- **Refining of copper**

In copper plating the copper transferred to the cathode is very pure,even if the anode may have been made of impure copper.This process is used to produce pure copper for electric cables.

- **Extraction of sodium and aluminium**

These metals are obtained by electrolysis of common salt for sodium and aluminium oxide for aluminium.

3.4 Magnetic effect of a current

In 1819 Hans Christian Oersted discoverd that electricity has a magnetic effect. Try the following activity to study the magnetic effect of an electric current.

Activity 3.13

Hold the wire over the compass needle as shown in Figure 3.22.Press the switch for a few seconds.When current flows observe the compass needle.Reverse the direction of current and observe the deflection of the compass needle again.

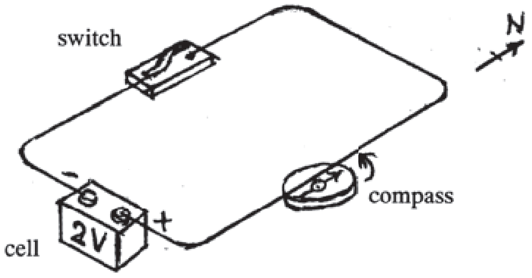


Fig 3.22 - Arrangement for oersted experiment

You will see the change in diflection of the compass needle.Reversing the direction of current also changes the direction of deflection.Deflection of the compass needle changes due to the formation of a magnetic field.Therefore it is clear that a magnetic field is formed around a conductor when an electric current flows through it.

Let us find how the magnetic field is arranged around a bar magnet.

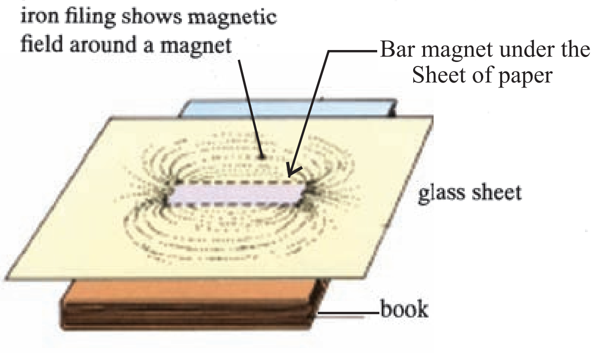


Fig 3.23 - Magnetic field around a bar magnet

Activity 3.14

Place a sheet of paper or a thin glass sheet over a bar magnet.Sprinkle a thin layer of iron filings over the paper or glass sheet and then tap the paper or glass sheet gently.Record your observations.

The magnetic field around a bar magnet consists of a number of lines of force. When tapping the glass sheet the iron filings, act like thousands of tiny compasses and point themselves along the lines of flux.Therefore the arrangement of iron filings as shown in the Figure 3.23 indicates the lines of force.

Magnetic field near a current- carrying long coil

When an electric current passes through a long coil or a **solenoid**, a magnetic field is formed around it, as shown in the Figure 3.24 (a).This magnetic field is equivalent to a magnetic field around a bar magnet.Therefore we see that a current carrying long coil or a solenoid acts as a bar magnet. Such magnets are called **electromagnets**.The polarities at each end of the solenoid, according to the direction of electric current can be identified as in figure 3.24 (b)

Let us find how the following factors depend on the magnetic field strength of an electromagnet.

- Magnitude of the current
- Number of turns of the coil
- Changing the soft iron core

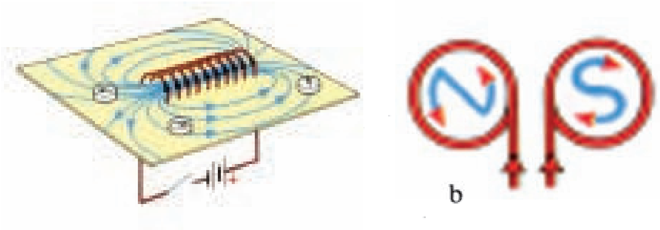


Figure 3.24 Magnetic field around a current carrying solenoid.

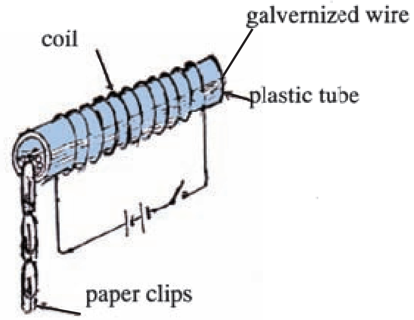


Figure 3.25 Arrangements to find the strength of an electro magnet

Activity 3.15

- Take a small thread winding plastic tube, and wind about 50 turns of insulated copper wire (30 swg) around the tube.
- Cut a galvanized wire into 2 inches pieces and keep a few pieces inside the tube.
- Scrape the insulation of the wire at each ends (Using emery paper or a knife) and connect each end to a circuit as shown in fig 3.25
- Close the switch and bring paper clips near one end of the coil.
- Count the maximum number of paper clips that can be hung from the galvarnized wire without falling.
- Repeat the above activity by increasing the number of cells.

- Similarly repeat the first activity by increasing the number of turns upto 100.
- Repeat the first activity by inserting more pieces of galvanized wires.

We will see here that the number of clips that can be hung is always greater than the first instance according to the increase of number of cells,number of turns of the coil and the number of galvanized wires in the core.

The number of clips that can be hung increases because the field strength of the electromagnet increases.The magnitude of the current flowing through the coil increases as the number of cells increases.

Therefore it is clear that the field strength of the electromagnet increases as the current flowing through the coil,number of turns of the coil,soft iron core increases.

Uses of magnetic effect of current

The magnetic effect of current is mostly used in home electrical appliances.It is also used in apparatus in the industrial field.

The electric bell

Study the diagram 3.26.When the bell-push completes the circuit a current flows through the coil. As a result of that the U shape soft -iron core becomes an electromagnet and the soft-iron is attracted towards the electromagnet and the hammer hits the gong. This movement breaks the circuit at X,so that the current stops flowing and switches off the electromagnet. The spring pulls the armature back so that contact is made and the sequence begins again and again.Because of this process, the bell will ring continuosly.

Instances where electromagnets are used

- Electromagnetic door locks
- Circuit breakers
- Electromagnetic relays
- Telephone ear piece
- Cranes in steel works and scrap yards
- To remove splinters of iron or steel in hospitals dealing with eye injuries

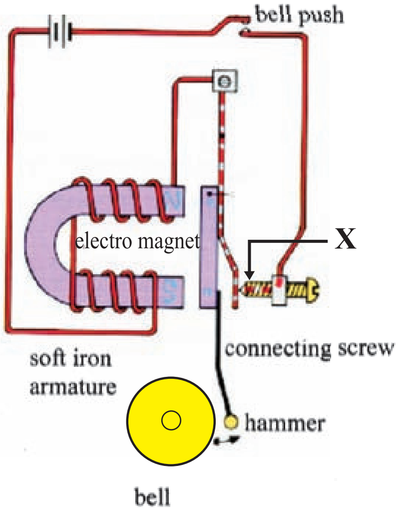


Fig 3.26 - Arrangemaent of an electric bell

Force acting on a current-carrying conductor in a magnetic field.

Let us try the following activity to investigate this;

Activity 3.16

Hang a thin copper wire between poles of a powerful horseshoe magnet and connect the wire to a cell and a switch as shown in figure3.27.Close the switch and observe the behaviour of the wire. Secondly repeat the first activity by changing the direction of current.Thirdly repeat the first activity by turning the magnet to the other side so that the polarity changes.

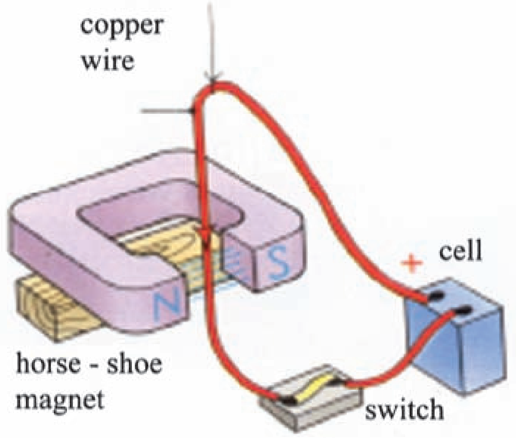


Figure 3.27 Force on a current carrying conductor

You will see that, in the first stage the copper wire moves outward from the horseshoe magnet,in the second and third stages the copper wire moves into the horseshoe magnet.The wire moves because the magnetic field of the permanent magnets reacts to the magnetic field due to the current in the wire.To remember the direction of movement we use Fleming's left hand rule.

Fleming's left hand rule

Hold the first finger,second finger and thumb of your left hand so that they are at right angle to each other.

- Point your first finger in the direction of the magnetic field.(From N to S)
- Rotate your hand about the first finger untill your second finger points in the direction of current.
- Then your thumb points in the direction of movement of the wire.

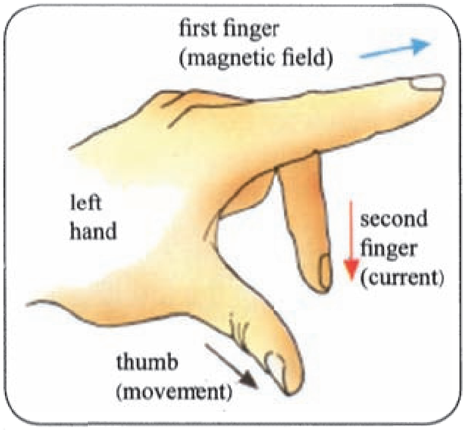


Fig 3.28 Fleming's, left hand rule

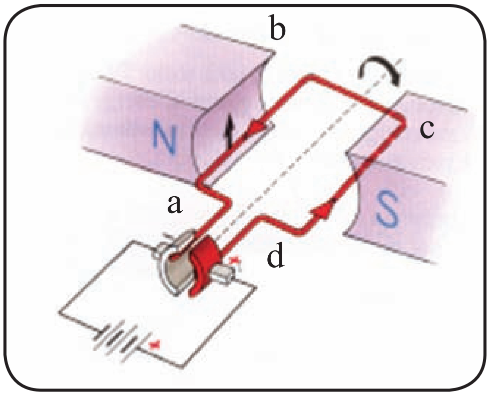
It is clear that the movement of the copper wire in the above activity was done, according to the Fleming's left hand rule.

Direct current motor (DC motor)

As shown in the Figure 3.29 (a) the simple type direct current motor consists of a rotatable coil kept in between the poles of a permanent magnet.The current from the battery passes through brushes to commutator which is connected to the ends of the coil.The commutator is a copper ring cut into two halves.

Use Fleming's left hand rule for the arm a b of the coil as shown in Figure 3.29 (b).

You will find that the wire moves upward so that the coil turns clockwise. When arm cd of the coil comes near the N-pole of the magnet, the half ring connected to cd is in contact with the brush connected to the negative terminal of the battery.Therefore the current is coming out towards us.This means that the force on cd is upwards and the coil will turn clockwise continuously.



(a) direct current motor

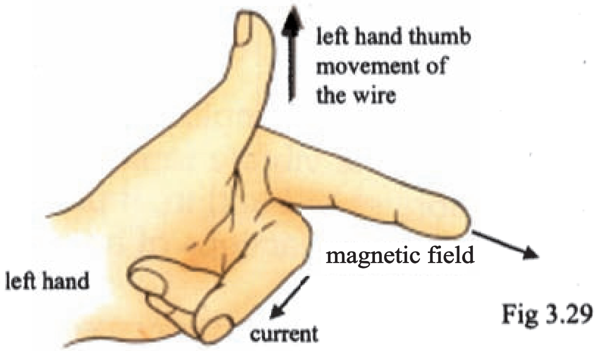
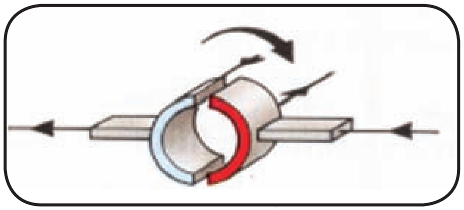


Fig 3.29

(b) Applied Fleming's left hand rule



(c) Commutator

Current enters through right side and coming out from left side

To keep the coil turning round in the same direction, we have to change the direction of current in the coil.That is reverse the current in the coil.Because of this, the current through the coil in a DC motor is reversed in every half turn by a commutator.What would happen if you reverse the terminals of the battery?

Let's consider the construction of a simple type direct current motor.

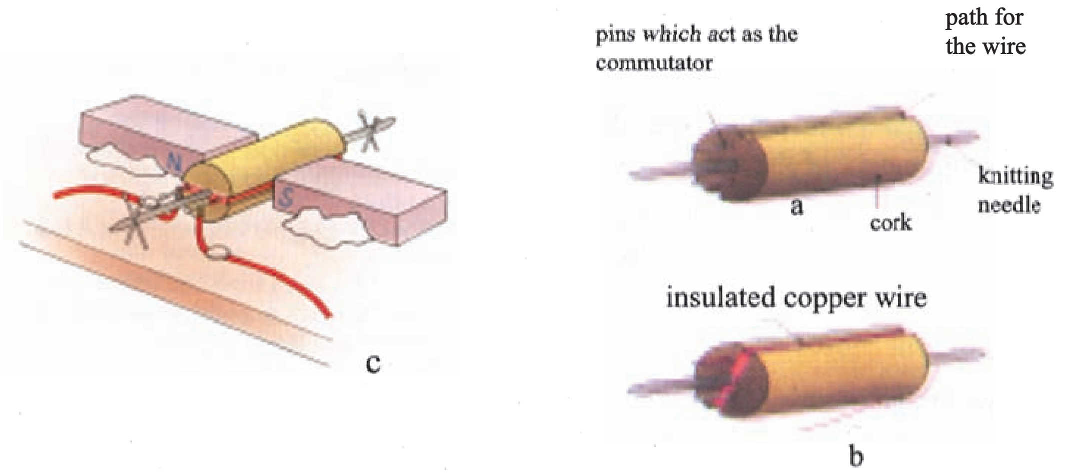


Fig 3.30 Construction of a direct current motor.

Activity 3.17

- Push a short knitting needle through large cork.
- Push two pins in one end of the cork, as shown, to make a simple commutator.
- Now wind round the cork about 50 turns of thin insulated copper wire, starting at one pin and finishing at the other. It will be helpful if you can cut a channel in the cork to take the wire.
- Scrap the insulation off at the ends of the wire(using emery paper or a knife) Wrap each end of the wire round the pins making good electrical contact.
- Push 2 pairs of long pins into a base board to support the axle at each end.
- Strip the insulation from the ends of 2 wires (1/044 wires)and use clips to hold them in position so that they just touch the commutator.
- Use plasticine to support magnets on each side of the coil (With opposite poles facing)
- Connect wires to a 3V supply and give the coil a flick to start.

3.5 Electro magnetic Induction

In 1831, **Michael Faraday** discovered how to make electricity using magnetism. To study the phenomenon of Electromagnetic Induction conduct the following activity.

Activity 3.18

- Connect a coil with large number of turns to a centre zero galvanometer as shown in the Figure 3.31 (a)
- First move a bar magnet with strong magnetic field strength quickly into the coil as shown in the Figure 3.31 (a) and observe the response of the galvanometer.
- Secondly keep the magnet at rest inside the coil as shown in the Figure 3.31(b) and observe the response of the galvanometer.
- Thirdly, pull the bar magnet quickly out of the coil as shown in the figure 3.31(c) and observe the response of the galvanometer.
- Repeat the activity by changing the following factors.
    - ✶ By moving magnets having low and high magnetic strength with the same speed into the coil.
    - ✶ Using a coil having less number of turns.
    - ✶ Moving the magnet slowly and quickly. Record your observations in each of the instances given above.

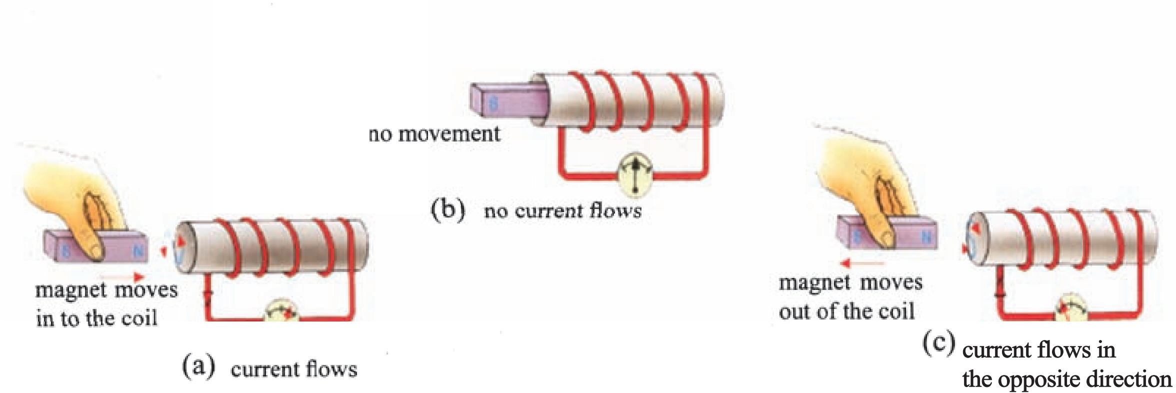


Fig 3.31 - Electro Magnetic Induction

You will see that the galvanometer shows responses in the first and third instances but does not respond in the second instance. You know that the galvanometer responds only when there is a current passing through it. You will see that a current is induced in the coil only when the magnet is moving. When the magnet moves, there is a change of **magnetic field** across the coil. across the coil. When there is a change in magnetic field across the coil, an electromotive force is induced between the ends of the coil. This is called **electromagnetic induction.**

If the ends of the coil are arranged as a closed circuit, an induced current flows through the coil due to the induced electromotive force.

You will see that the galvanometer reading increases with the strength of the magnet, number of turns of the coil and the speed of movement of the magnet. This is because when the induced electromotive force increases, the induce current too increases.

You know that when there is a change in magnetic field across a conductor, an electromotive force is induced between the ends of the conductor and from that a current is induced in a closed circuit. Let us find the direction of the induced current according to the form of changing the magnetic field.

Activity 3.19

Connect a straight piece of wire (AB) to a centre zero galvanometer as shown in the Figure 3.32 (a) and move the wire upward across the magnetic field. Repeat the activity again by moving the wire downwards. Check the direction of current in each of the instances above using the circuit as shown in the Figure 3.32 (b).

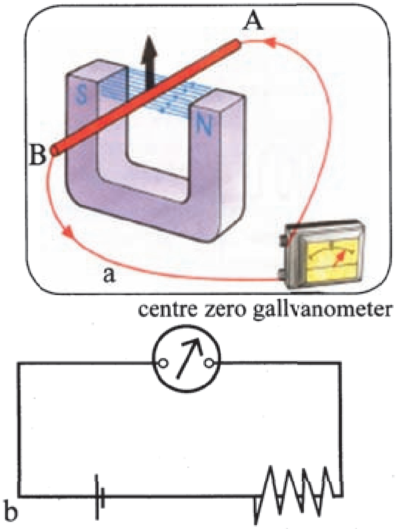


Fig 3.32

You will note that the induced current flows from A to B when the wire moves upwards and the induced current flows from B to A when the wire moves downwards.It is clear that the direction of the induced current flowing through the wire in the Activity 3.19 is according to the Fleming's Right-hand rule.

Fleming's Right - hand rule

- Hold the first finger,second finger and the thumb of your right -hand so that they are at right angles to each other.
- Point your first finger in the direction of the magnetic field (From N to S)
- Rotate your hand about the first finger untill your thumb point in the direction of movement of the wire.
- Then your second finger points in the direction of the induced current.

Do you know?

◆ Lenz found that the direction of flow of the induced current is such that it opposes the change producing it.

This is Lenz's Law

◆ Faraday found that the induced e.m.f is equal to the rate of change of magnetic flux linking the circuit (Coil)

This is Faraday's Law.

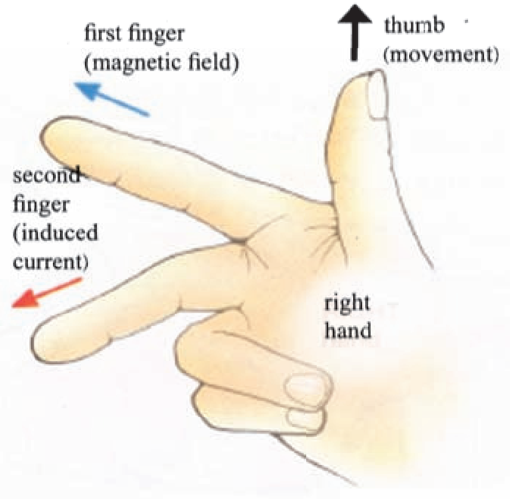


Fig 3.33

Fleming's right hand rule

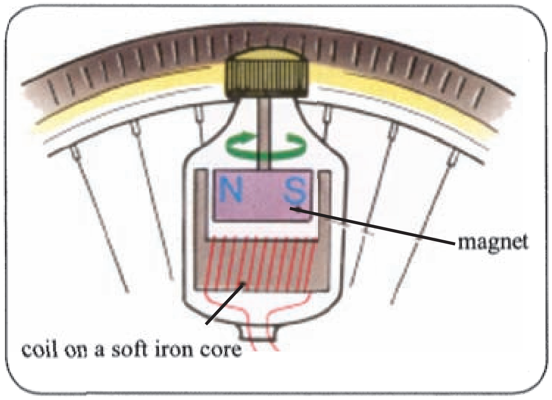


Fig 3.34 - Bicycle Dynamo

Uses of electromagnetic induction

Bicycle Dynamo

The Bicycle dynamo consists of a rotatable magnet near a coil of wire. So that the magnetic field is cut by the wire.

Then an induced electromotive force is generated between the ends of the coil. The coil is wound on a soft iron core so that the magnetic field is stronger.

Activity 3.20

First connect a bicycle dynamo to a lamp and observe the brightness of the lamp by turning it slowly and then quickly Connect the bicycle dynamo to a centre-zero ammeter and turn it slowly.Observe the direction of the pointer of the ammeter.

When the dynamo rotates quickly the brightness of the lamp is greater because the induced e.m.f is greater and when it rotates slowly the brightness of the lamp is lesser because the induced e.m.f is lesser.

In the second instance, you will observe that the ammeter pointer deflects to both sides.It is clear that in rotating the dynamo the induced current reverses the direction, because induced electromotive force reverses the direction. A current that reverses to and fro like this is called an **alternating current** (AC)

Induction coil

The induction coil is a device for getting a high voltage from a low one.It consists of a primary coil of about hundred turns of thick insulated copper wire wound around a core of soft iron wires,a secondary coil of about thousand turns of thin insulated copper wire and a make and break apparatus.Primary coil is connected to a battery of accumulators.Make and break apparatus switches the current on and off many times a second,thus varying the magnetic flux.A high e.m.f is induced in the secondary coil.Investigate instances where induction coil is practically used.

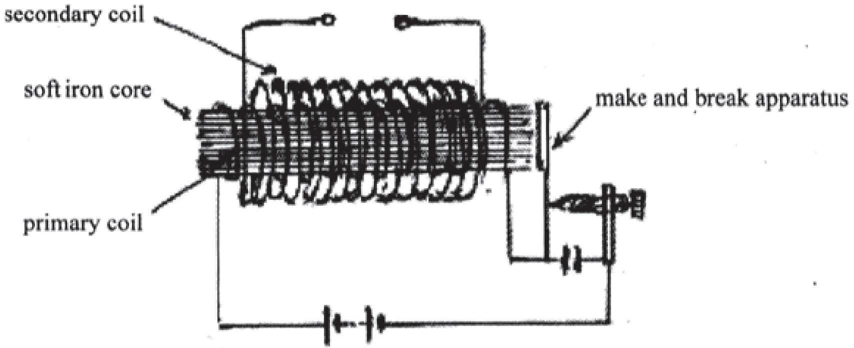


Fig 3.35 - Induction coil

Transformer

Transformer is a device to change or transform an a.c voltage from one value to another.That is from a lower value to a higher value or a higher value to a lower value.It has primary and secondary winding around a close laminated soft iron core so that the magnetic field formed due to varying current through the primary coil also passes through the secondary coil. Since the magnetic field through the secondary coil is changing a varying voltage is induced across the terminals of the secondary coil.

Activity 3.21

- Wind about 100 turns of insulated copper wire (30 swg) in one former as primary coil and about 200 turns of insulated copper wire (30 swg) in the other former as secondary coil.
- Insert the coils into two arms of a U shape soft iron core as shown in the Figure 3.36. Put the I shape soft iron arm above the two arms of the U shape core.
- Connect the terminals of the primary coil to a bicycle dynamo and an a.c. Voltmeter and the terminals of the secondary coil to another a.c. voltmeter as shown.
- Turn the bicycle dynamo quickly and record the reading of the two voltmeters Repeat the activity again by using coil having 200 turns as primary and a coil having 100 turns as secondary.

It is clear that in the first instance the reading of the voltmeter connected to the secondary coil is nearly equal to twice the reading of the voltmeter, connected to the primary and in the second instance the reading of the voltmeter connected to the secondary coil is nearly equal to half the reading of the voltmeter connected to the primary.

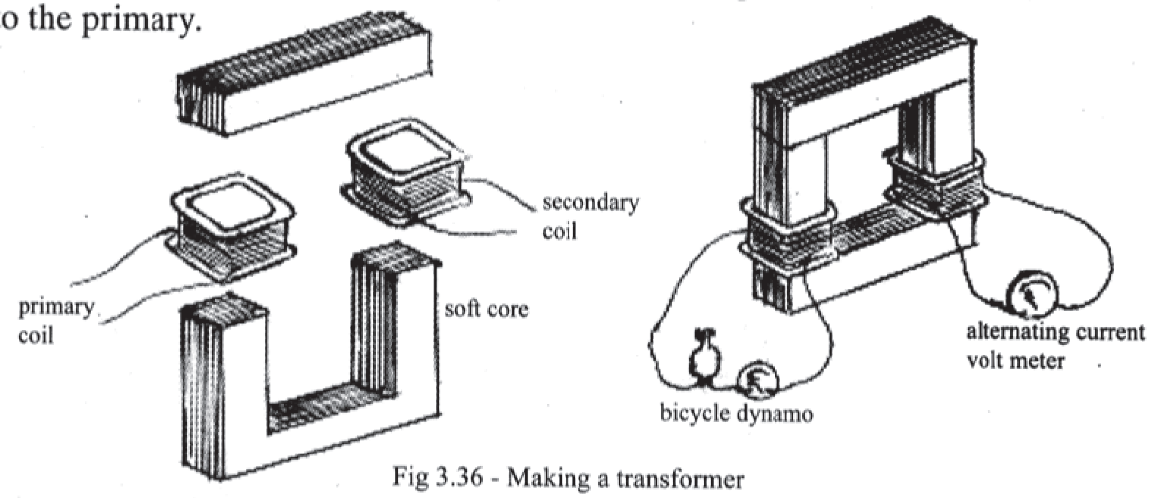


Fig 3.36 - Making a transformer

If the number of turns in the secondary coil is greater than that of primary the secondary voltage is greater than the primary voltage. So it is a **step-up transformer.**

If the number of turns in the secondary coil is less than that of primary the secondary voltage is less than the primary voltage. So it is a step-down transformer. To transfer electrical energy from power stations to your home the national grid uses step-up transformers. Since the output voltage is high, the current is low and the loss of power in the transference of electricity is less. Step-down transformers are used in industries for welding work. Since the output voltage is low, current is high and the heating effect is greater.

If the primary and secondary voltages of a transformer are Vp and Vs and the number of turns are np and ns respectively,

Then $$\boxed{\frac{n_p}{n_s} = \frac{V_p}{V_s}}$$

Exercises

(a) What is the technical term used for a liquid which conducts electricity?

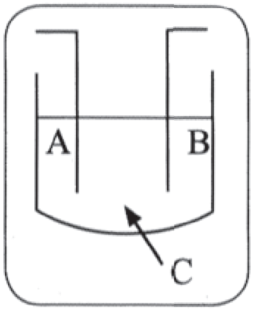
(b) Electrodes are named as anode and cathode according to the supply of electricty, Explain this.

(c) What do you call the apparatus used for electrolysis?

(d) How does electricity pass through an electrolyte?

(e) What are the factors which determine the mass of metal deposited in the process of electrolysis?

The diagram shows some apparatus used to copper-plate an object at B



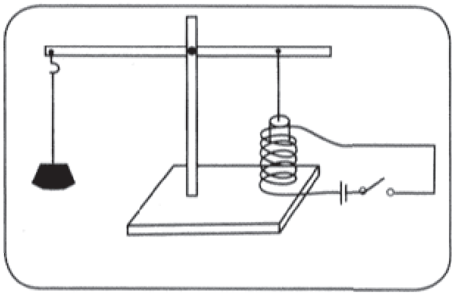
(a) What is the substance at A?

(b) What is the liquid C?

(c) What would be connected to the positive terminal of the battery?

(d) What are the changes that you can observe in the cathode and anode after electrolysis?

The diagram shows a design for an electricaly operated model lever which can be used to lift small weights.

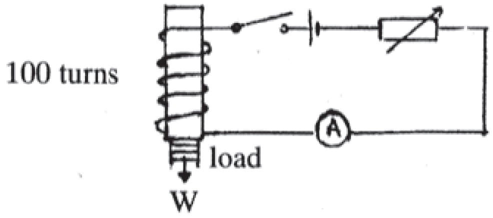


a) Explain, step by step how it works?

b) If you change the terminals of the battery, what will happen to the function of the lever?Explain this.

c) Suggest a way of lifting heavier weights using the same lever and explain it briefly.

4. Two students investigated how the strength of an electromagnet depends on the current.



Current (A)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Load (N)	0	0.2	0.8	1.6	3.0	5.4	10.0	13.6	14.6	14.9	15.0

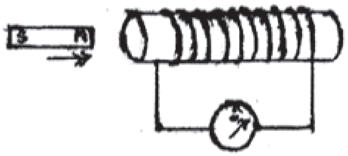
a) Use the data to plot a graph of load (Y -axis)against current (X-axis).

b) What load do you think could be supported if the current was
(1) 2.75 A (2) 6.0 A

c) Sketch the graph you would expect to get if the coil had only 50 turns

d) What is happening to the domains in the iron and why does the graph level off at the top?

5. A coil is connected to a centre - zero galvanometer.When the N-pole of a magnet pushes into the coil quickly, the galvanometer deflects to the right. What is deflection, if any is observed when



a) N- pole is pushes out of the coil

b) S- pole is pushes into the coil

c) The magnet is at rest in the coil

d) State three ways of increasing the deflection of the galvanometer.