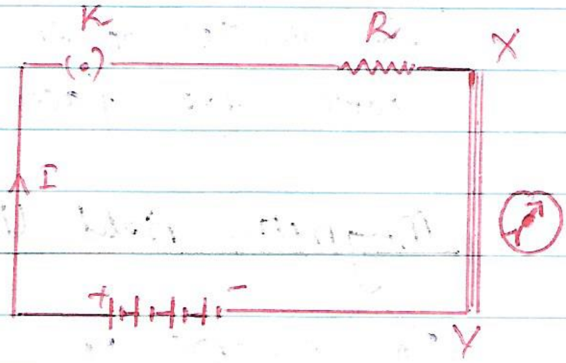
Physics.

Chapter 13 (Magnetic Effects of Electric Currents) - X

Introduction

The term 'magnetic effect of electric current' means that an electric current flowing in a wire produces a magnetic field around it. In other words, electric current can produce magnetism.



Compass needle is deflected on passing an electric current through a metallic conductor.

This is an example of magnetic effect of current.

A magnet is an object which attracts pieces of iron, steel, nickel and cobalt. A bar magnet is a long, rectangular bar of uniform cross-section which attracts pieces of iron, steel, nickel and cobalt.

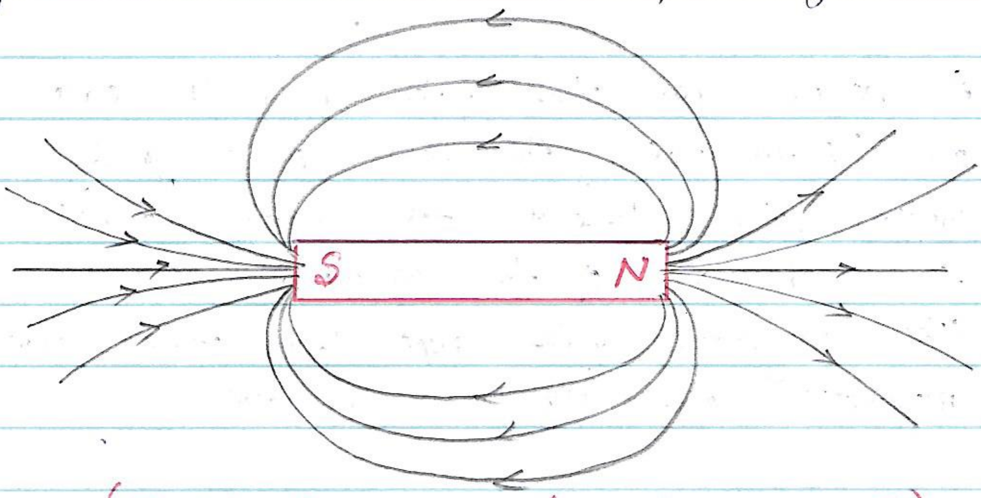
A magnet has two poles near its ends : north pole and south pole. The ends of a freely suspended magnet which points towards the north direction is called the north pole of the magnet.
Like magnetic poles repel each other whereas unlike magnetic poles attract each other.

Magnetic Field

The spaces surrounding a magnetic in which magnetic force is exerted, is called a magnetic field. The magnetic field has both, magnitude as well as direction. The direction of magnetic field at a point is the direction of the resultant force acting on a hypothetical north pole placed at that point.

Magnetic Field Lines

The magnetic field lines are the lines drawn in a magnetic field along which a north magnetic pole would move. The magnetic field lines are also known as magnetic lines of force. Since the direction of magnetic field lines is the direction of force on a north pole, so the magnetic field lines always begin from the N-pole of a magnet and end on the S-pole of the magnet.



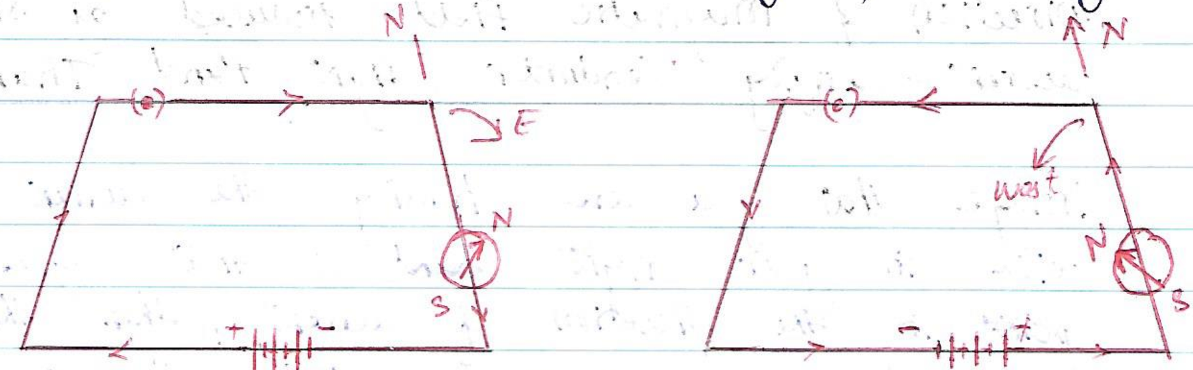
(Field lines around a bar magnet)

Properties: (i) The magnetic field lines originate from the north pole of a magnetic and end at its south pole.
(ii) The magnetic field lines come closer to one another near the pole of a magnet: but they are widely separated at other places. (iii) The magnetic field lines do not cross one another.

Magnetic effect of Current (or Electromagnetism)

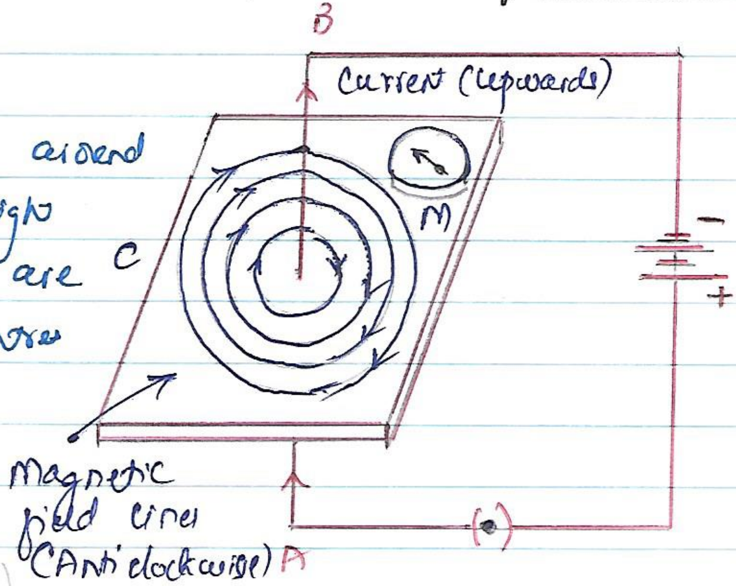
The magnetic effect of current was discovered by Oersted in 1820. A current flowing in a wire always give rise to a magnetic field around it. The electric motor, electric generator, telephone and radio, all utilize the magnetic effect of current.

The magnetic effect of current is also known as electromagnetism which mean electricity produces magnetism.



A simple electric circuit in which a straight copper wire is placed parallel to and over a compass needle. The deflection in the needle becomes opposite when the direction of the current is reversed.

Magnetic field due to a current through a straight conductor.



The magnetic field lines around a straight conductor (straight wire) carrying current are concentric circles whose centres lie on the wire.

It has been shown by experiments that magnitude of magnetic field produced by a straight current carrying wire at a given point is :

(i) Directly proportional to the current passing in the wire,

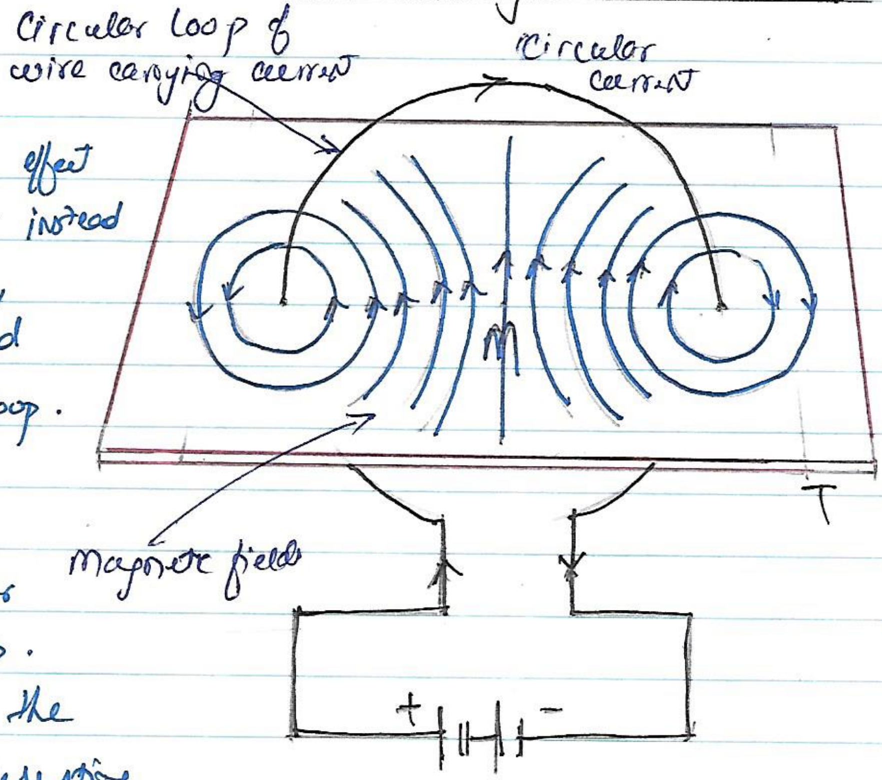
(ii) Inversely proportional to the distance of that point from the wire.

Direction of Magnetic Field Produced by Straight Current - Carrying Conductor (Right Hand Thumb Rule).

Image that you are holding the current - carrying wire in your right hand so that your thumb points in the direction of current, then the direction in which your fingure encircle the wire will give the direction of magnetic field lines around the wire.

Magnetic Field due to a current through a Circular Loop -

It has been found that the magnetic effect of current increases if instead of using a straight wire, the wire is converted into a circular loop.



The magnetic field lines are circular near the current carrying loop. As we move away, the concentric circles representing magnetic field lines become bigger and bigger.

At the centre of circular loop, the magnetic field lines are straight. At the centre of the circular loop, all the magnetic field lines are in the same direction and aid each other, due to which the strength of magnetic field increases.

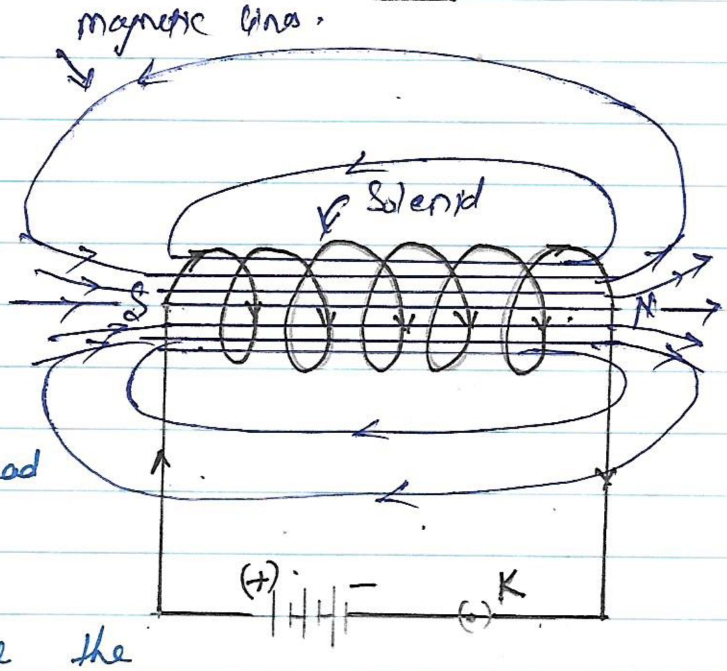
The magnitude of magnetic field produced by a current-carrying circular loop at its centre is :

(i) Directly proportional to the current passing through loop
(ii) Inversely proportional to the radius of circular loop.
(iii) Directly proportional to number of turns of wire (n).

Thus, the strength of magnetic field produced by a current carrying circular coil can be increased by : (i) by increasing the number of turns of wire in the coil (ii) by increasing the current flowing through the coil (iii) by decreasing the radius of the coil.

Magnetic field due to a Current in a Solenoid

The solenoid is a long coil containing a large number of close turns of insulated copper wire. The magnetic field produced by a current carrying solenoid is similar to the magnetic field produced by a bar magnet.



The magnetic field lines inside the solenoid are in the form of parallel lines. This indicates that the strength of the magnetic field is the same at all points inside the solenoid and it is said to be uniform magnetic field.

Strength of magnetic field depends on:

(i) Directly proportional to turns in the solenoid.
(ii) Directly proportional to current in solenoid.
(iii) The nature of core material. The use of soft iron rod as core in solenoid produces strong magnetism.

Clock Face Rule

(i) If the current around the face of circular wire (or coil) flows in the direction of clockwise, then that face of the circular wire (or coil) will be South pole (S-pole)
(ii) If current flow in loop is anticlockwise direction then that face of circular loop will be North pole (N-pole)

Question

1) Why do a compass needle gets deflected when brought near a bar magnet?

Ans) Because magnetic force is exerted by a bar magnet on the compass needle.

2) Draw magnetic field lines around a bar magnet.

Ans) Refer to notes.

3) List the properties of magnetic field lines.

Ans) Refer to notes.

4) Why do two magnetic field lines of force never intersect each other?

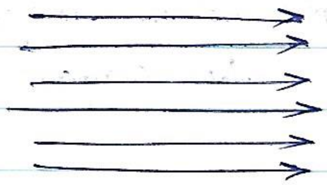
Ans) Two magnetic lines of force never intersect each other. If the lines intersect, then at the point of intersection there would be two direction (the needle would point towards two directions) for the same magnetic field, which is not possible.

(5) Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right hand rule to find out the direction of the magnetic field inside and outside the loop.

Ans) Since the current passes through the loop in clockwise direction, therefore, the front face of the loop will be south pole and back face touching the table will be north pole. According to right-hand rule, the direction of magnetic field inside the loop will be pointing downward. Outside loop, the direction of the magnetic field will be upward.

(6) The magnetic field in a given region is uniform. Draw a diagram to represent it.

Ans) A uniform magnetic field in a region is represented by drawing parallel and equidistant straight lines, all pointing in the same direction.



(7) The magnetic field inside a long straight solenoid carrying current: is the same at all points.

Q8) How does a solenoid behave like a magnet? Can you determine the north and south poles of current carrying solenoid with the help of a bar magnet? Explain.

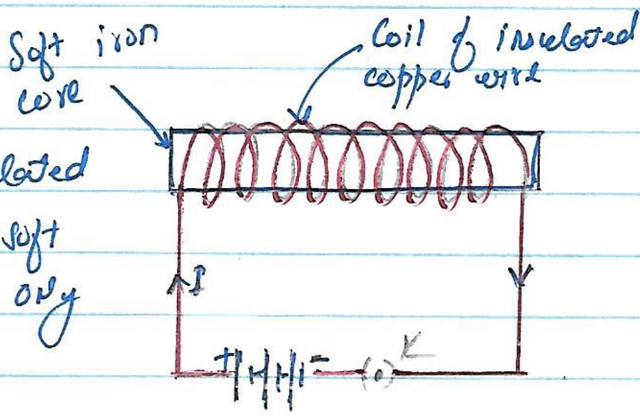
Ans) A solenoid has a large number of close, insulated circular turns. The magnet at the centre of current carrying circular wire is along the axis, so when current is passed in a solenoid, the magnetic fields due to all circular turns are added and hence the field lines becomes just as for a bar magnet.

YES. Suspend the bar magnet freely and note its end pointing along north and south direction and mark these ends N and S. Now bring N-pole near one end of freely suspended current carrying solenoid, if there is repulsion, then that end of solenoid is N-pole and other S-pole, but if there is attraction, then that end of solenoid is S-pole and the other is N-pole.

Electromagnet

An electric current can be used for making temporary magnets known as electromagnets.

An electromagnet is a magnet consisting of a long coil of insulated copper wire wrapped around a soft iron core that is magnetised only when electric current is passed through the coil.



(Electromagnet)

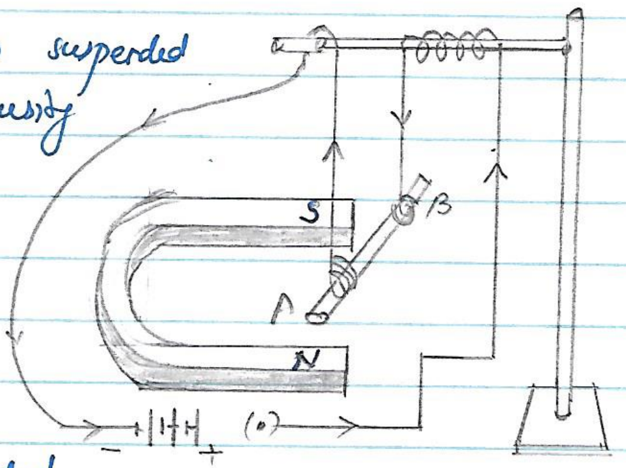
The core of the magnet must be of soft iron because soft iron loses all of its magnetism when current in the coil is switched off. On the other hand, if steel is used for making the core of an electromagnet, the steel does not lose all its magnetism when current is stopped and it becomes a permanent magnet. That is why steel is not used for making electromagnets.

An electromagnet is better than a permanent magnet because it can produce very strong magnetic fields and its strength can be controlled by varying the number of turns in its coil or by changing the current flowing through the coil.

Force on Current-carrying conductor Placed in Magnetic Field

Using Newton's third law of motion, if a current carrying wire exerts a force on a magnet, then the magnet will exert an equal and opposite force on the current carrying wire. In 1821, Faraday discovered that : when a current-carrying conductor is placed in a magnetic field, a mechanical force is exerted on the conductor which can make the conductor move. This is known as the motor principle and forms the basis of a large number of electrical devices like electric motor and moving coil galvanometer.

Q) Explain an activity to show that a current-carrying conductor experiences a force when placed in a magnetic field.



(i) A small aluminium rod is suspended horizontally from a stand using two connecting wires.

(ii) Place a strong horseshoe magnet in such a way that the rod lies between the two poles with magnetic field directed upwards. For this, put the north pole of the magnet vertically below and south pole vertically above the aluminium rod.

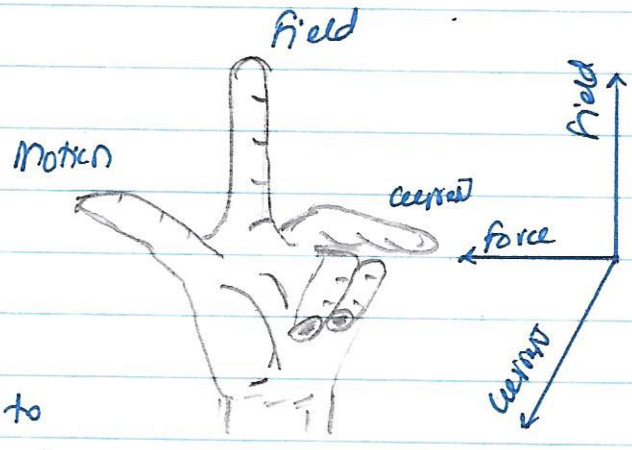
(iii) Connect the aluminium rod in series with a battery, a key and a rheostat.

(iv) Pass a current through aluminium rod from one end to other (B to A). The rod is displaced towards left.

(v) When the current is reversed, the displacement of rod across towards right.

The displacement of the rod in the above activity suggests that a force is exerted on the current-carrying aluminium rod when it is placed in a magnetic field. It also suggests that the direction of force is also reversed when the direction of current through the conductor is reversed.
Now change the direction of field to vertically downwards by interchanging the two poles of the magnet. It is observed that the direction of force acting on the current-carrying rod gets reversed.
Experiments have shown that the displacement of the rod is largest when the direction of current is at right angles to the direction of the magnetic field.

Q) State the rule which gives the direction of force acting on the conductor.



Fleming's left-hand rule.

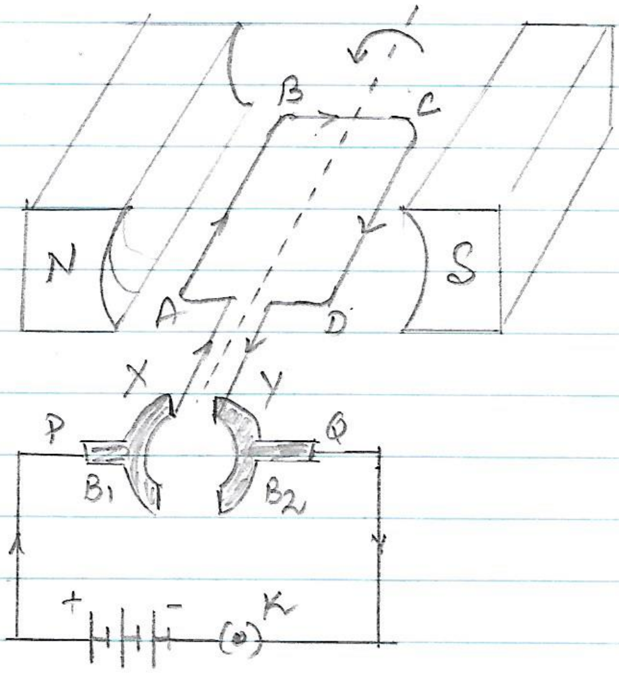
Stretch the thumb, forefinger and middle finger of your left hand such that they are mutually perpendicular to one another. If the forefinger points in the direction of magnetic field and the middle finger in the direction of current, then the thumb will point in the direction of motion or the force acting on the conductor.

Electric Motor

Devices that use current-carrying conductors and magnetic field include electric motor, electric generator, loud speakers, microphones and measuring instruments.

An electric motor is a rotating device that converts electrical energy to mechanical energy. Electric motor is used as an important component in electric fans, refrigerators, mixers, washing machines, computers, mp3 players etc.

Principle:



The electric motor works on the magnetic effect of current. Its principle is when a rectangular coil is placed in a magnetic field and current is passed through it, a force acts on the coil, due to which the coil rotates. When the coil rotates the shaft attached to it also rotates. The rotating shaft has mechanical energy. In this way electric energy supplied to motor is converted into mechanical energy.

Construction:

An electric motor has the following parts:

(i) Field Magnet

(ii) Armature (ABCD)

(iii) Split Rings and Brushes (X and Y)

The split rings touch the two strips of graphite B1, B2; these strips of graphite are called the brushes. These brushes are connected to two connecting screws P and Q. These brushes are fixed to the base of motor and they keep contact with the half rings lightly. The screws are connected to terminal of battery. When current is passed by means of battery, the current enters the coil from one brush and leaves through the other.

Working

Let initially coil ABCD be horizontal. When key is closed, the current begins to flow in the coil. Initially the sides AD and BC of coil are parallel to magnetic field, so no magnetic force acts on them.

By Flemings' left hand rule, the force on area AB of coil is vertically downward and on side CD of coil, it is vertically upward. These two forces are equal and opposite and hence form a couple. This tends to rotate the coil in anticlockwise direction. When rotating coil becomes perpendicular to its initial position, then couple becomes zero. But due to inertia the coil continuous to rotate along the same direction. As the split rings rotate with the coil, therefore, the split rings come in contact with other brushes. When this happens the direction of current in the coil is reversed.
This in turn reverses the direction of forces in AB and CD. The side of the coil will be on left hand side with a downward force on it and the side AB of coil will be on right hand side with an upward force on it.

Thus a couple acts on the coil which rotates the coil in the same direction (anti-clockwise). This process is repeated again and again the coil rotates continuously.

Due to rotation of the coil, its shaft gain kinetic energy; which may be used to run electric fan, water pump, washing machine, mixer and grinder etc.

The commercial motors use:

(i) an electromagnet in place of permanent magnet.
(ii) large number of turns of the conducting wire in the current-carrying coil.
(iii) a soft iron core on which the coil is wound, plus the coils, is called an armature which enhances the power of the motor.

↑

(In what ways these simple motors are different from commercial motors)

Electromagnetic Induction [Electricity from Magnetism]

The production of electricity from magnetism is called electromagnetic induction. For example, when a straight wire is moved up and down rapidly between the two poles of a horseshoe magnet, then an electric current is produced in wire. This is an example of electromagnetic induction. If a bar magnet is moved in and out of a coil of wire, even then an electric current is produced in the coil. This is also example of electromagnetic induction.

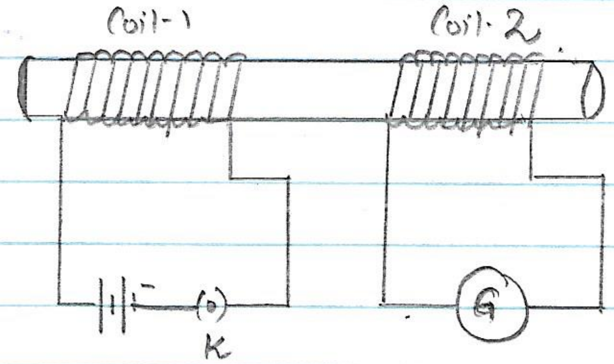
The process of electromagnetic induction has led to the construction of generators for producing electricity at power stations.

A Galvanometer is an instrument which can detect the presence of electric current in a circuit.

The direction of the induced current can be reversed by reversing the direction of magnetic field.

(Q) With help of a diagram, describe an experiment to show that a change in current flowing through a coil induces an electric current in a neighbouring coil.

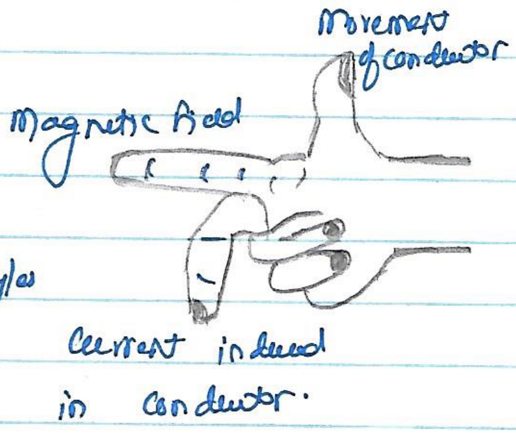
(i) Take two different coils of insulated copper wire having large number of turns.
(ii) Insert the coils over a non-conducting cylindrical thick paper roll.

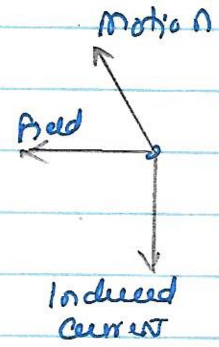


(iii) Connect a battery, a plug in series of coil-1.
(iv) with coil-2, connect a sensitive galvanometer.
(v) Now put the plug in key in coil-1 the needle momentarily moves, but to the opposite side. It means that now the current flows in the opposite direction in Coil-2.
(vi) So we conclude that current is produced in coil-2 whenever the current flowing in the neighbouring coil is changing.

Fleming's Right Hand Rule

The induced current is found to be the highest when the direction of motion of the coil is at right angles to the magnetic field.

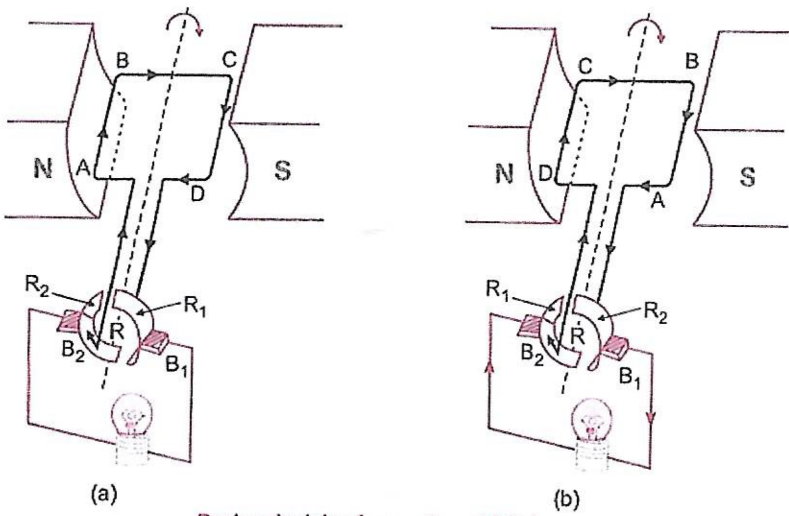




We can use a simple rule to know the direction of the induced current.

Stretch the thumb, forefinger and middle finger of right hand so that they are perpendicular to each other. If the forefinger indicates the direction of the magnetic field and thumb shows the direction of motion of conductor, then the middle finger will show the direction of induced current.
This simple rule is called Flemings right-hand rule.

Electric Generator



Basic principle of operation of DC dynamo

DC Dynamo (Direct Generator Generator)

Principle:

(i) A device used to convert mechanical energy into electrical energy is called an electric generator.

(ii) An armature coil rotating in a magnetic field develops an alternating emf (electro motive force) and sends alternating current in an external circuit.

If, however, the connections of the ends coil to the external circuit are interchanged every time the emf in the coil reverses, the current in the external circuit flows always in the same direction.

This is the principle of a DC dynamo.

Working:

(i) The working of a single-coil DC dynamo is shown in fig.

(ii) The ends of armature coil ABCD are connected to the two separated segments R_1 of a single copper ring R, which is called the 'split-ring commutator'. R_1 and R_2 rotate along with armature between two brushes B_1 and B_2 to which the external circuit is connected.

(iii) When the armature coil ABCD is rotated clockwise (say), an emf is induced in the coil and a current flows in the direction ABCD (Flemings Right Hand)

(iv) In the external circuit, the current flows from B_1 to B_2. For half the revolution, R_1 is in contact with B_1 and R_2 with B_2.

(v) But as soon as the coil passes the vertical, R_1 comes in contact with B_2 and R_2 with B_1 and remain so during the next half revolution.

(vi) Although the induced emf in the coil is reversed and the current in the coil flows in the direction BCBA, but in the external circuit the current still flows from B_1 to B_2

(vii) The current generated by such a simple dynamo is uni-directional. As long as the coil is rotating, the direct current flows through the device connected to the terminal of the generator.

To get a direct current (DC, which does not change its direction with time), a split ring type commutator must be used. With this arrangement, one brush is at all times in contact with the arm moving up in the field, while the other is in contact with the arm moving down. Thus a unidirectional current is produced. The generator is then called DC generator.

The difference between DC and AC (Alternating Current) is that the direct current always flows in one direction, whereas the alternating current reverses its direction periodically. Most power stations constructed these days produce AC. In India, the AC changes direction after every 1/100 second, that is, the frequency of AC is 50 Hz. An important advantage of AC over DC is that electric power can be transmitted over long distances without much loss of energy.

13.7 DOMESTIC ELECTRIC CIRCUITS

In our homes, we receive supply of electric power through a main supply (also called mains), either supported through overhead electric poles or by underground cables. One of the wires in this supply, usually with red insulation cover, is called live wire (or positive). Another wire, with black insulation, is called neutral wire (or negative). In our country, the potential difference between the two is 220 V.

At the metre-board in the house, these wires pass into an electricity meter through a main fuse. Through the main switch they are connected to the line wires in the house. These wires supply electricity to separate circuits within the house. Often, two separate circuits are used, one of 15 A current rating for appliances with higher power ratings such as geysers, air coolers, etc. The other circuit is of 5 A current rating for bulbs, fans, etc. The earth wire, which has insulation of green colour, is usually connected to a metal plate deep in the earth near the house. This is used as a safety measure, especially for those appliances that have a metallic body, for example, electric press, toaster, table fan, refrigerator, etc. The metallic body is connected to the earth wire, which provides a low-resistance conducting path for the current. Thus, it ensures that any leakage of current to the metallic body of the appliance keeps its potential to that of the earth, and the user may not get a severe electric shock.

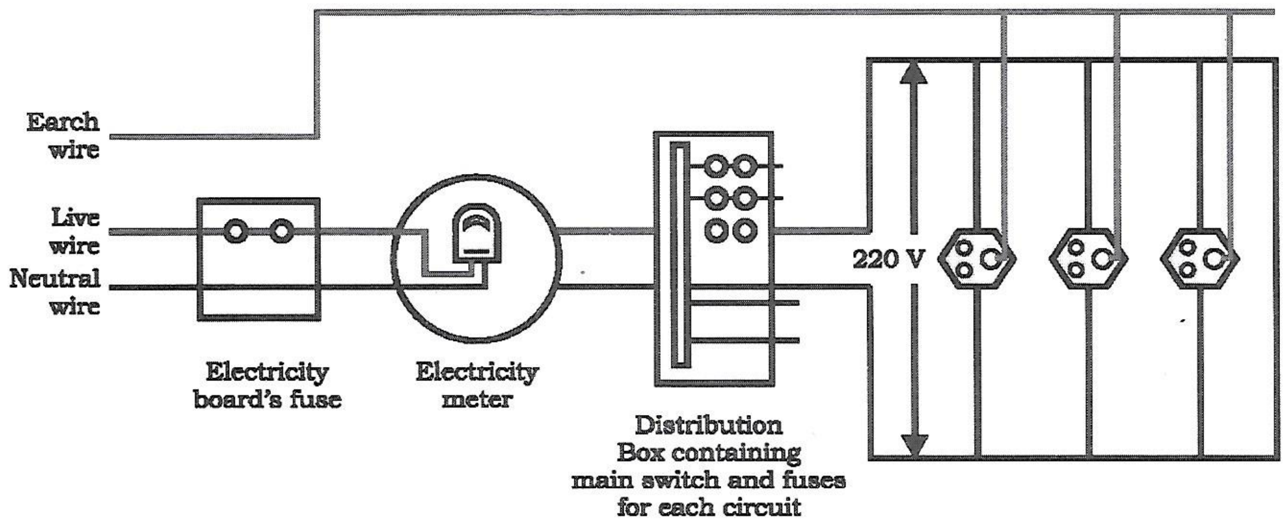


Figure 13.20 *A schematic diagram of one of the common domestic circuits*

Figure 13.20 gives a schematic diagram of one of the common domestic circuits. In each separate circuit, different appliances can be connected across the live and neutral wires. Each appliance has a separate switch to 'ON'/'OFF' the flow of current through it. In order that each appliance has equal potential difference, they are connected parallel to each other.

Electric fuse is an important component of all domestic circuits. We have already studied the principle and working of a fuse in the previous chapter (see Section 12.7). A fuse in a circuit prevents damage to the appliances and the circuit due to overloading. Overloading can occur when the live wire and the neutral wire come into direct contact. (This occurs when the insulation of wires is damaged or there is a fault in the appliance.) In such a situation, the current in the circuit abruptly increases. This is called short-circuiting. The use of an electric fuse prevents the electric circuit and the appliance from a possible damage by stopping the flow of unduly high electric current. The Joule heating that takes place in the fuse melts it to break the electric circuit. Overloading can also occur due to an accidental hike in the supply voltage. Sometimes overloading is caused by connecting too many appliances to a single socket.

Questions

(1) Which properties of a proton can change while it moves freely in a magnetic field?

Ans) Whenever a charged particle (proton) moves in a magnetic field, its velocity and as a result of this its momentum change.

(2) What is the direction of magnetic field when a positive charged particle (alpha-particle) is projected towards west is deflected towards north by a magnetic field.

Ans) Since the positively charged particle (alpha) projected towards west, so the direction of current is towards west. Now the deflection is towards north, so the force is towards north. Using flemings LHR, magnetic field is in the upward direction.

(3) State Flemings left hand rule.

Ans) Refer to notes.

(4) State different ways to induce current in coil.

Ans) (i) By rotating the coil in the magnetic field between the poles of U-shaped magnet.

(ii) By keeping the coil stationary and moving the magnet inside.

(iii) By changing the current continuously in an another coil kept near it.

(5) Name some sources of direct current (DC)

Ans) Dry cell battery, car battery and DC generator.

(6) Which sources produce alternating current?

Ans) Bicycle dynamos, car alternators and power house generators.

(7) A rectangular coil of copper wires is rotated in a magnetic field. The direction of the induced current changes once in each : Half Revolution.

(8) Name two safety measures commonly used in electric circuits and appliances.

Ans) (i) Electric fuse (ii) Earthing of metal bodies of electrical appliances.

(9) An electric oven of 2 kW power rating is operated in a domestic electric circuit (220 V) that has a current rating of 5A. What result do you expect? Explain.

Ans) $P = 2\ kW = 2000\ W$. $V = 220\ V$

$$\text{Power} = V \times I \quad \therefore I = \frac{P}{V} = \frac{2000}{220} = 9A \text{ appr.}$$

The current drawn by this electric oven is 9A whereas the fuse in the circuit is only 5A capacity. When a high current 9A flows through the 5A fuse, the fuse wire will get heated too much, melt and break the circuit.

Therefore, when a 2 kW power rating electric oven is operated in a circuit having 5A fuse, the fuse will blow off cutting off the power supply in this circuit.

(10) What precautions should be taken to avoid the overloading of domestic electric circuits?

Ans) (i) Too many electrical appliances should not be operated on a single socket.

(ii) Too many high power rating electrical appliances should not be switched on at the same time.

(11) When does an electric short circuit occur?

Ans) If the insulation of a live wire and neutral wire get damaged then the two wires touch each other. This touching of the live wire and neutral wire is known as short circuit. In this situation, the resistance of a circuit decreases to a very small. Due to this, current flowing through the wire becomes very large and heats the wire to a very high temperature, and a fire may be started.

(12) What is the function of an earth wire? Why is it necessary to earth the metallic appliances?

Ans) Sometimes, the insulation of live wire is thin and due to this the live wire touches the metallic body of the appliance. This causes the flow of current in metallic body. This current flows to the earth through the earth wire and does not harm the user of the appliance.

Therefore, to prevent the user getting an electric shock, due to leakage of current to metallic body, earth wire must always be used.

Q. 13 The device used for producing current is called a:

(*i*) Generator **(*ii*) Galvanometer**

(*iii*) Ammeter **(*iv*) Motor**

Ans. Generator is a device for producing electric current. So, choice (*i*) is correct.

Q. 14 The essential difference between an AC generator and a DC generator is that

(*i*) AC generator has an electromagnet while a DC generator has permanent magnet.

(*ii*) DC generator will generate a higher voltage.

(*iii*) AC generator will generate a higher voltage.

(*iv*) AC generator has slip rings while the DC generator has a commutator.

Ans. AC generator has slip rings while DC generator has a commutator. So, choice (*iv*) is correct.

Q. 15 At the time of short circuit, the current in the circuit

(*i*) reduces substantially **(*ii*) does not change**

(*iii*) increases heavily **(*iv*) varies continuously**

Ans. At the time of short circuit, the resistance of circuit becomes nearly zero; so current increases heavily. So, choice (*iii*) is correct.

Q. 16 State whether the following statements are true or false.

(*i*) An electric motor converts mechanical energy into electrical energy.

(*ii*) An electric generator works on the principle of electromagnetic induction.

(*iii*) The field at the centre of a long circular coil carrying current will be parallel straight lines.

(*iv*) A wire with a green insulation is usually the live wire of an electric supply.

Ans. (*i*) False, because an electric motor converts electric energy into mechanical energy.

(*ii*) True (*iii*) True

(*iv*) False, because a live wire has always **red** or **brown** insulation.

Q. 17 List three sources of magnetic field.

Ans. (*i*) Moving charges (*ii*) Electric current

(*iii*) Magnet

Q. 18 How does a solenoid behave like a magnet? Can you determine the north and south poles of a current-carrying solenoid with the help of a bar magnet? Explain.

Ans. A solenoid has a large number of close, insulated circular turns. The magnet at the centre of current carrying circular wire is along the axis; so when current is passed in a solenoid, the magnetic fields due to all circular turns are added and hence the field line becomes just as for a bar magnet.

Yes, we can determine the north and south poles of a current carrying solenoid with the help of a bar magnet. For this we suspend the bar magnet freely and note its ends pointing along north and south directions and mark on these ends N (north pole) and S (south pole).

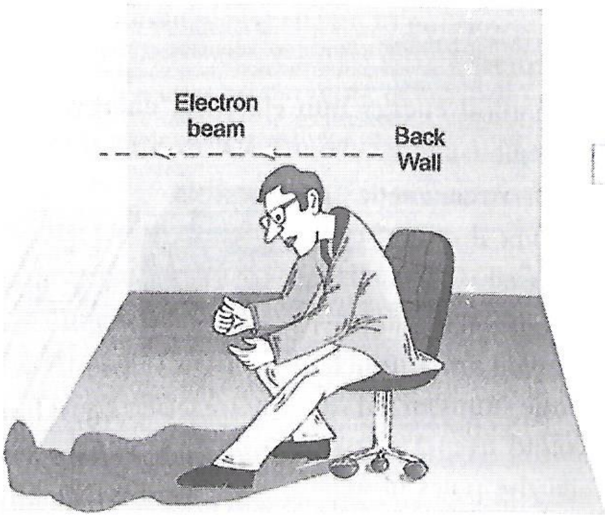
Now we bring N-pole near one end of freely suspended current carrying solenoid; if there is repulsion, then that end of solenoid is N-pole and other S-pole; but if there is attraction, then that end of solenoid is S-pole and the other is N-pole.

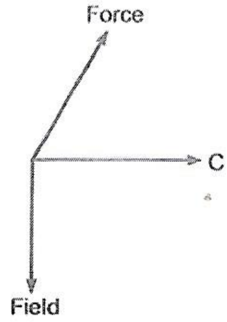
Q. 19 When is the force experienced by a current-carrying conductor placed in a magnetic field largest?

Ans. The force experienced by a current-carrying conductor placed in a magnetic field is largest when the direction of current is at right angles to the direction of the magnetic field.

Q. 20 Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of magnetic field?

Ans.





The current due to moving electron beam is in a direction opposite to motion. The force on electron is towards right. By Fleming's left hand rule, the direction of magnetic field is vertically downward.

Q.21. Name some devices in which electric motors are used.

Ans. Electric motors are used in electric fans, refrigerators, mixers, washing machines, etc.

Q.22. A coil of insulated copper wire is connected to a galvanometer. What will happen if a bar magnet is (*i*) pushed into the coil (*ii*) withdrawn from inside the coil (*iii*) held stationary inside of coil?

Ans. (*i*) When a bar magnet is pushed into the coil, a momentary deflection is observed in the galvanometer. This deflection indicates that a momentary current is produced in the coil.

(*ii*) When a bar magnet is withdrawn from the coil, the deflection of galvanometer is in opposite direction. It indicates that a current of an opposite direction is produced.

(*iii*) When a bar magnet is held stationary inside the coil, there is no deflection in the galvanometer. It indicates that no current is produced in the coil.

Q.23. Two circular coils A and B are placed close to each other. If the current in the coil A is changed, will some current be induced in the coil B? Give reason.

Ans. Yes, by changing current in coil A, some current will be induced in coil B. The reason is that when current in coil A is changed, the magnetic field around A changes, so magnetic flux linked with nearby coil B changes; this gives rise to induced current in coil B.

Q.24. State the rule to determine the direction of a (*i*) magnetic field produced around a straight conductor-carrying current (*ii*) force experienced by a current-carrying straight conductor placed in a magnetic field which is perpendicular to it and (*iii*) current induced in a coil due to its rotation in a magnetic field.

Ans. (*i*) The direction of magnetic field produced around a current-carrying conductor is given by **right hand thumb rule.** If the conductor carrying current is held in the right hand in such a way that the thumb points in the direction of current, then direction of curl of fingers gives the direction of the magnetic field.

(*ii*) The direction of force experienced by a straight conductor carrying current placed in a magnetic field, which is perpendicular to it is determined by **Fleming's left hand rule.** Hold the thumb and first two fingers of the left hand at right angles to each other with the first finger pointing in the direction of the Field and the second finger in the direction of the current, then the thumb points in the direction of the motion.

(*iii*) The direction of current induced in a circuit by changing magnetic flux due to motion of a magnet is determined by **Fleming's right hand rule.** If we stretch our right hand in such a way that the thumb, forefinger and central finger remain perpendicular to each other, so that the forefinger indicates the direction of the magnetic field and the thumb in the direction of motion of conductor; then the central finger indicates the direction of induced current.