Chapter **2**

MAGNETIC EFFECT OF CURRENT

Introduction

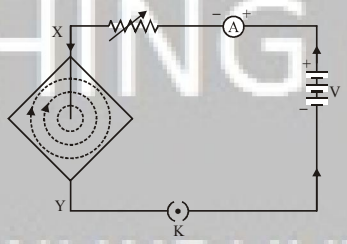
A magnet is that which attracts magnetic substances such as iron, steel, cobalt, nickel, etc., towards it.

Like magnetic poles repel while unlike magnetic poles attract each other.

- **Magnetic Field :**

The region surrounding a magnet, (or space around a current carrying conductor) in which the force of attraction or repulsion due to it can be detected is called its magnetic field. The SI unit of magnetic field is tesla (T) or weber/metre^2.

- **Magnetic Field due to a Current through a Straight Conductor :**



The magnitude of magnetic field (B) produced by a straight current carrying conductor at a given point is

(i) Directly proportional to the current flowing through the conductor.

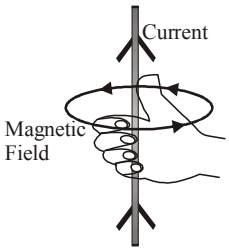
i.e. $B \propto I$

(ii) Inversely proportional to the distance of the point from the conductor

i.e. $B \propto 1/r$

➢ **Right Hand Thumb Rule :**

The direction of the magnetic field associated with a current carrying straight conductor can be obtained by applying the "right hand thumb rule".



- **Magnetic Field due to a Current through a Circular Loop** :

The magnitude of the magnetic field produced by a current carrying circular coil at its centre is

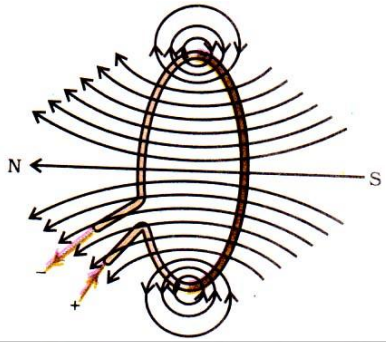
(i) Directly proportional to the current passing through the circular coil.

i.e. $B \propto I$

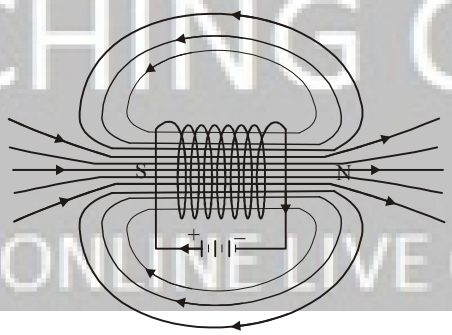
(ii) Inversely proportional to the radius of the circular coil.

i.e. $B \propto 1/r$

(iii) Directly proportional to the number of turns of the circular coil.



- **Magnetic Field due to Current in a Solenoid** :



The magnitude of the magnetic field produced by a current carrying solenoid depends on

(iii) The number of turns in the solenoid (*n*)

(ii) The strength of the current in the solenoid (I)

(iii) Nature of core material used in making solenoid.

$\therefore \quad B = \mu_0 nI$

- **Force on a Current Carrying Conductor in a Magnetic Field** :

When a current carrying conductor is placed in a magnetic field, a mechanical force is exerted on the conductor which makes it move.

- **Fleming's Left Hand Rule :**

The direction of force acting on a current carrying conductor can be easily determined by applying Fleming's left hand rule.

➢ **Factors on which force acting on a current carrying conductor placed in the magnetic field :**

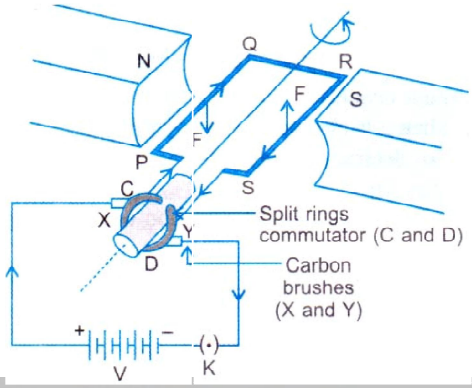
The magnitude of force acting on a current carrying conductor placed in a magnetic field depends on

(iii) The strength of the magnetic field (B) *i.e.,* $F \propto B$

(ii) The strength of the electric current (I) *i.e.,* $F \propto I$.

(iii) The length of the conductor (L) *i.e.,* $F \propto L$

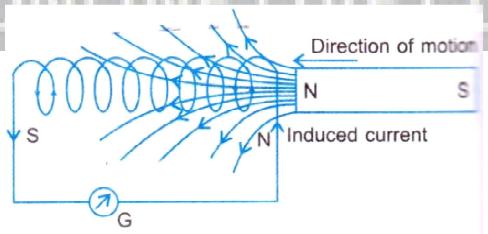
➢ **Electric Motor :**



Principle : An electric motor is a rotating device which converts electrical energy into mechanical energy. An electric motor works on the principle that a current carrying conductor placed in a magnetic field experiences a force which tends to move the conductor.

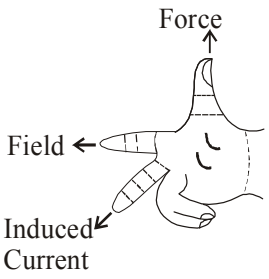
➢ **Electromagnetic Induction :**

The phenomenon due to which an induced current is set up in a closed coil whenever magnetic field around it is changing is called electromagnetic induction. Induced current lasts as long as change in magnetic field continues.



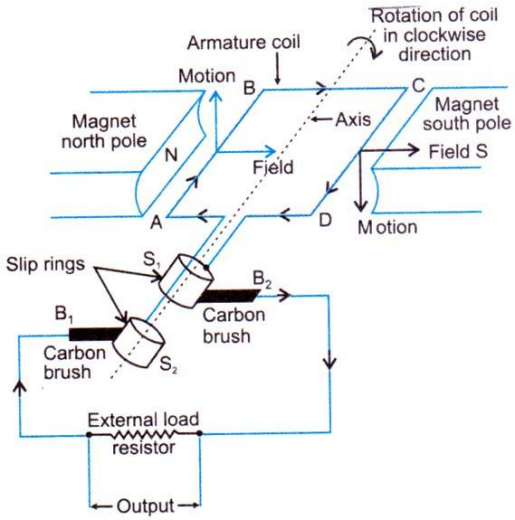
- **Fleming's Right Hand Rule :**

The direction of induced current produced in a conductor can be easily determined by applying Fleming's right hand rule.



- **Electric Generator :**

Principle : An electric generator or dynamo converts mechanical energy into electrical energy. It works on the principle of electromagnetic induction.



➢ **Direct Current (DC) :**

An electric current whose magnitude is either constant or variable but direction of flow remains the same is called direct current. Frequency of DC is zero.

➢ **Alternating Current (AC) :**

An electric current whose magnitude changes with time and direction reverses periodically is called alternating current.

➢ **Advantage of AC over DC :**

(i) AC can be easily converted to DC by using rectifier.

(ii) AC can be easily varied by using transformers

(iii) AC can be transmitted over long distances without much loss of energy.

➢ **Domestic Electric Circuits :**

In India, live wire is maintained at 220 V, while the neutral is at 0 V. So, a potential difference of 220 volts is maintained across these two wires. In addition to these wire, a third wire called earth wire is also used in domestic circuits as a safety measures.

- **Lightning Circuit :** A current rating of 5 A
- **Power Circuit :** A current rating of 15 A

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SOLVED EXAMPLES

Example 1:

An alternating electric current has a frequency of 50 Hz. How many times does it change its direction in one second?

Solution:

$50 \times 2 = 100$ times.

Example 2:

What will be the frequency of an alternating current, if its direction changes after every 0.01 s?

Solution:

Time of one A.C. cycle = 2×0.01 s = 0.02 s.

$\therefore$ Frequency of A.C. = $\frac{1}{0.02\text{s}}$ = 50 Hz.

Example 3:

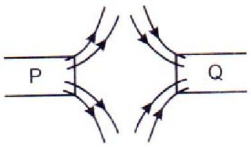
No two magnetic field lines can intersect each other. Explain.

Solution:

Two magnetic field lines cannot intersect each other at any point, because if they intersect, it means that there are two possible directions of magnetic field there, which is impossible.

Example 4:

In the Figure, identify the poles marked P and Q as north or south poles. Give Reason.



Solution:

The pole marked P is the North Pole because magnetic field lines are starting from it. Again the pole marked Q is the South Pole because magnetic field lines are ending there.

Example 5:

When is the force experienced by a current-carrying conductor placed in a magnetic field (i) maximum, (ii) minimum?

Solution:

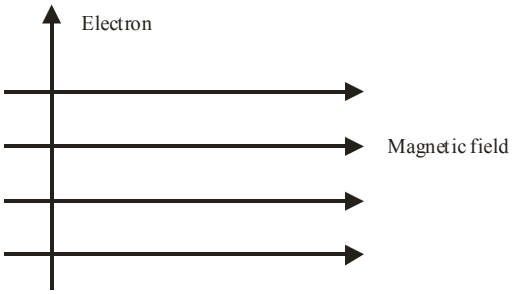
The force experienced by a current-carrying conductor placed in a magnetic field is

(i) maximum when direction of current is at right angles to the direction of magnetic field, and

(ii) minimum (zero) when direction of current is parallel or antiparallel to the direction of magnetic field.

Example 6:

An electron enters a magnetic field at right angle to it as shown in figure. In which direction will this electron move? State the principle applied by you in finding the direction of motion of the electron.



Solution:

Here motion of electron in the given direction is equivalent to a current in the opposite direction. Now by the use of Fleming's left-hand rule, we find that the force acting on the electron is directed perpendicular to plane of paper directed outward and hence the electron will move in that direction.

Fleming's left-hand rule states that stretch the forefinger, the central finger and the thumb of your left-hand mutually perpendicular to each other. If the forefinger shows the direction of the magnetic field and the central finger that of the current, then the thumb will point towards the direction of motion of the conductor (i.e., the thumb will point in the direction of force F).

Example 7:

An air conditioner of rating 2000 W, 220 V, is operated in a domestic circuit (220 V) that has a current rating of 5 A. What result do you expect? Justify your answer.

Solution:

As power rating of air conditioner P = 2000 W

and supply voltage V = 220 V

Hence, the electric oven will draw a current $I = \frac{P}{V} = \frac{2000\,W}{220\,V} = 9\,A.$

As the current rating of domestic electric circuit is only 5 A and the air conditioner draws a current 9 A, which is more than the current rating, hence the circuit will be damaged due to overheating / overloading.

Example 8:

Explain why fuse should be joined with the live wire and not with the neutral wire in a domestic circuit.

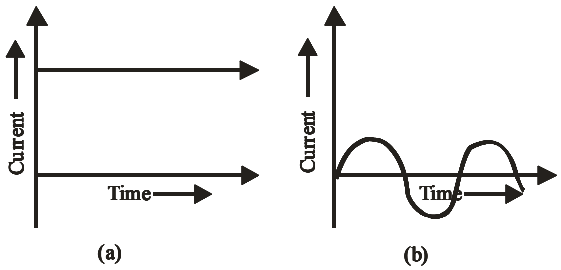
Solution:

In a domestic circuit, the phase is always at a potential 220 V higher than the neutral. The neutral is earthed at the substation. The earthed wire is earthed at

the premises of the consumer. All the coverings and those parts which should not be at a potential are earthed by joining with the earthed wire. Therefore, no fuse should be joined with the neutral wire because in the event of short-circuit such a fuse will break the system of connections only with the neutral and not with the live wire. It means that for proper functioning the fuse must be joined only with the live wire.

Example 9:

In our daily life we use two types of electric current whose current-time graphs are given in figure.



(i) Name the type of current in two cases.

(ii) What is the frequency of current in case (b) in our country?

(iii) Out of the two which one is used in transmitting electric power over long distances and why?

Solution:

(i) Current shown in figure (a) is direct current (D.C.) but current shown in Figure. (b) is an alternating current (A.C.).

(ii) In India frequency of A.C. is 50 Hz.

(iii) A.C. is used in transmitting electric power over long distances. It is so because transmission loss of electric power can be minimized for A.C. by employing suitable transformers at generating stations and consuming centres.

Example 10:

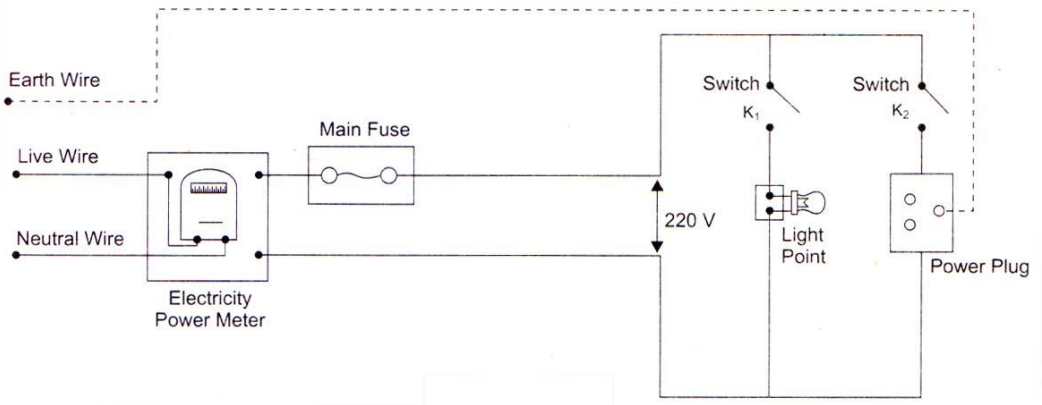
(a) Draw a schematic labeled diagram of a domestic wiring circuit which includes

(i) a main fuse, (ii) a power meter, (iii) one light point, and (iv) a power plug.

(b) Why is it necessary to connect an earth wire to electric appliances having metallic covers?

Solution:

(a) Labelled diagram of domestic wiring circuit is given below in figure.



(b) It is necessary to connect an earth wire to electric appliances having metallic covers as a safety measure. The metallic body connected to the earth wire provides a low resistance conducting path for the current. It ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of earth and the person using that appliance will not get a severe electric shock.

Example 11:

The mains power supply of a house is through a 5-A fuse. How many 100-W bulbs can be used in this house at the correct voltage?

Solution:

The current in each bulb is

$$i = \frac{P}{V} = \frac{100\,W}{220\,V} = \frac{5}{11}A.$$

For the current through the fuse to be 5 A, the number of bulbs

$$= \frac{5\,A}{5/11\,A} = 11.$$

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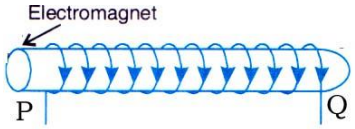
EXERCISE

LEVEL-I

1. An electron does not suffer any deflection while passing through a region of uniform magnetic field. What is the direction of magnetic field?

2. The diagram shows a coil of wire wound on a soft iron core forming an electromagnet. A current is passed through the coil in the direction indicated by the arrows. Mark the N and S poles produced in the iron core.

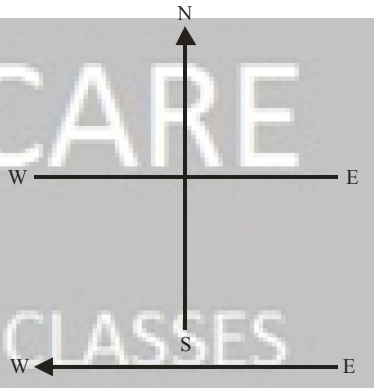


3. How can a solenoid be used to magnetize a steel bar?

4. What is electromagnetic induction?

5. Name two devices using permanent magnets.

6. A constant current flows in a horizontal wire in the plane of the paper from east to west as shown in Figure. The direction of magnetic field at a point will be North to South



(a) Directly above the wire (b) Directly below the wire

(c) At a point located in the plane of the paper, on the north side of the wire

(d) At a point located in the plane of the paper, on the south side of the wire

7. The magnetic field lines due to a straight wire carrying a current are

(a) Straight (b) Circular

(c) Parabolic (d) Elliptical

8. You have a coil and a bar magnet. You can produce an electric current by moving

(a) The magnet, but not the coil (b) The coil, but not the magnet

(c) Either the magnet or the coil (d) Neither the magnet nor the coil

9. An AC generator is connected to an electric appliance. In 10 revolutions of the armature, the current in the appliance changes direction

(a) 5 times (b) 10 times

(c) 20 times (d) 40 times

10. Which of the following describes the common domestic power supplied in India?

(a) 220 V, 100 Hz (b) 110 V, 100 Hz

(c) 220 V, 50 Hz (d) 110 V, 50 Hz

LEVEL-II

1. The magnetic field associated with a current carrying straight conductor is in anticlockwise direction. If the conductor was held along the east-west direction, what will be the direction of current through it? Name and state the rule applied to determine the direction of current.

2. What is induced current? Explain briefly two different ways to induce current in a coil.

3. State the rule which is used to determine force experienced by a conductor carrying current in uniform magnetic field.

4. What are electromagnets?

5. State the principle of electric motor.

6. Give one example each of the use of (i) Permanent magnet (ii) Electromagnet.

7. What is short circuit? State one factor/condition that can lead to it. Name a device in the household that acts as a safety measure for it. State the principle of its working.

8. Write one application of each of the following :

(a) Right hand thumb rule

(b) Fleming's left hand rule

(c) Fleming's right hand rule

9. What is the difference between direct current generator and alternating current generator? State the advantages of using alternating current over direct current. Give one disadvantage of alternating current.

10. Draw a sketch of the pattern of field lines of magnetic field through and around a current carrying solenoid.

LEVEL-III

1. (a) What is an electromagnet?

(b) List any of its two uses.

(c) Draw a labeled diagram to show how an electromagnet is made.

(d) What is the purpose of the soft iron core used in making an electromagnet?

2. Suggest an activity to show the pattern of magnetic field lines, when you are provided with a bar magnet, a cardboard piece and iron filings. Draw a rough sketch of the field lines.

3. A coil of insulated wire is connected to a galvanometer. What would be seen if a bar magnet with its north pole towards one face of the coil is

(i) Moved quickly towards it,

(ii) Moved quickly away from the coil and

(iii) Placed near its one face?

4. Two coils A and B of insulated wires are kept close to each other. Coil A is connected to a galvanometer while coil B is connected to a battery through a key. What would happen if

(i) A current is passed through coil B by plugging the key, and

(ii) The current is stopped by removing the plug from the key?

Explain your answer mentioning the name of the phenomena involved.

5. Mr. Vinod, a physics teacher, was doing an experiment in lab using dry cell battery. The dry cell was weak, giving less voltage, which was not sufficient to give proper reading. One of the student asked, "Sir, can't we use direct a. c. supply to this apparatus in lab"? Teacher replied, No, we always use battery eliminators for the sensitive equipments.

(a) What values are displayed by the student?

(b) Why direct supply of a. c. cannot be use for small range equipments?

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WORKSHEET-1

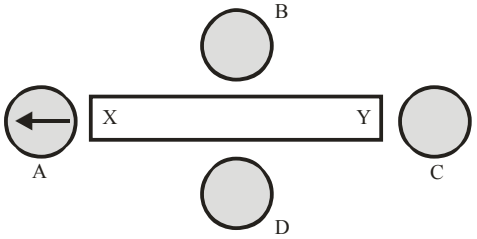
1. What is magnetic field? How can the direction of magnetic field lines at a place be determined?

2. State any two properties of magnetic field lines.

3. Why does a compass needle get deflected when brought near a bar magnet?

4. Explain why, two magnetic field lines do not intersect each other.

5. (a) The diagram shows a bar magnet surrounded by four plotting compasses. Copy the diagram and mark in it the direction of the compass needle for each of the cases B, C and D.



(b) Which is the north pole, X or Y?

6. Name the rule for finding the direction of magnetic field produced by a straight current-carrying conductor.

7. State and explain Maxwell's right-hand thumb rule.

8. (a) Draw the magnetic lines of force due to a circular wire carrying current.

(b) What are the various ways in which the strength of magnetic field produced by a current-carrying circular coil can be increased?

9. The front face of a circular wire carrying current behaves like a north pole. The direction of current in this face of the circular wire is :

(a) Clockwise (b) Downwards

(c) Anticlockwise (d) Upwards

10. State and explain Fleming's right hand rule.

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WORKSHEET-2

1. When is the force experienced by a current-carrying conductor placed in a magnetic field largest?

2. What is the principle of an electric motor? Name some of the devices in which electric motors are used.

3. (a) In a d. c. motor, why must the current to the coil be reversed twice during each rotation?

(b) What device reverses the current?

4. What is the function of brushes in an electric generator?

5. (a) Explain the principle of an electric generator.

(b) State two ways in which the current induced in the coil of a generator could be increased.

6. What name is given to the device which automatically cuts off the electricity supply during short-circuiting in household wiring?

7. What is the usual capacity of an electric fuse used (i) in the lighting circuit, and (ii) in the power circuit, of a small house?

8. When does an electric short circuit occur?

9. (a) Of what substance is the fuse wire made? Why?

(b) Explain why, a copper wire cannot be used as a fuse wire.

10. What is the maximum number of 60 W bulbs that can be run from the mains supply of 220 volts if you do not want to overload a 5 A fuse?

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