

## REVIEW QUESTIONS

- 15.1 Demonstrate by an experiment that a magnetic field is produced around a straight current carrying conductor.

See Q. No. 2

- 15.2 State and explain the rule by which the direction of the lines of force of magnetic field around a current carrying conductor can be determined.

See Q. No. 5

- 15.3 You are given an unmarked magnetized steel bar and bar magnet its north and south ends marked N and S respectively. State how would you determine the polarity at each and the unmarked bar?

When one end of unmarked magnet bring close to end 'N' of marked magnet. If marked magnet attract the unmarked then this show that there is south pole on unmarked and if 'N' pole of marked magnet repel the end of unmarked, this show that there is also north 'N' pole of unmarked magnet.

- 15.4 When a straight current carrying conductor is placed in a magnetic field, it experiences a force. State the rule by which the direction of this force can be found out.

See Q. No. 5

- 15.5 State that a current carrying coil in a magnetic field experiences a torque.

See Q.No. 6

- 15.6 What is an electric motor? Explain the working principle of D.C motor?

See Q. No. 7

- 15.7 Describe a simple experiment to demonstrate that a changing magnetic field can induce e.m.f in a circuit.

See Q. No. 8

- 15.8 What are the factors which affect the magnitude of the e.m.f induced in a circuit by a changing magnetic field?

See Q. No. 9

- 15.9 Describe the direction of an induced e.m.f in a circuit? How this phenomenon is related to the conservation of energy?

See Q.No. 10

- 15.10 Draw a labeled diagram to illustrate the structure and working of A.C. generator.

See Q.No. 11

- 15.11 What do you understand by the term mutual induction? Name and define SI unit of mutual inductance.

See Q.No. 12

- 15.12 What is transformer Explain the working of transformer in connection with mutual induction.

See Q.No. 13

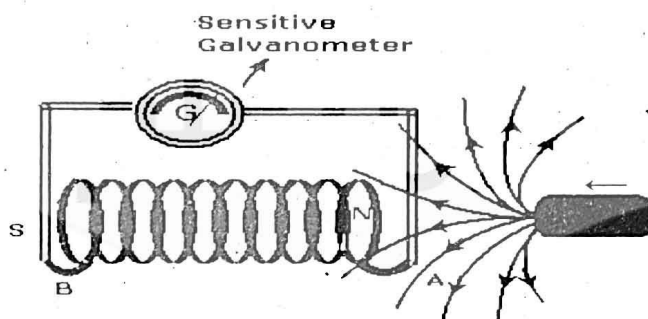
## CONCEPTUAL QUESTIONS

**15.1** Suppose someone handed you three similar iron bars and told you one was not magnet but the other two were. How would you find the iron bar that was not the magnet.

**Ans:** Take two bars at a time and test the nature of force between their ends. This can be done by bringing two bars close together. If changing the ends of two bars also changes the nature (attraction or repulsion) of force, it means both bars are magnet. If there exists a force of attraction (even on changing the ends) between the bars, it means one of the bars is not magnet. To test which one is not magnet bring each bar close to the third bar. In case of attraction between bars (even by changing their ends), the first (or second) bar will not be magnet while the third bar will be magnet.

**15.2** Suppose you have coil of wire and a bar magnet. Describe how you could use them to generate an electric current.

**Ans** By moving a magnet and coil towards each other or away from each other would induce voltage in the coil. This induced voltage will cause current in the coil. You can also induce current in the coil by moving magnet and keeping the coil fixed and vice versa.



**15.3** Which device is used for converting electrical energy into mechanical energy?

**Ans:** Motor is an electrical device which can be used to convert electrical energy into mechanical energy as in fans.

**15.4** Suppose we hang a loop of wire so that it can swing easily. If we now put a magnet into the coil, the coil will start swinging. Which way will it swing relative to the magnet and why?

**Ans:** The coil will swing opposite to the direction of motion of the magnet according to Lenz's law. It is due to the fact that current in the coil is always induced in such a way so as to cancel the cause which induces it.

**15.5** A conductor wire generates a voltage while moving through a magnetic field. In what direction should the wire be moved, relative to the field to generate the maximum voltage?

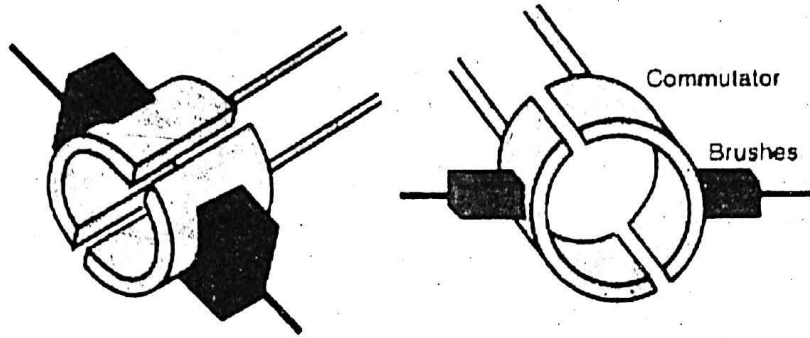
**Ans:** To generate maximum voltage through the conductor, it must be moving perpendicular to the direction of magnetic field in this case maximum magnetic force will act upon the conductor.

**15.5** What is the difference between a generator and a motor?

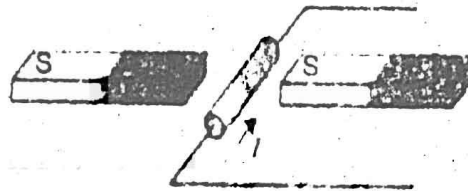
**Ans:** A motor is essentially an electrical inventor that operates in reverse. A generator converts electrical energy into mechanical energy. Whereas a motor converts electrical energy into mechanical energy.

**15.7 What reverses the direction of electric current in the armature coil of D.C. motor?**

**Ans:** To reverse the direction of current the connection to coil is made through an arrangement of brushes and a ring that is split into two halves, called splitting commutator. The split ring is ranged so that each half of the commutative changes the brushes just as the coil reaches the vertical position. Changing brushes reverse the current in the loop.



**15.8 A wire lying perpendicular to an external magnetic field carries a current in the direction shown in the diagram below. In what direction will the wire move due to the resulting magnetic force?**



**Ans:** According to Fleming's left hand rule it will move downward direction.

**15.9 Can a transformer operate on direct current?**

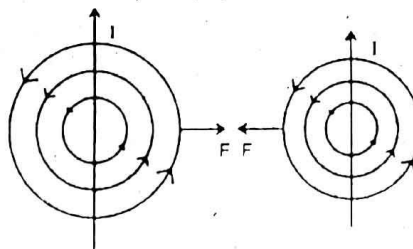
**Ans:** No, the cycle doesn't change in D.C. that is why there is not change in magnetic flux in core of transformer, that is why, there is no change of flux in secondary coil and current is not induced.

## INFORMATION BASED QUESTIONS AND THEIR ANSWERS

Activity (Page 129)

**Q.1 Suppose the direction of current passing through two straight wires is same. Draw the pattern of magnetic field of current due to each wire. Would the wires attract or repel each other?**

**Ans.** When current flows through wires in the upward direction, the magnetic field lines around each wire are in the form of concentric circles as shown in fig.



The magnetic field lines of two wires cancel the effect of each the in the space between them. Hence, the two wires attract each other due to weak magnetic field between them and the stronger magnetic field on the other sides of the wires.

## EXERCISE

### MULTIPLE CHOICE QUESTION

- (1) Which statement is true about the magnetic poles?  
 (a) Opposite poles repel (b) Like poles attract  
 (c) Magnetic poles do not effect each other. ☒ (d) A single magnetic pole does not exist
- (2) What is direction of the magnetic field lines inside a bar magnet?  
 (a) From the pole of south pole ☒ (b) From south pole to north pole  
 (c) From side to side (d) There are no magnetic field lines
- (3) The presence of a magnetic field can be detected by a  
 (a) Small mass (b) Stationary positive charge  
 (c) Stationary negative charge ☒ (d) Magnetic campus
- (4) If the current in a wire which is placed perpendicular to a magnetic field increases, the force on the wire  
☒ (a) Increase (b) Decrease (c) Remain the same (d) Be zero
- (5) A D.C motor converts  
☒ (a) Mechanical energy into electrical energy (b) Mechanical energy into chemical energy  
☒ (c) Electrical energy into mechanical energy (d) Electrical energy into chemical energy
- (6) Which part of a D.C motor reverses the direction of current through the coil every half cycle?  
 (a) The armature ☒ (b) The cominutator (c) The brushes (d) The slip rings
- (7) The direction of induced e.m.f in a circuit in accordance with conservation of  
 (a) mass (b) charge (c) momentum ☒ (d) energy
- (8) The step-up transformer  
 (a) Increase the input current ☒ (b) Increases the input voltage  
 (c) Has more turns in the primary (d) Has less turns in the secondary
- (9) The turn ratios of a transformer is 10. It means  
 (a)  $I_s = 10I_p$  (b)  $N_s = N_p/10$  ☒ (c)  $N_s = 10N_p$  (d)  $V_s = V_p/10$

### ANSWER KEY

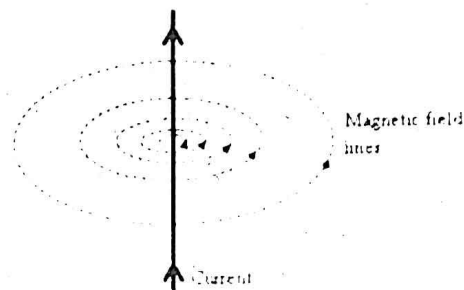
| Q  | Ans | Q  | Ans | Q  | Ans | Q  | Ans | Q  | Ans |
|----|-----|----|-----|----|-----|----|-----|----|-----|
| 1. | d   | 2. | b   | 3. | d   | 4. | a   | 5. | c   |
| 6  | b   | 7. | d   | 8. | b   | 9. | c   | d  |     |

## SHORT QUESTIONS

### 15.2 and 15.2 Magnetic Effects of a Steady Current and Force on a Current – Carrying Conductor Placed in Magnetic Field

- (1) How magnetic lines of force are formed in the straight current carrying conductor?

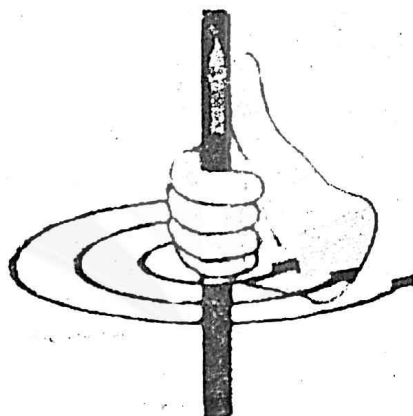
Ans: When current passes through a conductor, a magnetic field is produced in the space around it. If the conductor is a straight wire, the lines of force of this magnetic field would be in the form of concentric circles. These lines of force can be traced on a piece of cardboard with the help of a compass needle.



- (2) What is Right Hand Grip Rule?

The **Right Hand Grip Rule**:

“Grasp a wire with your right hand such that your thumb pointed in the direction of the conventional (positive) current. Then curling fingers of your hand will point in the direction of the magnetic field”



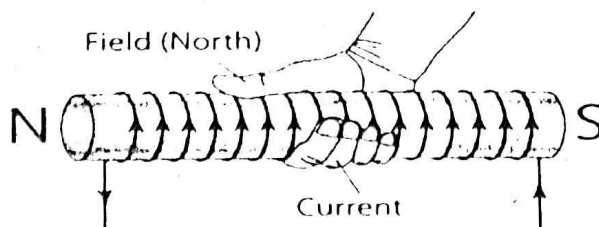
- (3) What do the cross (x) and dot (•) stand for?

Ans: A dot (•) indicates that the current is directed out of the plane of the paper i.e. it is flowing towards us whereas a sign of cross (x) would mean that the current is directed into the paper i.e. it is flowing away from us.

- (4) Write down the rules to find the polarity of solenoid.

Ans: **Right Hand Grip Rule**:

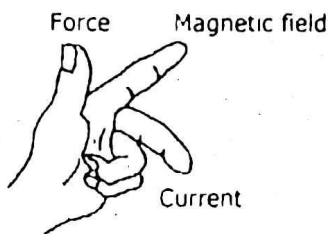
If we grip the coil with our right hand by curling our fingers in the direction of the conventional current, our thumb will indicate the north of the coil.



(5) **State Fleming's Left Hand Rule.**

**Ans:** The direction of the force acting on the wire can be determined by Fleming's left hand rule.

"According to this rule, stretch the thumb, forefinger and the middle finger of the left hand mutually at right angle to each other. If the forefinger points in the direction of the magnetic field, the middle finger in the direction of the current, then the thumb would indicate the direction of the force acting on the conductor".



(6) **When the force on the current carrying conductor in a magnetic field is maximum and when it is minimum?**

**Ans:** When the current carrying conductor makes an angle of  $90^\circ$  with the magnetic field or it is perpendicular to the field, force on it is maximum. If the conductor is placed along or parallel to the magnetic field, no force acts on the conductor.

**15.3 and 15.4 Turning effect on current carrying coil in magnetic field and D.C motor**

(7) **What is D.C. Motor?**

**Ans:** "D.C. motor is a device that converts the electrical energy into mechanical energy, which is utilized for different types of work".

(8) **Describe working Principles of D.C Motor.**

**Working Principles**

When a current-carrying coil is placed in magnetic field, it experiences a couple due to which the coil begins to rotate. A D.C motor operates on this principle.

(9) **How can we make the coil of D.C Motor rotate continuously**

The coil can be rotate continuously by reversing the direction of the current just as the coil reaches its vertical position. This reversal of current will allow the coil to rotate continuously. To reverse direction of current, the connection to coil is made through an arrangement of brushes and a ring that is split into two halves, called a split ring commutator as shown in figure. Brushes, which are usually pieces of graphite, make contact with the commutator and allow current to flow into the loop. As the loop rotates, so does the commutator. The split ring is arranged so that each half of the commutator changes brushes just as the coil reaches the vertical position. Changing brushes reverse the current in the loop. As a result, the direction of the force on each side of the coil is reversed and it continues to rotate.

(10) **What is the function of split rings in D.C. motor?**

**Ans:** Split rings connect the coil to the battery through carbon brushes. When coil rotates between the pole pieces of a magnet, split rings keep the current in the same direction in the rotating coil. Split rings change the direction of current in the sides of coil after every half cycle, so the direction of force is changed after every half cycle.

(11) How the total force acting on the armature can be increased?

Ans: The total force acting on the armature can be increased by

- ✦ Increasing the number of turns on the coil
- ✦ Increasing the current in the coil
- ✦ Increasing the strength of the magnetic field
- ✦ Increasing the area of the coil

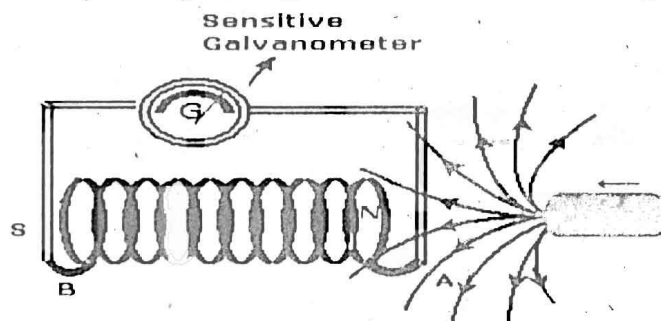
(12) What is the function of carbon brushes in D.C. motor?

Ans: Two carbon brushes are used to press slightly against the split rings by means of springs and give continuous passage of current to the coil.

**Ans: 15.5, 15.6 and 15.7 Electromagnetic Induction, Direction of Induce e.m.f – Lenz's Law and A.C generator**

(13) Define electromagnetic induction.

Ans: The process of generating an induced current in a circuit by changing the number of magnetic lines of force passing through it is called electromagnetic induction.



(14) State Faraday law of Electromagnetic Induction.

Ans: "The value of the induced e.m.f is directly proportional to the rate of change of flux".

Mathematically:

$$e.m.f = \text{rate of change of magnetic flux} \left( \frac{d\phi}{dt} \right)$$

(15) Define A.C. Generator.

Ans: "A device which produces or generates an alternating e.m.f is called A.C. generator". A.C. generator converts mechanical energy into electrical energy.

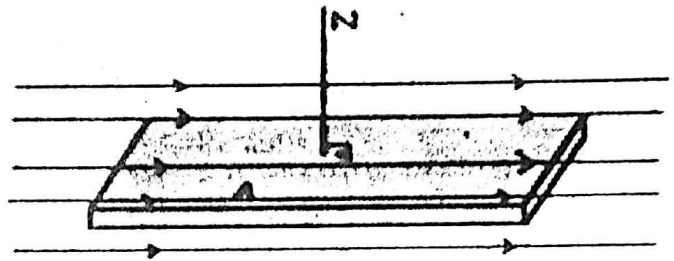
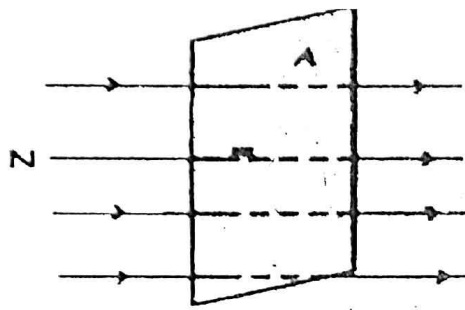
(16) Write down the principle of A.C. generator.

Ans: When a coil rotates in a magnetic field, the flux passing through it continuously changes. This change of flux induces an e.m.f in the coil. This is the principle on which an A.C generator works.

(17) What is meant by magnetic flux? When it is maximum and minimum?

Ans: "The number of magnetic lines of force passing through a certain surface is known as magnetic flux passing through that surface"

It is maximum when the area is held perpendicular to the direction of magnetic lines and minimum when the area is held parallel to the direction of magnetic lines of force.



(18) Is it possible that a constant current flowing in a coil produces an induced current in another coil?

Ans: No, a constant current flowing in one coil cannot produce induced current in another coil. In order to produce induced current in another coil, the current in first coil must be changing continuously so that magnetic flux may pass through another coil

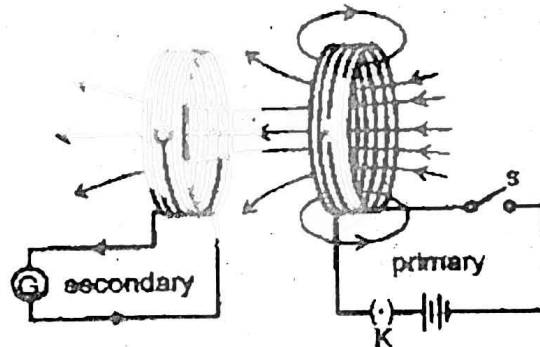
## 15.8 and 15.9 Mutual induction and Transformer

(19) Define Mutual induction.

Ans: "If a current is induced in a circuit due to a change of current in another circuit, this phenomenon is known as mutual induction"

Unit:

S.I unit of mutual induction is Henry

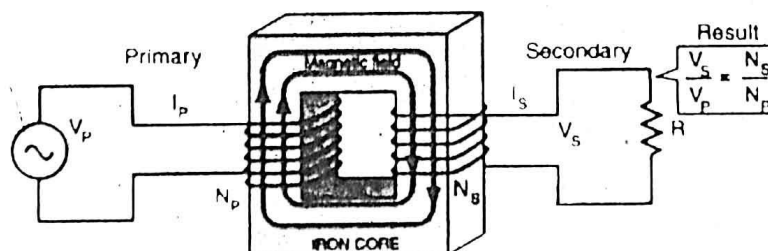


(20) Define Self Induction.

Ans: "If the current through a coil or a circuit changes and this change induces an e.m.f in the circuit itself, the phenomenon is known as self induction"

(21) Define Transformer.

Ans: "This is an electrical device which is used to increase or decrease the value of alternating voltage".



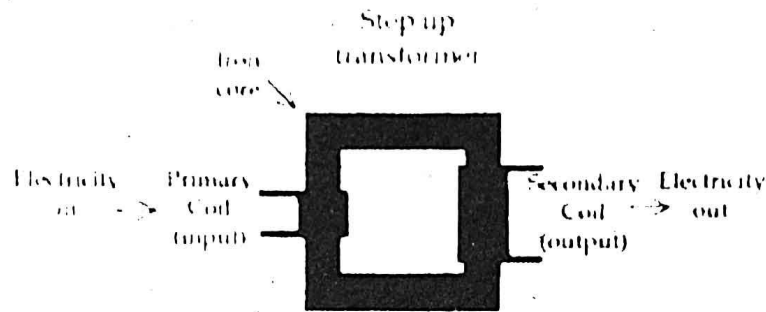
(22) What do you know about Primary coil and Secondary coil?

Primary coil

Ans: "The coil of transformer in which the change in current produces induced current in another coil is known as primary coil"

## Secondary coil

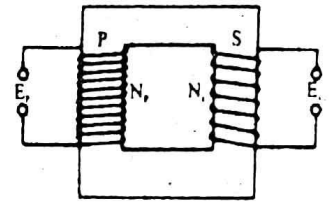
"The second coil of transformer in which current is induced is known as a secondary coil".



(23) Define Step Down Transformer and Step Up transformer.

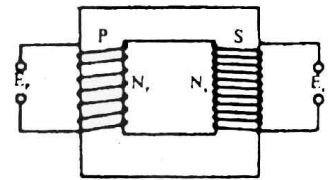
Ans: Step Down Transformer

If the number of turns in the secondary coil is less than the number of turns in primary coil ( $N_s < N_p$ ), then such transformer is called step down transformer. It is used to decrease the A.C. voltage.



## Step Up Transformer

If the voltage applied to the primary coil is to be increased, the number of turns in the secondary would be larger as compared to number of turns in the primary. ( $N_p < N_s$ ) Such a transformer is known as a step up transformer.

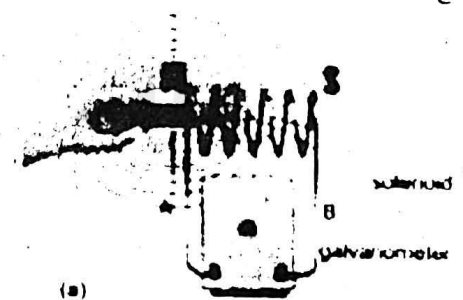


(24) What is the function of core in the transformer?

Ans: The iron core enhances the magnetic flux produced in the primary coil and the magnetic flux linked to the secondary coil through iron core.

(25) State Lenz's law?

"The direction of an induced current in a circuit is always such that it opposes the cause that produces it".



(26) Prove that Lenz law is a manifestation of the law of conservation of energy.

or

How does Induce e.m.f relate to conservation of energy?

Ans : Induce e.m.f and conservation of energy

If we apply the law of conservation of energy to electromagnetic induction, we realize that the electrical energy induce in a conductor appears from the kinetic energy of the moving magnet. We do some work on the magnet to bring it close to the solenoid. This work done consequently appears as electrical energy is the conductor. Thus mechanical energy of our hand used to push the magnet towards or away from the coil results into electrical energy. Hence Lenz law is a manifestation of the law of conservation of energy.

**(27) Why alternating voltage is stepped up at the generating station?**

**Ans:** Electric power is usually generated at places which are far from the places where it is consumed. The power is transmitted over long distances at high voltage to minimize the loss of energy in the form of heat during transmission. As heat dissipated in the transmission cable of resistance  $R$  is  $I^2 R t$ . Hence by reducing the current through the cable, power loss in the form of heat dissipation can also be reduced. So the alternating voltage is stepped up at the generating station.

**(28) How voltages are stepped down?**

High voltages are transmitted to the main sub-station. This voltage is stepped down and is transmitted to the switching transformer station or the city sub-station. At the city sub-station it is further stepped down to 20V and supplied to the consumer.

**(29) Why mains power is supplied as alternating current?**

Transformers play an essential part in power distribution. Transformer work only with AC. This is one reason why mains power is supplied as alternating current.

**(30) What is an electromagnet?**

**Electromagnet**

“Magnetic effect of current is called electromagnet”.

**(31) What is Relay Circuit ?**

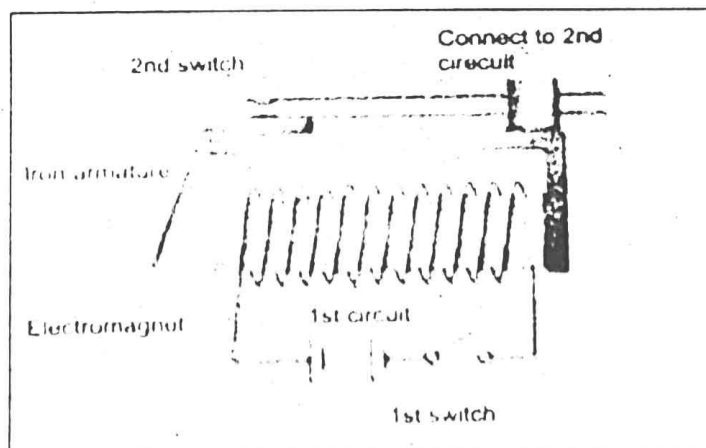
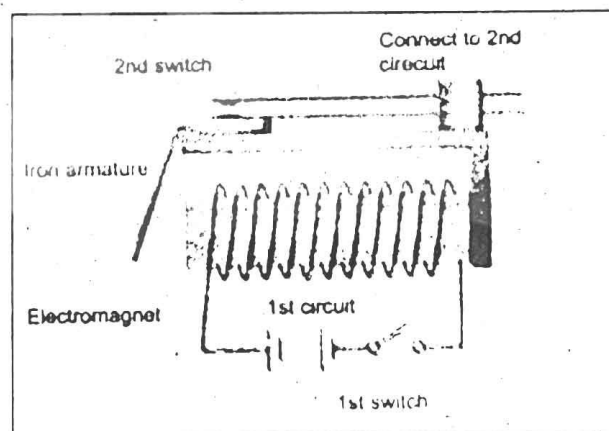
**Relay Circuit**

“A relay is an electrical switch that opens and closes under the control of another electrical circuit”. The relay is used to control a large current with the help of small current as shown in fig.

**(32) Explain Working principle of relay circuit .**

**Working principle of relay circuit**

The 1<sup>st</sup> circuit (input circuit) supplies current to the electromagnet. The electromagnet is magnetized and attracts one end of the iron armature. The armature is then closes the contacts (2<sup>nd</sup> switch) and allows current to the electromagnet stops. Now electromagnet loses its magnetism and the 2<sup>nd</sup> switch is opened. Thus the flow of current stops in the 2<sup>nd</sup> circuit.



# LONG QUESTIONS

Q.1: What is meant by electromagnetism?

Electromagnetism

“Electromagnetism is the study of magnetic effects of current.”

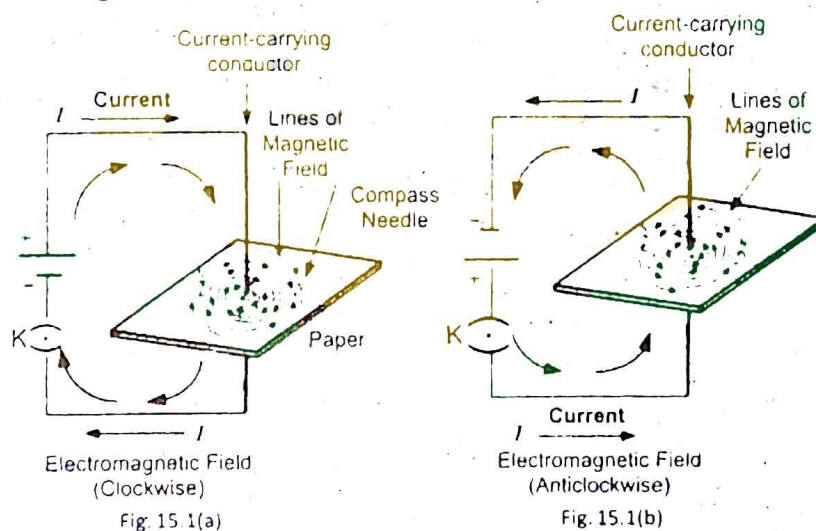
Q.2: Demonstrate by an experiment that a magnetic field is produced around a straight current carrying conductor also state the rule by which direction of the lines of force of magnetic field around a current carrying conductor can be determined?

## Magnetic Effects of a Steady Current

Ampere discovered that when a current passes through a conductor it produces magnetic field around it.

### Experiment:

To demonstrate this, we take straight, conductor wire and pass it vertically through a cardboard. Now connect the two ends of the conductor wire with the terminals of the battery so that current flows through the circuit in the clock wise direction. The lines of force of the magnetic field produced around the wire would be in the form of concentric circles. As shown fig 1 (a).



If we place compass needle at different points in the region of magnetic field, it will align along the direction of magnetic field. Also if we sprinkle some iron filings on the cardboard around the wire, they will align themselves in concentric circles in the clockwise direction.

If we reverse the direction of the current by reversing the terminals of the battery, the compass needle also reverses its direction. Now the magnetic field lines will align in the anticlockwise direction.

The magnetic field produced is stronger near the centre of the current – carrying conductor and weaker farther away from it. As shown fig 1 (b).

## Direction of Magnetic Field

The direction of the magnetic field is governed by the direction of the current flowing through the conductor. A simple method of finding the direction of magnetic field around the conductor is the Right Hand Grip Rule.

### Right Hand Grip Rule:

"Grasp a wire with your right hand such that, your thumb pointed in the direction of the conventional (positive) current. Then curling fingers of your hand will point in the direction of the magnetic field."

**Q. 4: What is solenoid? Explain magnetic field produced in current carrying solenoid.**

**OR**

**Explain magnetic field produced solenoid in resents to bar magnet.**

**Solenoid:**

A long coil of wire consisting of many loops is called a solenoid.

**Magnetic Field of a solenoid:**

The field from each loop in a solenoid adds to the fields of the other loops and creates greater total field strength as shown in fig. Electric current in the coil of wire produces magnetic field which is similar to the magnetic field of a permanent bar magnet. When this current – carrying coil is brought close to a suspended bar magnet, one end of the coil repels the north pole of the magnet. Thus, the current – carrying coil has a north and a south pole and use itself a magnet.

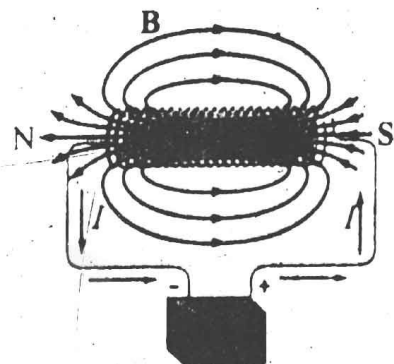


Fig. 15.4: Magnetic field due to a coil

**Electromagnet:**

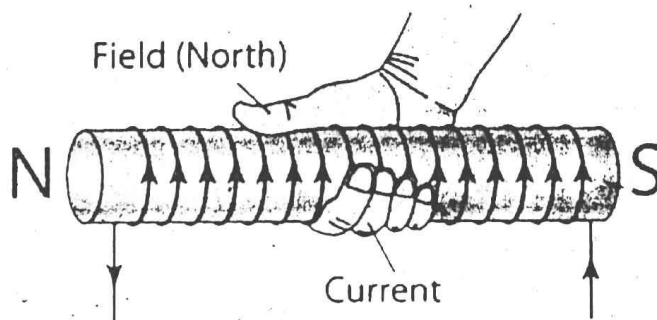
"The type of temporary magnet, which is created when current flows through a coil, is called an electromagnet."

**Direction of the magnetic field:**

The direction of the field produced by a coil due to the flow of conventional current can be found with the help of right hand grip rule stated as

**Right Hand Grip Rule:**

If we grip the coil with our right hand by curling our fingers in the direction of the conventional current, our thumb will indicate the north of the coil.



## FORCE ON A CURRENT-CARRYING CONDUCTOR PLACED IN A MAGNETIC FIELD

**Q. 3:** Explain When a straight current-carrying conductor is placed in a magnetic field, it experiences a force. State the rule by which the direction of this force can be found out.

### Force on a current-carrying conductor placed in a magnetic field:

We know that electric current produces a magnetic field similar to that of a permanent magnet. Since a magnetic field exerts a force on a permanent magnet, it implies that current-carrying wire should also experience a force when placed in a magnetic field.

#### Explanation:

The force on a wire in a magnetic field can be demonstrated using the arrangement. A battery produces current in a wire placed inside the magnetic field of a permanent magnet. Current-carrying wire produces its own magnetic field which interacts with the field of the magnet. As a result a force is exerted on the wire. Depending on the direction of the current, the force on the wire either pushes or pulls it towards left as shown in fig 1(a) and 1(b).

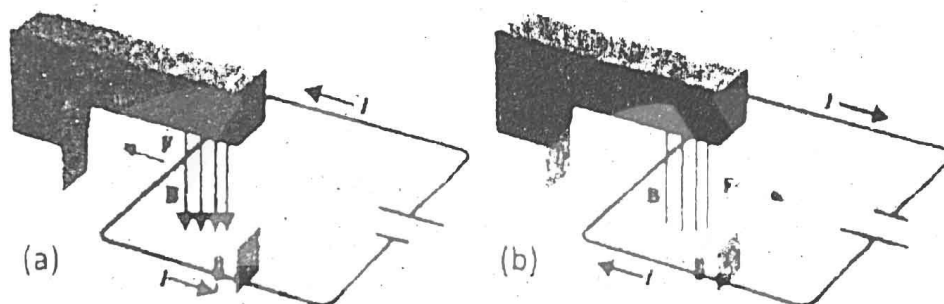


Fig. 15.6 Force on a current-carrying wire in magnetic field

Michael Faraday discovered that the force on the wire is at right angles to both the direction of the magnetic field and the direction of the current.

#### Factor affecting the force:

The force is increased if

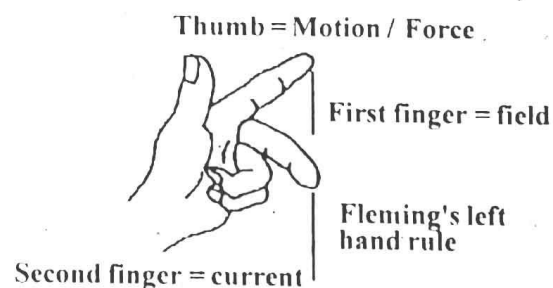
- The current in the wire is increased
- Strength of magnetic field is increased
- The length of the wire inside the magnetic field is increased

#### Determining the direction of force

Faraday's description of the force on a current-carrying wire does not completely specify the direction of force because the force can be towards left or towards right. The direction of the force on a current – carrying wire in a magnetic field can be found by using Fleming's left hand rule stated as:

#### Fleming's Left Hand Rule

Stretch the thumb, forefinger and the middle finger of the left hand mutually perpendicular to each other. If the forefinger points in the direction of the magnetic field, the middle finger in the direction of the current, then the thumb would indicate the direction of the force acting on the conductor.



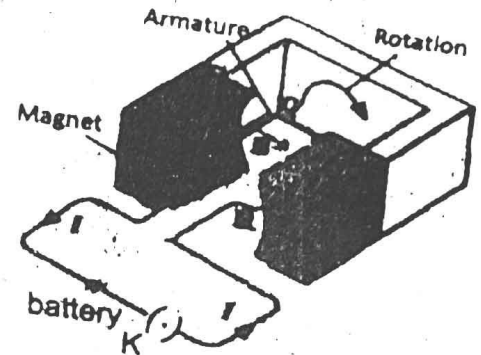
**Q.6:** State that a current carrying coil in a magnetic field experiences a torque.

### **TURNING EFFECT ON A CURRENT – CARRYING COIL IN A MAGNETIC FIELD**

If instead of a straight conductor, we place a current, carrying loops inside the magnetic field, the loop will rotate due to the torque acting on the coil. This is also the working principle of electric motors.

#### **Explanation:**

Consider a rectangular coil of wire with sides PQ and RS, lying perpendicular to the field, placed between the two poles of a permanent magnet as shown in fig. Now if the ends of the coil are connected with the positive and negative terminals of battery, a current would start flowing through the coil. The current passing through the loop enters from one end of the loop and leaves from the other end.



Now apply Fleming's left hand rule to each side of the coil as shown in the fig. We can see the PQ side of the loop force acts upward, while on the RS side of the loop force acts downward. It is because the direction of the current through the two sides of the loop facing the two poles is at right angles to the field but opposite to each other. The two forces which are equal in magnitude but opposite in direction form a couple. The resulting torque due to this couple rotates the loop, and the magnitude of the torque acting on the loop is proportional to the magnitude of the current passing through the loop. If we increase the number of loops, the turning effect is greatly increased. This is the principle involved in electric motors.

## **15.4 D.C Motor**

**Q.7** What is electric motor? Explain its construction and working principle.

### **Electric Motor**

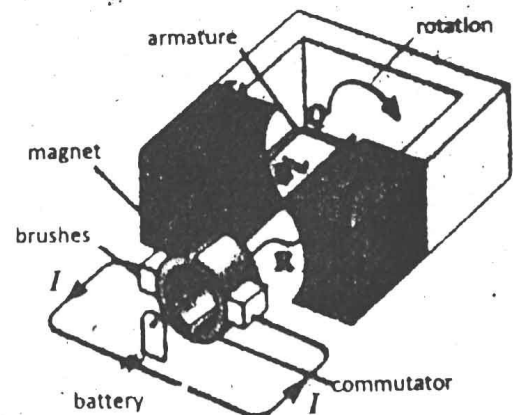
"It is an electrical apparatus (device) that converts electrical energy into rotational kinetic energy".

### **Working Principles**

When a current-carrying coil is placed in magnetic field, it experiences a couple due to which the coil begins to rotate. A D.C motor operates on this principle.

### **Construction of D.C Motor**

D.C motor consists of a rectangular coil PQSR mounted on a shaft or axle. Coil is placed in a field of permanent magnet or in a field which is produced by an electromagnet, called a field of coil. There are two carbon brushes which are usually pieces of graphite. These brushes are made the contact with copper ring. This ring is split into two halves, called a split ring commutators show in fig.1.



(Fig 1.)

## Working of D.C Motor

When the coil of the motor is connected to the battery, the current starts flowing through it. The simple coil placed in a magnet cannot rotate more than  $90^\circ$ . The forces push the PQ side of the coil up and the RS side of the loop down until the loop reaches the vertical position. In this situation, plane of the loop is perpendicular to the magnetic field and the net force on the coil is zero. So the loop will not continue to turn because of the forces are still up and down and balanced.

### i. Function of Commutator

The coil can be rotate continuously by reversing the direction of the current just as the coil reaches its vertical position. This reversal of current will allow the coil to rotate continuously. To reverse direction of current, the connection to coil is made through an arrangement of brushes and a ring that is split into two halves, called a split ring commutator. Brushes, which are usually pieces of graphite, make contact with the commutator and allow current to flow into the loop. As the loop rotates, so does the commutator. The split ring is arranged so that each half of the commutator changes brushes just as the coil reaches the vertical position. Changing brushes reverse the current in the loop.

As a result, the direction of the force on each side of the coil is reversed and it continues to rotate. This process repeats at each half-turn, causing coil to rotate in the magnetic field continuously. The result is an electric motor, which is an apparatus that converts electric energy into rotational kinetic energy.

In a practical electric motor the coil, called a armature, is made of many loops mounted on a shaft or axle. The magnetic field is produced either by permanent magnets or by an electromagnet, called a field coil. The torque on the armature, and as a result, the speed of the motor, is controlled by varying the current through the motor.

### Factors effecting on force

The total force acting on the armature can be increased by

- Increasing the number of turns on the coil
- Increasing the current in the coil
- Increasing the strength of the magnetic field
- Increasing the area of the coil

## 15.5 Electromagnetic Induction

Q.8 Describe by an experiment to demonstrate that changing magnetic field can induced e.m.f in a circuit?

OR

What is electromagnetic induction? Explain with experiment that a changing magnetic field can induce an e.m.f in circuit?

### Electromagnetic Induction

“The process of generating an induce current in a circuit by changing the number of magnetic lines of force passing through it is called electromagnetic induction”.

## Explanation

Hans Christian oersted and Ampere discovered that an electric current through a conductor produces a magnetic field around it. Michael Faraday described that change of magnetic field in any circuit must produce an electric current in it.

Honery also showed that a changing magnetic field could produce electric current.

## Magnetic flux

The number of magnetic lines of force passing through any surface is known as strength of magnetic field (magnetic flux).

## How e.m.f. is induce in the coil?

Strength of the magnetic field is maximum when the surface is held perpendicular to the magnetic lines of force.

Strength of the field is minimum when surface is held parallel to the magnetic lines of force.

## Magnetic field of a bar magnet through coil

In case of a bar magnet the lines of force are emerging from north pole of a magnet. If we place a coil in the magnetic field of a bar magnet, some of the magnetic lines of force will pass through it.

## When the coil is far away from the magnet

If the coil is far away from the magnet, only a few lines of force will pass through the coil.as shown in fig a.

## When the coil is closed to the magnet

If the coil is close to the magnet, a large number of lines of force will pass through it, In this way we can change the number of magnetic lines of force through a coil by moving it in the magnetic field. This change in the number of magnetic field lines will induce and e.m.f in the coil as shown in fig b.

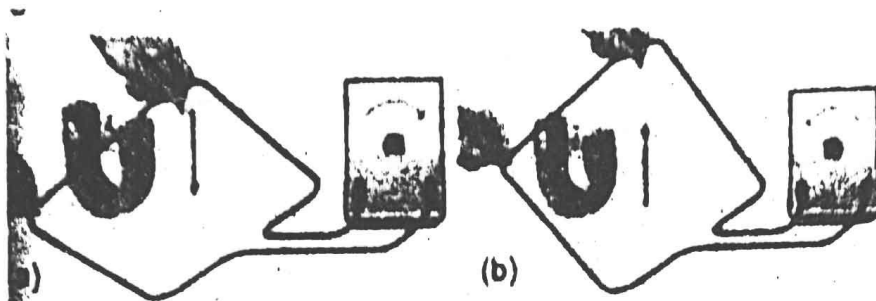


**Note:** This is the basic principle of production of electricity and working of transformer.

## Experiment:

Take a rectangular loop of wire and connect its two ends with a galvanometer. Now hold the wire stationary or move it parallel to the magnetic field of a strong u-shaped magnet. Galvanometer shows no deflection and hence there is no current. Now move the wire downward through the field, current is induced in one direction as shown by the deflection of the galvanometer (Fig. 15.3-b). Now move the wire upward though the field, current is induced in the opposite direction.

It implies that an electric current is generated in a wire only when the wire cuts magnetic field lines. This induced current is generated by induced e.m.f. in the circuit. Faraday found that to generate current, either the conductor must move thorough a magnetic field or a magnetic field must pass through the conductor.



### Conclusion:

It is concluded that an electric current is generated in a wire only when the wire cuts magnetic field lines. This induced current is generated by the induced e.m.f in the circuit.

**Q. 9 States Faraday's law of electromagnetic induction. Explain with experiment how current is induced in a solenoid? Write factors.**

### Faraday's law of electromagnetic induction

"The value of induced e.m.f in a circuit is directly proportional to the rate of change of number of magnetic lines of force through it."

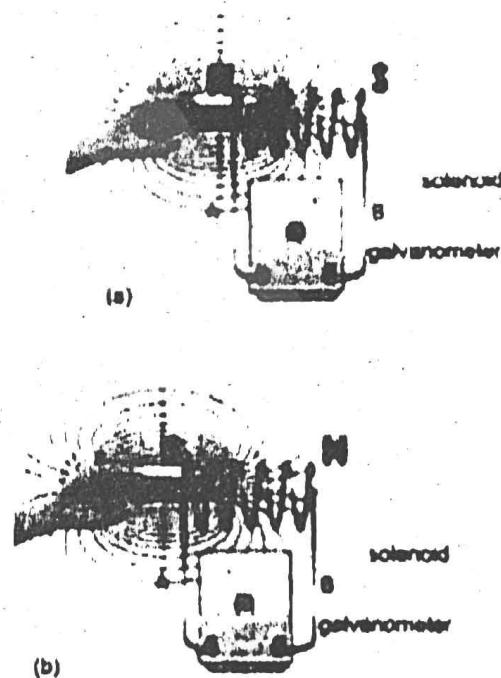
### Induce current in solenoid

Faraday performed experiments in which a current is induced by moving a magnet into the solenoid or out of the solenoid.

When the magnet is stationary, no current is induced. When the magnet is moved towards the solenoid, the needle of the galvanometer deflects towards the right, indicating that current is being induced in the solenoid. As shown in fig (a).

When the magnet is pulled away from the solenoid, the galvanometer deflects towards the left, indicating that the induced current in the solenoid is in the opposite direction as

shown in fig.(b)



### Conclusion

From the experiments it is concluded that an e.m.f is induced in the coil when there is a relative motion between the coil and the magnet.

### Electromagnetic Induction

The phenomenon in which an e.m.f is induced due to the relative motion between the coil and the magnet is called electromagnetic induction.

### Factors affecting induced e.m.f

The magnitude of induced e.m.f in a circuit depends on the following factors:

- Speed of relative motion of coil and magnet
- Number of turns of coil.
- Amount of current passing through coil.

## 15.6 Direction of Induced e.m.f ----- Lenz's Law

**Q.10** State Lenz's law? Describe the direction of an induced e.m.f in a circuit. How does this phenomenon relate to conservation of energy?

### Lenze's Law

"The direction of an induced current in a circuit is always such that it opposes the cause that produces it".

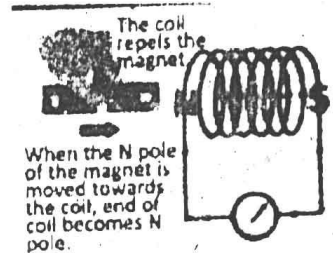
### Direction of induced e.m.f

Lenz devised a rule to find out the direction of a current induced in a circuit.

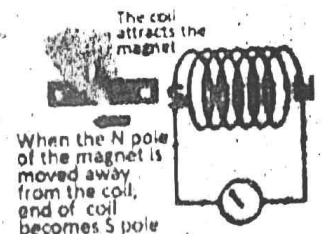
### Experiment

If we bring a north pole of a bar magnet near a solenoid, an e.m.f will be induced in the solenoid by electromagnetic induction.

The direction of the induced current in the solenoid by the induced e.m.f will be such that it will repel the north pole of the magnet. This is only possible if the right end of the solenoid becomes North Pole. Hence according to right hand grip rule the direction of the induced current in the solenoid will be counter clockwise.



Similarly, when we move the north pole of the magnet away from the solenoid the direction of the induced current will be clockwise.



### Induce e.m.f and conservation of energy

If we apply the law of conservation of energy to electromagnetic induction, we realize that the electrical energy induced in a conductor appears from the kinetic energy of the moving magnet. We do some work on the magnet to bring it close to the solenoid. This work done consequently appears as electrical energy in the conductor. Thus mechanical energy of our hand used to push the magnet towards or away from the coil results into electrical energy. Hence Lenz law is a manifestation of the law of conservation of energy.

## 15.7 A.C Generator

**Q.1.** What is A.C. Generator? How is it constructed? How current is induced in it?

### A.C Generator

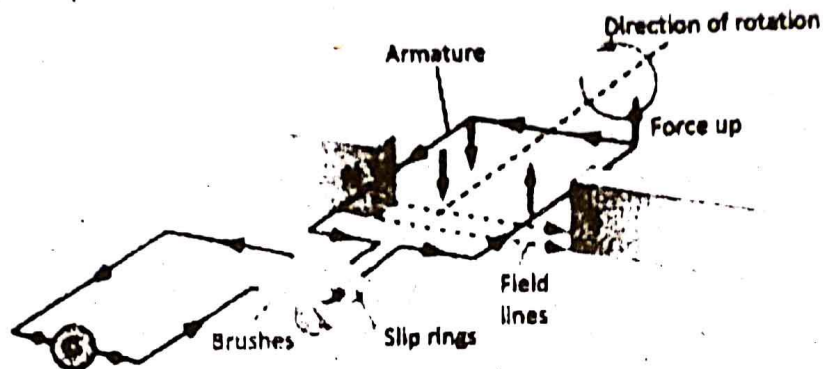
"A device which generates an alternating e.m.f is called A.C. generator". A generator converts mechanical energy into electrical energy.

### Principle of working

An A.C generator consists of a coil and magnet. When this coil is made to rotate in a magnetic field, the magnetic flux through it continuously changes due to which an alternating voltage is induced in it. Thus A.C. generator converts mechanical energy into electrical energy.

### Construction and Working

A simple generator consists of a rectangular coil, which is rotated between the poles of a permanent magnet. Both the ends of the coil are soldered to the two slip rings fixed on the arm of the coil as shown in figure.

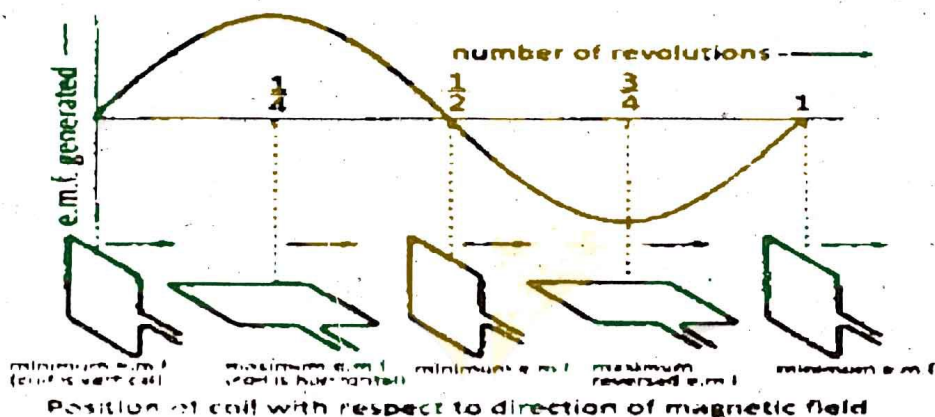


Two carbon brushes are kept in contact with these slip rings with the help of two springs. Current is drawn from the coil through these brushes.

The armature is arranged so that it can rotate freely in the magnetic field. As the armature turns, the wire loops cut through the magnetic field lines and induces an e.m.f. The e.m.f. developed by the generator depends on the length of the wire rotating in the field. Increasing the number of loops in the armature increases the wire length, thereby increasing the induced e.m.f.

### Current from a generator

When a generator is connected in a closed circuit, the induced e.m.f generates an electric current. As the loop rotates the strength and the direction of the current changes as shown in fig.



The current is minimum when the plane of the loop is parallel to the magnetic field; that is, when the loop is in the vertical position. As the loop rotates from the vertical to the horizontal position, it cuts through large magnetic field lines per unit of time, thus the e.m.f. and the current increase. When the loop is perpendicular to the field, so the e.m.f. and the current reaches their maximum values. As the loop continues to turn, the segment that was moving up begins to move down and reverses the direction of the e.m.f. and the current in the loop. This change in direction takes place each time the loop turns through  $180^\circ$ . Thus, the e.m.f. and the current change smoothly from zero to some maximum values and back to zero during each half-turn of the loop.

**Q.12** What is meant by mutual induction? Name and define SI unit of mutual inductance.

### Mutual Induction:

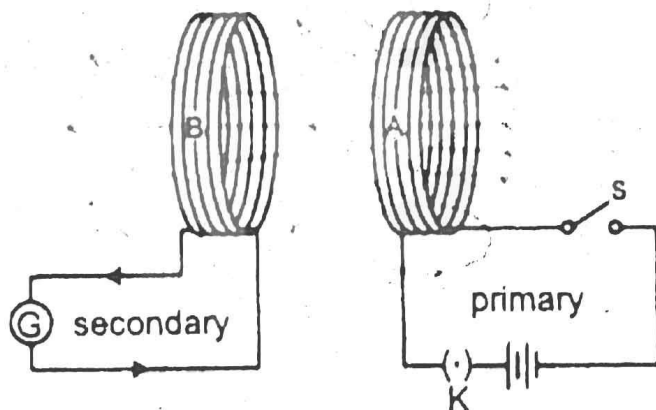
“The phenomenon of production of induced current in one coil due to change of current in a neighboring coil is called mutual induction”.

### Circuit:

Suppose a system of two coils A and B placed close to each other. The coil A is connected to a battery and a switch, while a sensitive galvanometer is connected to the coil B. We observe that as soon as the switch of the coil A is closed, the galvanometer shows a momentary deflection. Similarly when the switch is opened the galvanometer again shows a deflection but this time its direction is opposite to that of the previous case.

### Explanation

We can explain these observations using Faraday's law of electromagnetic induction. When the switch of coil A is closed, a current is induced in the coil due to which magnetic field is developed across the coil. Some of the magnetic lines of force of this field start passing through the coil B. Since current is changing in the coil A, hence number of magnetic lines of force across the coil B also changes due to which a current is induced in the coil B in accordance with Faraday's law. When current in the coil A becomes steady, number of magnetic lines of force across the coil A also becomes constant. Therefore there is no more change in number of magnetic lines of force through the coil B due to which induced current in B reduces to zero.



Similarly when the switch of the coil A is opened, the flow of current through it stops and in few moments its magnetic field reaches to zero. The number of magnetic lines of force through the coil B decreases to zero due to which current is again induced in it but in opposite direction to that in the previous case.

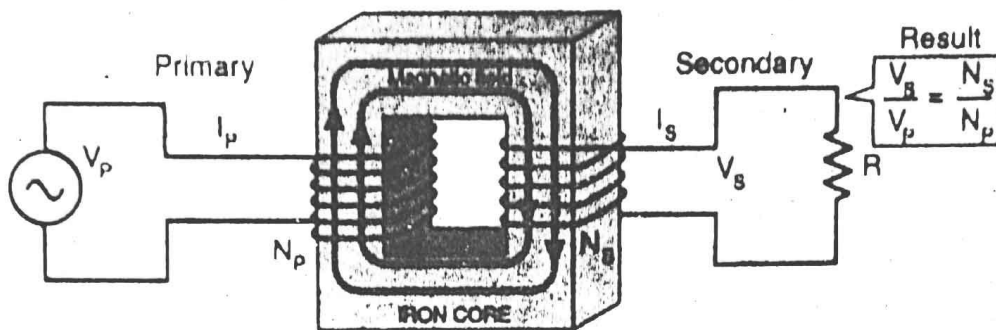
**Q.13 What is transformer? Explain its construction, working principle and types.**

### Transformer

“Transformer is an electrical device which is used to increase or decrease the value of alternating voltage”.

### Construction

A transformer has two coils, electrically insulated from each other, but wound around the same iron core. One coil is called the primary coil. The other coil is called the secondary coil. Number of turns on the primary and the secondary coils are represented by  $N_p$  and  $N_s$  respectively.



## Working Principle

When the primary coil is connected to a source of A.C, voltage, the changing current creates a changing magnetic field, which is carried through the core to the secondary coil. In the secondary coil, the changing field induces a varying e.m.f. This effect is called mutual inductance.

## Voltages and number of turns of coil

The e.m.f induced in the secondary coil, called the secondary voltage  $V$  is proportional to the primary voltage  $V_p$ . The secondary voltage also depends on the ratio of the number of turns on the secondary coil to the number of turns on the primary coil, as shown by the following expressions,

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

## Types

There are two types of transformer

- i. Step – up transformer
- ii. Step-down transformer

### i. Step – up transformer:

If  $N_s > N_p$ , then secondary voltage is larger than the primary voltage, then the transformer is called a step-up transformer.

### ii. Step-down transformer:

If  $N_p > N_s$  then the secondary voltage is smaller than the primary voltage, then transformer is called a step-down transformer.

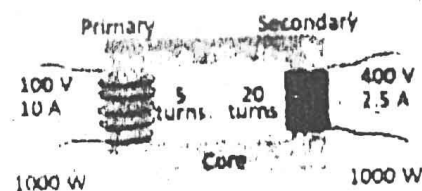


Fig (1.b) Step Up Transformer

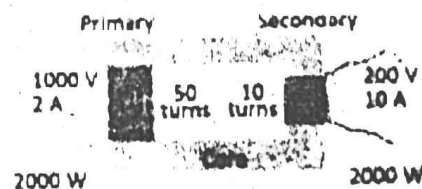


Fig (1.c) Step Down Transformer

## An Ideal Transformer

In an ideal transformer, the electric power delivered to the secondary circuit equals the power supplied to the primary circuit. An ideal transformer dissipates not power itself and for such a transformer we can write:

$$P_p = P_s$$

$$V_p I_p = V_s I_s$$

## Uses of transformer

Transformer are used to increase or decrease AC voltages. Usage of transformers is common because they change voltages with relatively little loss of energy. In fact, many of the devices in our homes, such as game systems, printers and stereos have transformers in side their casings or as part of their connecting cords.

**Q.14 How high voltage transmission reach from power station to consumer?**

OR

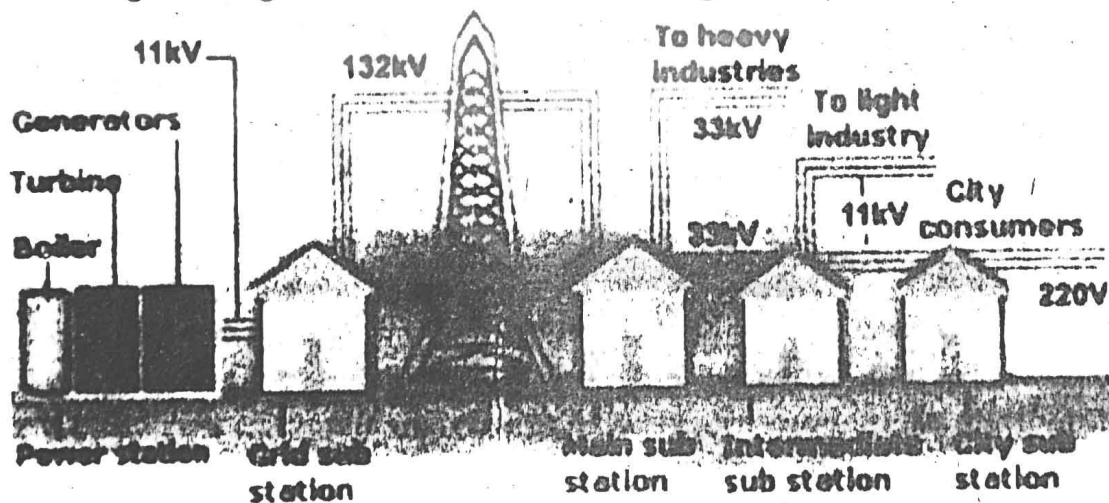
**Why alternating voltage is stepped up at the generating station?**

**Why heat dissipates in transmission?**

Electric power is usually generated at places which are far from the places where it is consumed. The power is transmitted over long distances at high voltage to minimize the loss of energy in the form of heat during transmission. As heat dissipated in the transmission cable of resistance  $R$  is  $I^2Rt$ . Hence by reducing the current through the cable, power loss in the form of heat dissipation can also be reduced. So the alternating voltage is stepped up at the generating station.

**How voltages are stepped down?**

High voltages are transmitted to the main sub-station. This voltage is stepped down and is transmitted to the switching transformer station or the city sub-station. At the city sub-station it is further stepped down to 20V and supplied to the consumer. A schematic diagram of height voltage transmission is shown in fig.



**Main power is supplied as alternating current.**

Transformers play an essential part in power distribution. Transformer work only with AC. This is one reason why mains power is supplied as alternating current.

**Q.15 What is an electromagnetic? Explain its uses giving one practical example**

**Electromagnet**

“Magnetic effect of current is called electromagnet”.

**Application:**

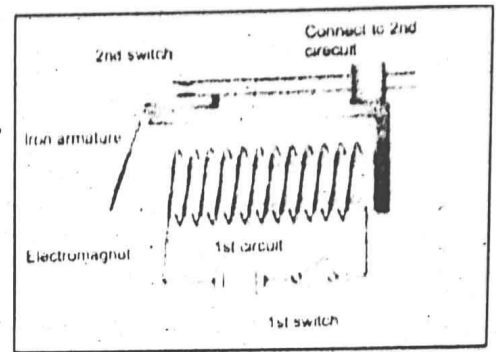
This affect is used in many devices like relay, electric bell etc. soft iron gains and loses magnetism easily in such devices.

## Relay Circuit

"A relay is an electrical switch that opens and closes under the control of another electrical circuit". The relay is used to control a large current with the help of small current as shown in fig.

### Working principle of relay circuit

The 1<sup>st</sup> circuit (input circuit) supplies current to the electromagnet. The electromagnet is magnetized and attracts one end of the iron armature. The armature is then closes the contacts (2<sup>nd</sup> switch) and allows current to the electromagnet stops. Now electromagnet loses its magnetism and the 2<sup>nd</sup> switch is opened. Thus the flow of current stops in the 2<sup>nd</sup> circuit:



## NUMERICAL PROBLEMS

- 15.1 A transformer is needed to convert a mains 240 V supply into a 12V supply. If there are 2000 turns on the primary coil, then find the number of turns on the secondary coil.

**Solution:**

**Given Data:**

$$V_p = 240 \text{ V}$$

$$V_s = 12 \text{ V}$$

$$N_p = 2000$$

**Required:**  $N_s = ?$

**Formula:**

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$N_s = \frac{V_s \times N_p}{V_p} = \frac{12 \times 2000}{240} = 100$$

- 15.2 A step-up transformer has a turn ratios of 1:100. An alternating supply of 20V is connected across the primary coil. What is secondary voltage?

**Solution:**

**Given Data:**

$$N_p : N_s = 1:100$$

$$V_p = 20 \text{ V}$$

**Required :**

$$V_s = ?$$

**Formula**

$$\frac{N_p}{N_s} = \frac{1}{100}$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{N_s \times V_p}{N_p} = \frac{100}{1} \times 20$$

$$V_s = 2000 \text{ Volt} \quad \text{Ans}$$

- 15.3 A step – down transformer has a turns ratio of 1:100. An ac voltage of amplitude 170V is applied to the primary. If the current in the primary is 10 mA, what is the current in the secondary?

Solution:

Given Data:

$$N_s : N_p = 1:100$$

$$\frac{N_s}{N_p} = \frac{1}{100}$$

$$V_p = 170\text{V}$$

$$I_p = 10\text{mA} = 1 \times 10^{-2} \text{ A}$$

Required

$$I_s = ?$$

Formula

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{N_s}{N_p} \times V_p$$

$$= \frac{1}{100} \times 170 = 1.7\text{V}$$

For an ideal transformer

Power of primary = Power of secondary

$$P_p = P_s$$

$$I_p V_p = I_s V_s$$

$$\frac{I_p V_p}{V_s} = I_s$$

$$\frac{1 \times 10^{-2} \times 170}{1.7} = I_s$$

$$0.1 \text{ A} = I_s \Rightarrow I_s = 0.1\text{A Ans}$$

- 15.4 A transformer, designed to convert the voltage from 240 V a.c. mains to 12V, has 4000 turns on the primary coil. How many turns should be on the secondary coil? If the transformer were 100% efficient, what current would flow through the primary coil when the current in the secondary coil was 0.4A?

Solution:

Given Data:

$$V_p = 240\text{V}$$

$$V_s = 12\text{V}$$

$$N_p = 4000$$

Required:  $N_s = ?$

Formula:

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$N_s = \frac{V_s \times N_p}{V_p} = \frac{12 \times 4000}{240}$$

$$N_s = 200 \text{ Ans}$$

$$I_p = ?$$

$$I_s = 0.4 \text{ A}$$

$$P_p = P_s$$

$$I_p V_p = I_s V_s$$

$$I_p = \frac{I_s V_s}{V_p} = \frac{0.4 \times 12}{240}$$

$$I_p = 0.02 \text{ A}$$

**15.5** A power station generates 500 MW of electrical power which is fed to a transmission line. What current would flow in the transmission line if the input voltage is 250 kV?

**Solution:**

**Given Data:**

$$V = 250 \times 10^3 \text{ V}$$

$$\text{Power} = P = 500 \times 10^6 \text{ W}$$

**Required:**  $I = ?$

**Formula:**  $P = IV$

$$\frac{P}{V} = I$$

$$\frac{500 \times 10^6}{250 \times 10^3} = I$$

$$2 \times 10^3 \text{ A} = I \Rightarrow I = 2 \text{ KA Ans}$$

**15.6** The diagram shows a wind turbine which a 150 kW generator with an output voltage of 1000V. The voltage is increased by transformer  $T_1$  to 10 000 V for transmission to a town 5 km away through power lines with a total resistance of  $2\Omega$ . Another transformer,  $T_2$ , at the town reduces the voltage to 250V. Assume that the transformers are 'Ideal' when the system is running at full power: (Figure from the textbook page 143)

**Solution:**

**Given Data:**

$$\text{Power} = P = 150 \text{ kW}$$

$$P = 150 \times 10^3 \text{ W}$$

At  $T_1$   $V_p = 10000 \text{ V}$

$$R = 2\Omega$$

At  $T_2$   $V_s = 250$