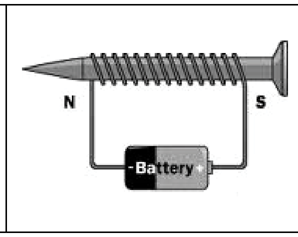
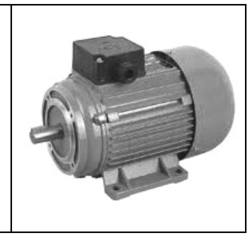
Chapter twelve

MAGNETIC EFFECT OF CURRENT

[As the current has magnetic effect, the magnet has the electric effect also. Many electric tools have been made by using these two effects. These tools have solved many problems of us, have brought out various comforts and have developed the standard of our life. In this chapter, we shall discus about the functions and uses of electromagnet, electromagnetic induction, induced current and induced electric power, electric motor, generator, transformer etc.]

By the end of this chapter we will be able to -

1) Explain magnetic effect of electric current

2) Explain electromagnetic induction.

3) Explain induced current and induced electric power

4) Explain the main principles of motor and generator.

5) Explain the main principles of transformer.

6) Explain the functions of step-up and step-down transformer.

7) Praise the various uses and contributions of current in our life.

12.1. Magnetic Effect of Current.

[Figure 12.1]

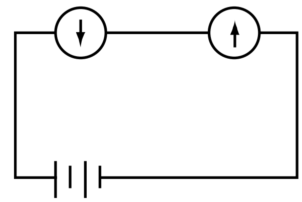


Figure: 12.1

Oersted invented the magnetic effect of current.

Do yourself. Make a circuit like the picture aside. Place a compass under the wire as if it faced to North-South. Now let the switch on. What is happening to the needle of compass?

We see that the needle is moving to one side after switching on the current on circuit. If we alter the electric connection, the needle of the compass will move the other side. From this effect, we can understand that a magnetic field is produced when a current flows through a wire.

12.2. Magnetic effect of current carrying conductor.

Experiment: Make an electric circuit by putting a conducting wire into hard paper. Keep the paper horizontal and spread some dust of iron on the paper. Now connect the current through circuit or conductor and strike slowly with your finger on hard paper.

It is seen that the dust of the iron will get them arranged like the figure 12.2.If you draw a dot using a small compass and added to it, you will find the same. If you change the direction of the current, the needle of the compass will direct the opposite side which will remain facing to the opposite direction. So the flow of electricity produced magnetic field around the conductor also.

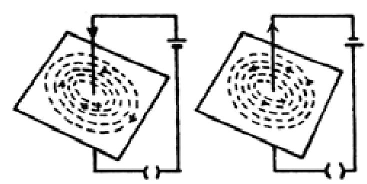


Figure: 12.2

12.3. Solenoid

We can increase the magnetic field intensity by coiling the above mentioned wire (see the figure 12.3).Due to flow of the current through the coil, most of the lines of the force will be concentrated in the centre of the coil. The magnetic field will be look alike the magnetic field of bar magnet. This type of coil is called Solenoid. If we insert any iron rod through it, the iron rod will be turned into magnet. If we stop the current, it will not remain magnet. If the direction of current is changed, the pole of magnet will be changed. Through this process, the iron is turned into magnet which is called electromagnet.

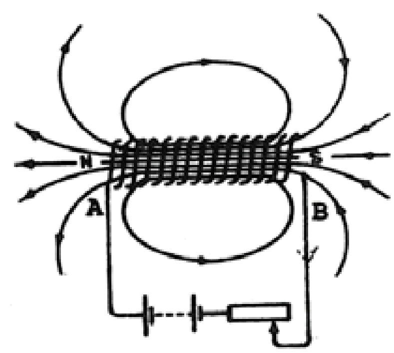


Figure: 12.3

12.4. Electromagnet.

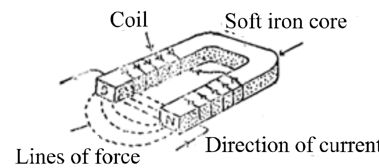


Figure: 12.3 a

If we insert any iron rod through the solenoid, we can get more powerful magnetic field that the solenoid has. During the flow of current, it is converted into more powerful magnet. This is called electromagnet. The intensity of this magnet can be increased -

-by increasing the flow of current

- by increasing the number of coil of the solenoid

- by bending the iron rod in the form of alphabet U and keeping two ends of U as close as possible .

Now examine with the help of your teacher, how much paper clips or alpines are attracted by the magnetic iron rod for the flow of various current or for increasing the numbers of turn of the solenoid coil. Electromagnet is used to make the electric bell, to carry the heavy load up and down made by steel or iron or to make crane which is used to remove the rubbish. This magnet is used to remove the dust of iron from the eye. Besides, this magnet is also used as earpiece of telephone and lock of magnetic door.

12.5. Electromagnetic Induction

Many scientists tried to invent electric current from the magnetic field when Oerested invented electromagnetic effect. Among the scientists who worked on this subject, Michael Faraday of England, Joseph Henry of America and H.F.E. Lenz of Russia achieved success individually. But at first Michael Faraday published the result of his experiments in 1831.He shows that a variable magnetic field can produce electromotive force which creats electric current through a closed circuit. The phenomena to produce electric current in a closed circuit by variable magnetic field is called electromagnetic induction. Faraday made two experiments to invent electromagnetic induction. You can also do the experiments.

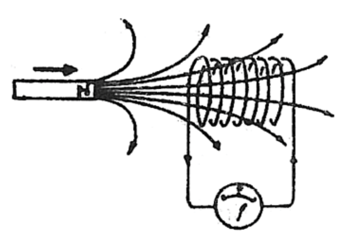


Figure: 12.4

Experiment-1: An insulated wire is wound over a card board cylinder in the form of a coil. Connect a galvanometer with two sides of this coil to understand the presence of electric current. You have to open the non conducting cover during the time of connection. Now insert the south pole of a magnet bar inside the coil. What's happening? Deflection of the galvanometer is taking place. It means the current is flowing through the coil. Now remove the magnet. What's happening? The deflection of galvanometer will be the opposite of that time when magnet was entered to the coil. If the magnet is kept stationary now, the galvanometer will show the deflections when the coil is moved towards or away from the magnet. If the coil is moved away from the magnet, we can see the deflection at the opposite side.

Experiment-2: For this experiment two closed coil made of insulated copper wire to be taken. A galvanometer is to be connected with the first coil. In the second coil, a battery, a rheostat and a tapping key are to be connected [12.5a]. The coil which is connected to the sources of emf is called the primary coil and which is connected to the galvanometer is called secondary coil. When the current is switched on in the primary coil, the deflection of galvanometer will be seen for a moment in the secondary coil [12.5b]. Again the deflection of galvanometer will be seen at the time of disconnecting the electric current but the deflection will be opposite to the direction of former.

If the current is continuously varied in the primary coil, the galvanometer will show the deflections. In this case, the direction in which the galvanometer will deflect during rise of current is opposite to that during fall of current. Keeping the current fixed in the primary coil a variation of the distance between the two coils will produce a momentary deflection of the galvanometer. The direction of deflection due to increase of distance is opposite to that due to reduction in distance between the coils.

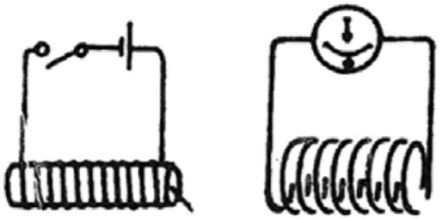


Figure: 12.5 a

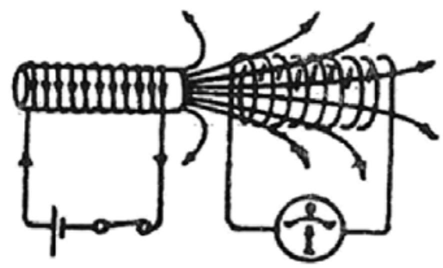


Figure: 12.5 b

12.6. Induced current and induced voltage

From these two experiments, it is observed that the deflection of the galvanometer proves the existence of an emf. So if we move a magnet towards or away from the the coil or if we move a coil towards or away from a magnet, the electric current will be produced there. This is called electromagnetic induction. If we move a coil towards or away from electric circuit or electric wire, the electric current will be produced there also. This is also called electromagnetic induction. So we can say that the process of creating electric current through the change of the distance of the circuit which can create voltage temporarily to another closed circuit is called electromagnetic induction. This voltage is known as induced voltage and the current is known as induced current. If there have no relative motion between magnet and coil, the deflection will not be seen. The more will be the relative motion, the more will be the deflection. So it is said that how long the relative motion will last between magnet and coil, induced current will be durable for that period. If the pole of magnet is altered, the side of induced current will be altered. Induced current and induced voltage can be created in the following way-

-by increasing the polar power of magnet

-by moving the magnet quickly

-by increasing the number of coil.

12.7. Effect of magnet on current carrying wire

We know that current carrying wire produced a magnetic field of its own. There happens action and reaction between magnetic field exsisting inside the opposite pole of a powerful magnet and the magnetic field of current carrying wire.

Your teacher can show you the action and reaction. You can do it yourself or with the help of your teacher.

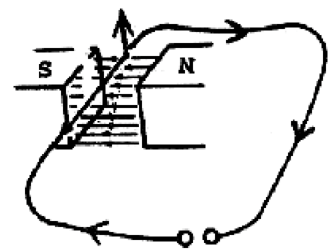


Figure: 12.6

Put an electric wire between the two poles of a powerful magnet like the picture. Let the electricity flow through this wire. You will see that it will jump to the up. It is understood that a force is working on that. From where does this come?

If you look at the picture 12.7(a), you will see the lines of force between the poles of the magnet. The magnetic field created by electric current has also been shown. The lines of force created from the combination of two fields has also been shown in the picture 12.7(b). The lines of force are more in the down than that of the up of the wire. The reason is that both the fields are working towards the same direction. [Again see the picture 12.7(a)].The fields above the wire are opposing each-other, some lines of force are rejecting one-another. As a result the number of lines is less there. As the line wants to keep themselves very tight to each other (like elastic rubber), they apply upward force on the wire.

Figure: 12.7 a

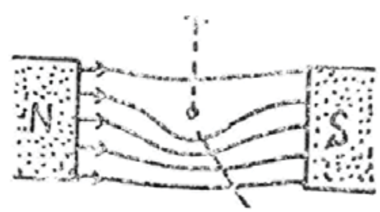


Figure: 12.7 b

If the wire remains free, it moves upward. If the direction of electric current is changed to opposite, the wire goes to downward.

12.8. Electric motor:

Suppose a loop or coil of wire like picture 12.8(a) is used between the two poles of magnet .As the loop has returned to the opposite direction from A to B, the opposite electricity will flow between the two half of the loop or coil. So, the wire will go to the upward in A and downward in B. For this the wire moves in clockwise. At the vertical position of the wire like figure 12.8(b) no force will act on it. For this it will be stopped. To keep the coil rotating, we will use a device named commutator. It consists of two equal segments made of copper (see figure12.9). Each segment is connected to A and B respectively. The outer part of the separated segment makes a contact with the electric source through carbon brush. The segment moves with the coil and when its' gap between two side remains opposite to the carbon brush, no current will flow. But despite this fact, the movement will remain continue for its inertia and it will get force newly when it will come to the contact of the moving brush. Thus the rotation will remain continue.

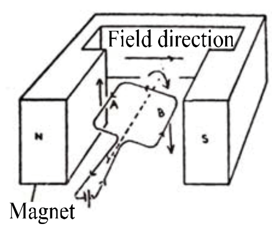


Figure:12.8 a,

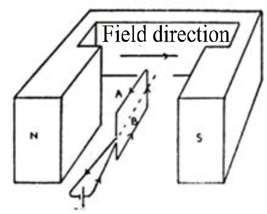


Figure: 12.8 b

It is noticeable that though A and B have changed their position, the comutator current will enter from the right side of the loop like before and will come out from the left, (see the figure 12.9) and the coil will rotate clockwise. This is the principle of electric motor. Electric motor converted the electric energy into mechanical energy. To increase the speed and power of it, the intensity pf the magnetic field will have to increase.

The intensity of the of the magnetic field can be increased in many ways. These are –

-By increasing the electric current.

-By increasing the number of turn in the loop or coil.

-By using powerful magnet.

-By increasing length and width of the coil.

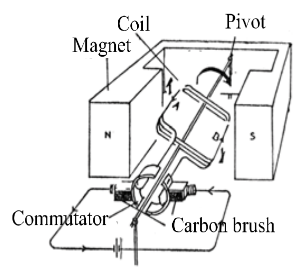


Figure: 12.9

The electric motor that we use also works in the same way. But extra parts will have to add to increase the power and flexibility of the rotation. Many coils or loops are made instead of only one coil or loop and they are arranged neatly around the central axis or orbit. Each of these wires is connected to its commutator. It helps to move continuously and easily.

Each of coils is made of hundred scrape on the soft rod of iron (which is called armature).For this, the armature is magnetized during current flow and increase the intensity of the magnetic field. (In figure 12.10, two broken lines of three armatures have been shown).The rotation can be increased by bending two sides of the magnet.

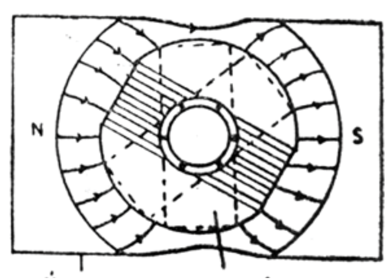


Figure: 12.10

Uses: Electric motor is used to electric fan, pump, rolling mill etc.

12.9. Generator

The electric machine in which mechanical energy is converted into electrical energy is called generator. The basic principals of this machine are established on the basis of electromagnetic induction. Generator can be of two kinds. Such as

1) AC generator

2) DC generator

1. AC generator: The structure and functions of it are being discussed in the following as it is widely used:

Structure : There is a field-magnet NS in it. There is rectangular coil of wire in the middle of the magnet on the soft sheet of iron (AB). The iron sheet is called armature. The armature is rotated at the uniform speed in mechanical way on the middle of the magnet. The two sides of the rectangular coil are connected to two slip rings.

The two slip rings can rotate to same orbit of armature. The two carbon brushes are set in such a way that they touch the two slip rings when the armature is being rotated. The resistance R of external circuit is connected to the brushes.

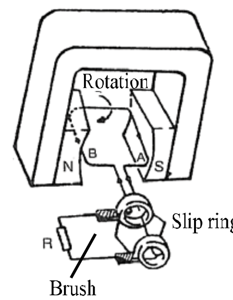


Figure: 12.11

Functions: When the armature undergoes rotation, the armature coil intersect the lines of force of the magnetic field and the electromotive force is induced in the coil according to electromagnetic induction. As the two sides of the coil are connected to the external circuit a alternating current is develop in the circuit. The magnitude of induced current mainly depends on the intensity and speed of the rotation of the magnetic field. During one complete rotation of the coil the direction of the induced curent is changed once. Thus the alternating current is produced from the mechanical energy.

12.10. Transformer:

The electrical device through which the high alternating potential can be changed into low alternating potential and low potential into high potential is called transformer. This device is made on the basis electromagnetic induction. There are two kinds of transformers.

These are -

1. Step up Transformer: The transformer which converts an electric current of greater strength at a low voltage into an electric current of weaker value at high voltage is known as step up transformer.

2. Step down Transformer: The transformer which changes the high potential less electric current into low potential much electric current is step down transformer.

Construction : A transformer is made on a soft iron core in rectangular form in which two coils of insulated copper wire are inserted in its two opposite limbs (Fig 12.12) The coil in which an a.c. or emf is applied is known as primary coil. The coil in which an a.c or emf is induced is known as secondary coil. In step up transformer the number of turns in the secondary coil is greater than that in the primary coil. In step down transformer the number of turns in the secondary is less than that in the primary coil.

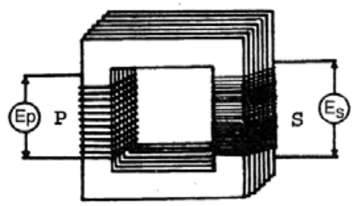


Figure: 12.12 a

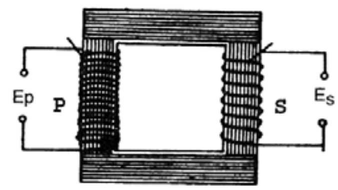


Figure: 12.12 b

Let an a.c emf E_p be applicd to a primary coil n_p turns. A current I_p flows in this coil. This curent by magnetising the core produces magnetic lines of foorce that ultimately produces induced emf in the primary coil. If there is no diminution of the magnctic lines same number of magnetic lines remain associated with each turn of the sccondary coil. Consequently an emf is induced in the secondary coil. If the number of turns in the secondary coil be n_s and the induced emf be E_s,

We have: $\frac{E_p}{E_s} = \frac{n_p}{n_s}$ 12.1

That is to say that the induced emf in the coil is proportional to the number of turns.

For a step up transformer $n_s > n_p$ and for a step down transformer $n_s < n_p$. If no energy is dissipated in the transformer core, the energy input to the primary coil is wholly transferred to the secondary coil.

Therefore, voltage of the primary coil x current of primary coil =

Voltage of secondary coil x current of secondary coil

i.c. $E_p I_p = E_s I_s$

Therefore, $\frac{E_p}{E_s} = \frac{I_s}{I_p}$ 12.2

This equation suggests that the rate at which a transformer reduces the voltage is exactly equal to the rate at which it increase the current so that the total power remains constant.

Therefore, a transformer transforms both the voltage and the current.

For transmission of electric power over long distances step up transformer is used. Step down transformer is used for domestic power supply such as radio, television, tape recorder, VCR, VCP, electric watch etc.

Mathematical example: 12.1: In a transformer, the voltage of primary coil is 10V and current 6A.If the voltage of secondary coil is 20 V; calculate the current of secondary coil.

We know:

$$\frac{Ep}{Es} = \frac{Is}{Ip}$$

Or, Is= $\frac{Ep}{Es} \times Ip = \frac{10V \times 6A}{20V} = 3A$

Here,
the voltage primary coil, Ep=10V
the voltage of secondary coil, Es=20V
The current of primary coil Ep=6A
The current of secondary coil, Is=?

Ans: 3A

Mathematical example: 12.2.The number of turns of primary coil in a transformer is 50, voltage 210V. If the number of turns in the secondary coil is 100, what will be the voltage?

We know:

$$\frac{E_p}{E_s} = \frac{n_p}{n_s}$$

$$E_s = \frac{n_s}{n_p} \times E_p$$

$$= \frac{100}{50} \times 210V = 420V$$

Here,
The number of round of primary coil, n_p=50 The
voltage of primary coil, Ep=210V
The number of round of secondary coil, ns=100
the voltage of secondary coil, Es=?

Ans: 420V

Mathematical Example: 12.3.The number of turns of primary coil in a transformer is 18 and the number of turns of secondary coil is 90. If the electric current of primary coil is 7A, what will be the electric current of secondary coil?

We know,

$$\frac{I_s}{I_p} = \frac{n_p}{n_s}$$

$$I_s = \frac{n_p}{n_s} \times I_p$$

$$\therefore I_s = \frac{18}{90} \times 7A = \frac{7}{5} A = 1.4 A$$

Ans: 1.4A

Exercise

A. Multiple choice questions:

Tick (√) the correct answer

1. What will happen of magnetic field if electric –current flows through a solenoid made by insulated wire wound over a cylinder.

   a) Will be condensed and weak　　b) Will be condensed and strong

   c) Will be less condensed and weak　　d) Will be less condensed but strong

2. In which functions, electromagnetic induction is used?

   A) Transistor　　(b) Motor

   (c) Amplifier　　(d) Transformer

3. In which process, electromotive force is produced-

   i) If any magnet is kept motionless in a wire coil

   ii) If any wire coil is rotated in a magnetic field

   iii) If any magnet is rotated around a motionless wire coil

Which one is correct of the following?

   (a) i　　(b) ii

   (c) i and ii　　(d) ii and iii

5. What will happen of induced electric current if the number of turns of coil is increased?

   a) The electric current will be reduced

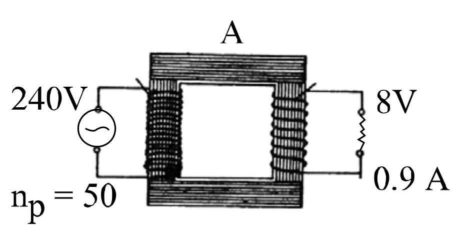
   b) The electric current will be increased

   c) The magnitude of electric current will be zero

   d) The magnitude of electric current will be negative

B. Creative Questions

1. Answer the following question seeing the picture:



a) In this device, what is the name of (A) marked thing?

b) Explain rule or fact on which the device has been made.

c) Calculate the electric current in the primary coil of this device.

d) Explain the function of this device mathematically on the basis of data.

C. General question:

1. What is magnetic effect of electric-current?
2. What is electromagnet? What are the uses of this magnet?
3. What is generator? What are the functions of generator?
4. What is the difference between generator and electric motor?
5. What are the functions or activities of step up and step down transformer?
6. How can the intensity be increased of electromagnet?
7. Any transformer is connected with the source of 240V AC. The number of turns of its primary coil and secondary coil is successively 1000 and 50. What is the voltage of its secondary coil?