversed. Apply the same rule to determine the direction of magnetic lines of force around the conductor.

Is the direction of lines of force clockwise or anti clockwise in this case?

Two other rules viz. Maxwell's Cork screw rule and Ampere's swimming rule can also be easily used to determine the direction of magnetic field.

Interactive Questions

1. Name the rule used for determination of direction of magnetic field produced due to flow of electric current through a metallic conductor.
2. State Maxwell's right hand rule.

Methodology used : Lecture-cum-discussion method has been used in the above section to clarify concepts to the students. Effort has been made to involve the students in the teaching-learning process for better learning.

Check Your Progress

Notes : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

4. State Maxwell's Cork screw rule used for determination of direction of magnetic field produced due to flow of electric current through a St. metallic conductor.

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5. Can Maxwell's right hand rule be used to determine the direction of magnetic field due to flow of current in a circular metallic conductor. Sketch the magnetic lines of force due to current flowing through such a conductor.

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7.4 MAGNETIC FIELD AFFECTS CURRENT

7.4.1 A Current Carrying Conductor Kept in a Magnetic Field Experiences Force

Main Teaching Points

- A current carrying conductor in a magnetic field experiences force.
- The direction of force on the conductor depends upon direction of magnetic field and direction of current.

- Fleming's left hand rule is used to determine the direction of force on the conductor.

Teaching-Learning Process

You have studied that a current carrying conductor produces a magnetic field around it. You also know that two magnets repel or attract when kept near each other. What do we expect when a current carrying conductor is kept in a magnetic field region? Let us perform a simple activity to answer this question:

Take a straight copper wire, a source of direct current, a rheostat, a bar magnet, little mercury and connecting wires. Make the arrangement of the circuit as shown in the figure 7.3.

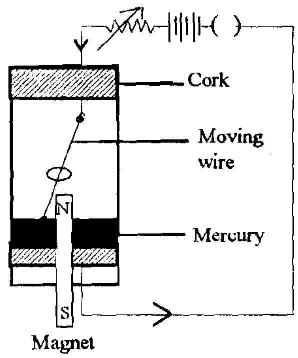

Fig. 7.3 : Faraday's experiment showing that a live conductor is rotated by a magnet

Switch on the circuit. What do we observe? Why does the straight conductor move when the circuit is closed ?

The observation can be explained on the fact that the current flowing through the st. conductor produces its own magnetic field. Due to interaction of this magnetic field and the fields of the bar magnet, the conductor experiences force and starts rotating.

Interactive Questions

1. How will the motion of conductor be affected if we reverse the direction of current through the conductor?

Since the reversal of direction of current in the conductor reverses the direction of magnetic field around it, the direction of force acting on the conductor also reverses. Fleming's left hand rule is used to determine the direction of force acting on such a conductor. Let us try to understand it with the help of figure shown below:

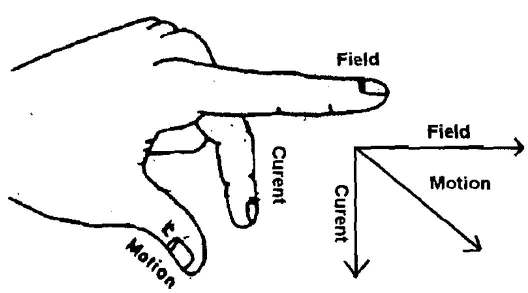

Fig. 7.4(i) : Fleming's left-hand thumb rule

The empirical rule states that :

If the thumb, the forefinger and the middle finger of our left hand are stretched mutually at right angles to one another such that the forefinger points in the direction of field, central finger points in the direction of conventional current then the thumb points out in the direction of force acting on the conductor.

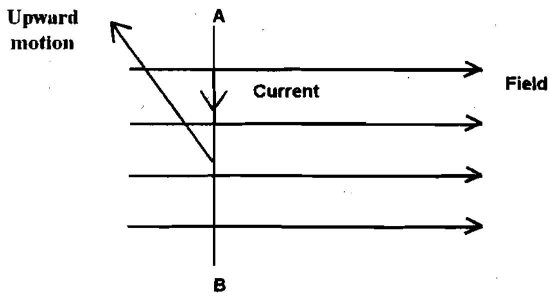

Fig. 7.4(ii)

Figure (ii) shown above illustrates the direction of motion of the conductor under the given conditions.

It should be noted clearly that the force experienced by the conductor is maximum when the direction of magnetic field is at right angles to direction of flow of current whereas the conductor experiences no force when the direction of magnetic field and flow of current are parallel to each other.

Interactive Questions

1. Why does a current carrying conductor kept in a magnetic field experience force?
2. State the factors on which the direction of force acting on a current carrying conductor kept in a magnetic field depands.
3. State Fleming's Left Hand Rule.
4. How will the direction of force on a current carrying conductor change when the direction of flow of current is reversed?

Methodology used : Demonstration-cum-discussion method has been used in the above section to present the content. Care has been taken to make the process interactive and interesting by asking relevant questions in below.

Check Your Progress

Notes : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

6. How will the direction of force acting on a conductor be affected when the direction of magnetic field as well as direction of flow of electric current are reversed simultaneously?

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7. Give two examples of above phenomenon of electric current in daily life situations.

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8. State three factors on which the force on a current carrying conductor kept in a magnetic field depends.

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7.4.2 An Electric Motor Works on the Principle that Current Carrying Conductor kept in a Magnetic Field Experiences Force

Main Teaching Points

- A rectangular metallic current carrying loop kept in a strong magnetic field experiences a couple and hence rotates.
- Fleming's Left Hand Rule helps to determine the direction of force on each side of the loop.
- An electric motor consists of a coil of wire, a powerful magnetic field and a commutator.
- Many useful machines and instruments such as moving coil meters, loudspeakers and microphones work on the above principle.

Teaching-Learning Process

You have observed that a current carrying conductor kept in a magnetic field experiences a force. The direction of the force can be determined by using Fleming's Left Hand Rule. Let us try to understand as to what would happen if a rectangular current carrying metallic loop is kept in a strong magnetic field. The figure given below will help us to understand the same:

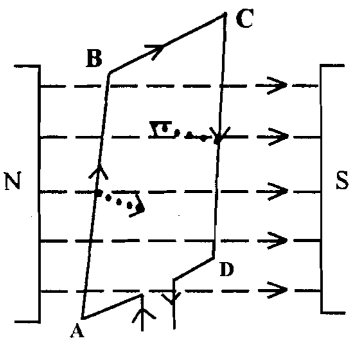

Fig. 7.5

By applying Fleming's Left Hand Rule, it can be easily seen that part AB of the loop will experience a force directed into the paper whereas part CD will experience a force in a direction coming out of the paper. The two equal and opposite forces will constitute a couple and produce a rotating effect. This forms the basic principle of working of an electric motor. Let us see the working of an electric motor with the help of a working model :

Suggested Demonstration : (Actual demonstration using a working model of a motor.)

By passing electric current through the coil kept in the magnetic field, it is observed that it starts rotating. It can also be seen that when the direction of current is reversed, the direction of rotation of the coil also gets reversed. This form the basic principle on which a d.c. motor works.

Let us look at the diagram given below. The main parts of the motor are :

- a coil of wire, called armature, which can turn about a fixed axis.
- a powerful magnetic field in which the coil turns.
- a commutator, which is a split copper ring whose two halves are insulated from each other.

The ends of the coil are connected to the two parts of the commutator which rotates with the coil. As it turns, fixed brushes press against the commutator so that direct current from the source always flows through the commutator into the coil.

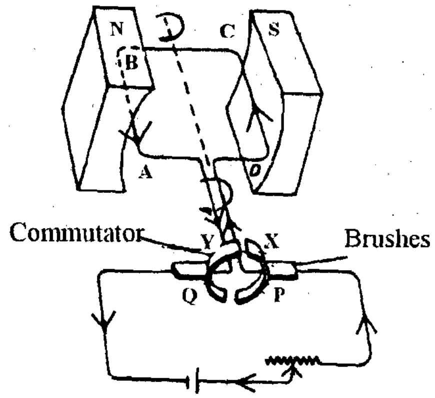

Fig. 7.6

Working of an electric fan is the simplest example of use of an electric motor. Can you think of some other devices or machines where electric motor is used?

Interactive Questions

1. State the principle of working of an electric motor.
2. Name the parts of a d.c. motor.
3. Name two devices or machines in which an electric motor is used.
4. Explain, with the help of a diagram, why a current carrying rectangular metallic loop rotates when kept in a magnetic field.

Methodology used : Lecture-cum-demonstration method has been used to clarify the concepts involved in the sub-topic. Question answer technique has been used extensively to strengthen the learning of various concepts.

Check Your Progress

Notes : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

9. In the figure 7.6 why the force acting on part BC and AD of the rectangular loop has not been considered?

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10. Name different parts of a d.c. motor.

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11. How will the working of d.c. electric motor be affected if the source of direct current is replaced by a source of alternating current?

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7.5 ELECTROMAGNETIC INDUCTION

7.5.1 Changing Magnetic Field Associated with a Metallic Conductor Produces Induced e.m.f.

Main Teaching Point

- Whenever there is a change in the magnetic lines of force associated with a metallic conductor, it results in generation of induced e.m.f. across its ends.

- The magnitude of induced emf depends upon the rate at which the magnetic flux changes.

Teaching-Learning Process

You have learnt that electric current flowing through a metallic conductor produces magnetic field. Faraday, the renowned British Physicist, tried to find out if electricity could be produced from magnetic field. Let us repeat the same experiment which he performed to answer the above question.

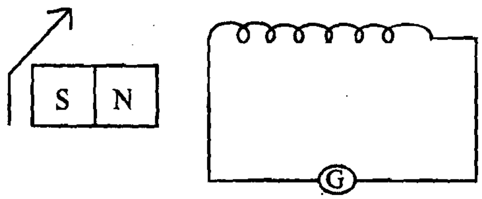

Fig. 7.7

What do you observe in the galvanometer when the magnet is taken into the coil? The deflection in the galvanometer indicates that when the pole of the magnet is pushed towards one end of the coil, an electric current is produced in the circuit. This is called induced current and the phenomenon is called **Electromagnetic induction**. The e.m.f generated across the ends of the coil due to which electric current flows is called induced e.m.f. Similarly when the magnet is moved out of the coil, the deflection in the galvanometer in the reverse direction indicates the flow of current in the circuit in the reverse direction.

Let us repeat the same experiment by moving the magnet into the coil with greater speed. What difference do you observe? Why is the deflection in the galvanometer more? The movement of magnet changes the magnetic lines of force linked with the coil when the magnet is moved with greater speed, it results in greater rate of change of magnetic flux linked with the coil and hence larger induced e.m.f. is produced. The same phenomenon can be observed by repeating the experiment with magnets of different strengths.

Interactive Questions

1. Define the term electromagnetic induction.
2. State two factors on which the magnitude of the induced e.m.f. depends.
3. Distinguish between the terms induced e.m.f and induced current.
4. What difference will it make in the above experiment if the magnet is kept fixed and the coil moved with respect to the magnet?
5. What difference will make in the above experiment if the magnet is kept inside the coil without moving it?

Methodology used : Demonstration-cum-discussion method has been followed in the above sub-section to clarify the concept. Question answer technique has been used to reinforce learning.

Check Your Progress

Notes : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

12. Why is an electric current produced when there is relative motion between the magnet and the coil?

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13. Why is electric current zero when the magnet is kept stationary inside the coil?

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14. How will the magnitude of induced current be affected when a strong magnet is used to perform the above experiment and why?

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7.5.2 An Electric Generator Works on the Principle of Electromagnetic Induction

Main Teaching Points

- An electric generator consists of a rotating coil, a powerful magnetic field and a commutator.
- An induced e.m.f. gets generated across the ends of a coil being rotated in a powerful magnetic field.
- Fleming's right hand rule helps to determine the direction of induced current produced in the coil.

Teaching-Learning Process

You have noticed that whenever there is a change in the magnetic flux linked with a coil, there is an induced e.m.f. produced across its end. This phenomenon of electromagnetic induction is used in the working of an electric generator. Let us try to understand it with the help of a simple demonstration.

Demonstration : Demonstration to be made using a (coil and a magnet).

It can be seen that when the coil is rotated in the magnetic field, and induced e.m.f. is produced across its end.

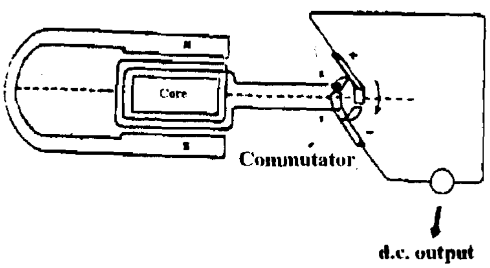

Fig. 7.8: The principle of the dynamo or the electric generator

Look at the figure above:

The three major parts of the generator are (i) the coil (ii) the field magnets and (iii) the spilt ring arrangement or the commutator.

Fleming's right hand rule can be used that the current always flows in the same direction in the external circuit.

Interactive Questions

1. Name the parts of a d.c. electric generator.
2. State the principle on which an electric generator works.
3. Draw a labelled diagram of a d.c. electric generator.

Methodology used : Demonstration method has again been used to explain the working of an electric generator. Chart can be used to show different parts of the generator. Students can be involved by asking questions wherever possible.

Check Your Progress

Notes : a) Write your answers in the space given below.

b) Compare your answers with those given at the end of the unit.

15. Does the commercial generator work on the same principle as above?

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16. Name three different types of electric generators utilising different sources of energy.

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17. What is a dynamo? On what principle does it work?

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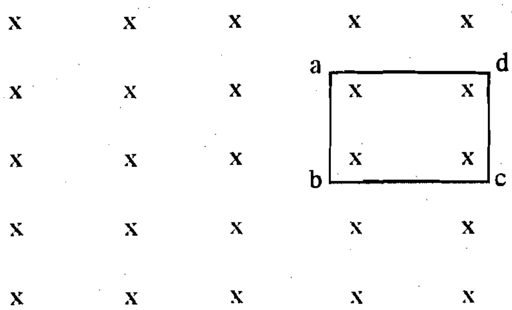
7.6 LET US SUM UP

In this unit, we have tried to understand the basic principles of interaction between magnetism and an electric current. You have studied that an electric current produces magnetic field and changing magnetic field produces electric current. We have also learnt that:

- an electric current flowing through a metallic conductor produces a magnetic field whose direction depends upon the direction of flow of current,
- a current carrying conductor kept in a magnetic field experiences force and the direction of this force depends both upon the direction of electric current as well as magnetic field,
- an electric motor works on the principle that current carrying conductor kept in a magnetic field experiences a force,
- changing magnetic field associated with a metallic conductor produces induced e.m.f. across its ends, and
- an electric generator works on the principle of electromagnetic induction.

7.7 UNIT-END EXERCISES

- Name three devices which work on the principle that current carrying conductor kept in a magnetic field experiences force.
- On what factors does the e.m.f generated by an electric generator depend?
- The adjoining figure shows metallic loop abcd moved out of a region of magnetic field which is directed normal to the plane of the loop and away from the reader.

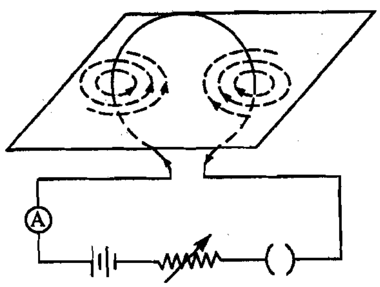


Determine the direction of induced current produced in the loop.

- Every current carrying metallic conductor is associated with a magnetic field. Will two such current carrying conductors kept near each other exert a force on each other?

7.8 ANSWERS TO CHECK YOUR PROGRESS

1. No, due to reversal of direction of current the average deflection would be zero.
2. Try-out the demonstration before it is shown in the classroom.
3. No, it can not be detected.
4. Maxwell corkscrew rule states that in a vertical conductor, if the current is moving upwards, then the direction of magnetic field is anticlockwise, and if the current is moving downwards, the direction of magnetic field is clockwise.
5. Yes. See adjoining Fig.



6. It will remain unaltered.
7. i) An electric fan
   ii) An electric mixer.
8. i) Magnitude of magnetic fields,
   ii) Strength of electric current, and
   iii) Angle between direction of magnetic fields and direction of fields of electric current.
9. The force acting on parts BC and AD is zero.
10. Armature, fields magnets, commutator and brushes.
11. It will not work.
12. The changing magnetic fields exerts force on free electrons in the metallic conductor which results in flow of electric current.

13. The magnetic fields does not change and hence there is no force on electrons.
14. It will increase due to increased rate of change of magnetic flux.
15. Yes
16. i) Hydro-electric generator
    ii) Thermal-power generator
    iii) Atomic-power generator
17. i) Device to convert mechanical energy into electrical energy.
    ii) Whenever a metallic conductor is moved in a magnetic field such that there is a change in magnetic lines of force associated with it, there is an induced e.m.f. produced across its ends.

7.9 SUGGESTED READINGS

NCERT : *Science Textbook for Class IX*.

A.F. Abbott : *O-Level Physics*.

NCERT : *Physics Textbook for Class XII*.

Fundamental Physics, Pradeep Publishers.