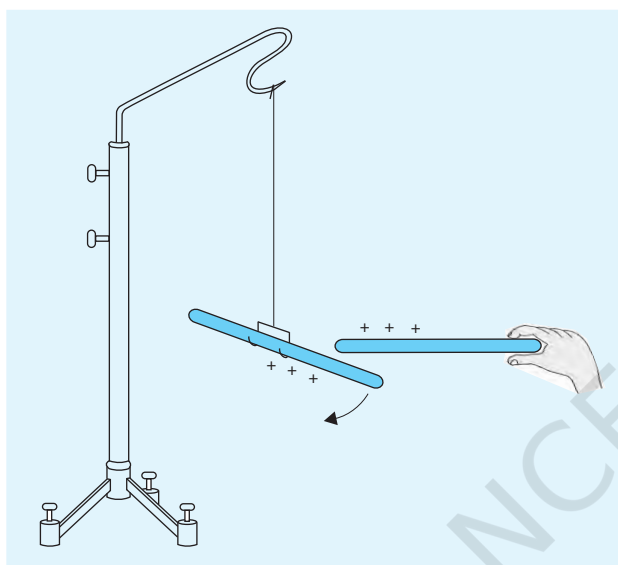
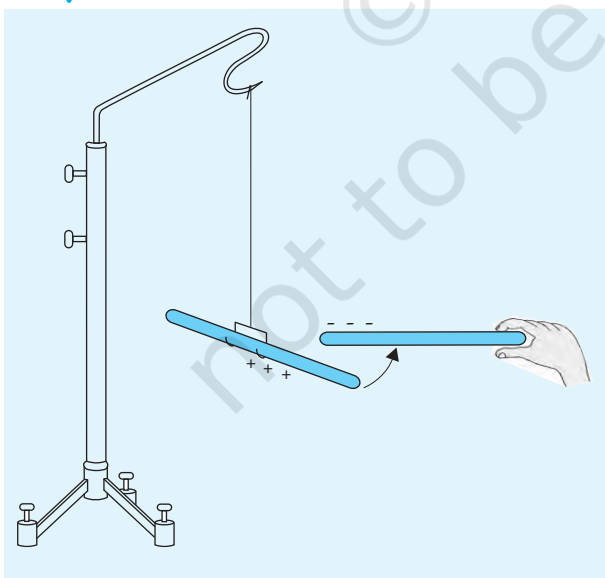


## DEMONSTRATIONS

# DEMONSTRATION 1



**Fig. D 1.1** Like charges repel each other



**Fig. D 1.2** Unlike charges attract each other

**To demonstrate that there are two kinds of charges and that like charges repel and unlike charges attract each other.**

(i) *Like charges repel each other*

Rub a glass rod with a piece of silk cloth. Place this rod horizontally in a wire frame suspended by silk or a nylon thread as shown in Fig. D 1.1. Rub a second glass rod similarly and bring the rubbed end of this glass rod near the rubbed end of the suspended glass rod. Observe, what happens. You will find that the two glass rods repel each other. Repeat the experiment with two ebonite rods rubbed against woollen cloth. In each case you will notice that like charges repel each other. Since both the glass rods have been rubbed in a similar fashion, the two must have acquired same kind of charge. From this experiment, we conclude that similar or like charges repel each other.

(ii) *Unlike charges attract each other*

Rub a glass rod with a piece of silk cloth. Place it as in the previous demonstration horizontally in a wire frame suspended by a silk or nylon thread. Rub an ebonite rod with a woollen cloth and bring the rubbed end of the ebonite rod near the rubbed end of the suspended glass rod (Fig. D 1.2). Observe, what happens. You will notice that the ebonite rod attracts the glass rod. This experiment shows that unlike charges attract each other.

**Notes**

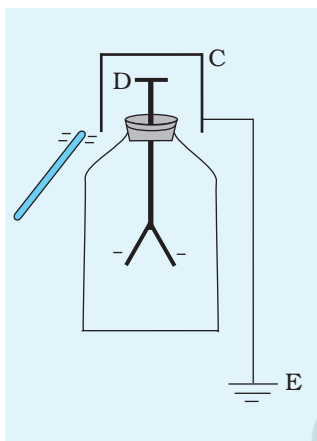
1. The charged ebonite rod behaves differently from the charged glass rod i.e., the ebonite rod acquires a different kind of charge.
2. It is a matter of convention that the charged glass rod and all other charged bodies which behave like it are said to be positively charged.
3. Similarly, the charged ebonite rod and all other charged bodies which behave similar to it are said to be negatively charged.

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# DEMONSTRATION 2

## To demonstrate electrostatic shielding.

Charge the electroscope either by contact or by the method of induction. The deflection in the electroscope indicates that it is charged. Bring a charged ebonite or glass rod (or a piece of thermocole) near the knob of the charged electroscope. An increase or decrease in the deflection indicates that the nature of charge on the rod is similar or opposite to that on the charged electroscope. Remove the charged rod away from the electroscope. Make sure that electroscope is still charged. If not, charge it again. Fix one end of a wire on the body of the metal can with the help of a tape. Fix other end of this wire on the ground. The metal can is now earthed. Now suspend the grounded tin can from a laboratory stand such that its open end is towards the ground. Gradually, lower the metal can in such a manner that it completely covers the knob of the charged electroscope. Take care that the metal can does not touch the knob or the body of the electroscope while it covers the knob from all sides (Fig. D 2.1). Note that the electroscope is still charged which is indicated



**Fig. D 2.1** The earthed can C shields the disc D from the field of ebonite rod

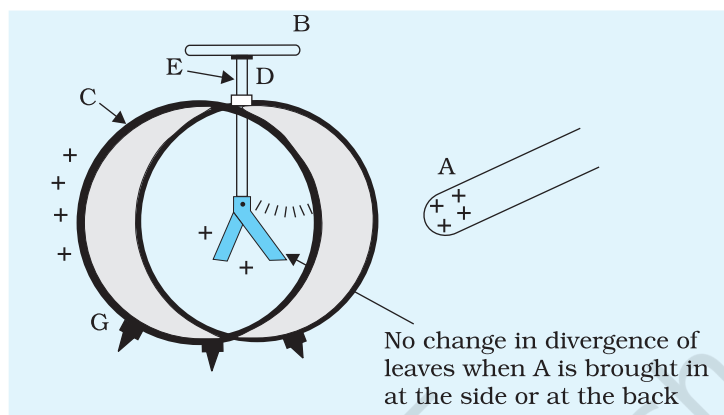
by deflection of its leaves or the needle. Again bring a charged ebonite or glass rod near the knob of the electroscope on the outside of the metal can. Take care that the charged rod does not touch the metal can. Is there any change in deflection in the charged electroscope as was observed earlier? If not, it means that the earthed metal can is providing an electrostatic shield to the charged electroscope. Discuss your observations, especially the role of grounded metal can. The presence of a charged ebonite or glass rod near the knob of the electroscope or the outside of the *metal can* hardly affects the leaves of the electroscopes. This is electrostatic shielding.

### Notes

1. You will see that a sensitive gold leaf electroscope which is supposed to measure charge accurately needs to be shielded properly so that the neighbouring charges do not affect the leaves. In order to shield the electroscope properly, it is made in a metal can C (Fig. D 2.2). In order to be able to see the leaves, the lid of the can

\* An improvised electroscope can be easily made using a glass tumbler and aluminium foil. Refer to Appendix-1 for detail.

is replaced by a circular glass sheet G. Thus there is no change in the divergence of leaves if an undesirable charge A is brought in at the sides or at the back of the electroscope. The stem E holding the leaves may be insulated from the earthed can by an insulated stopper D.



**Fig. D 2.2** A shielded electroscope

# DEMONSTRATION 3

## To demonstrate

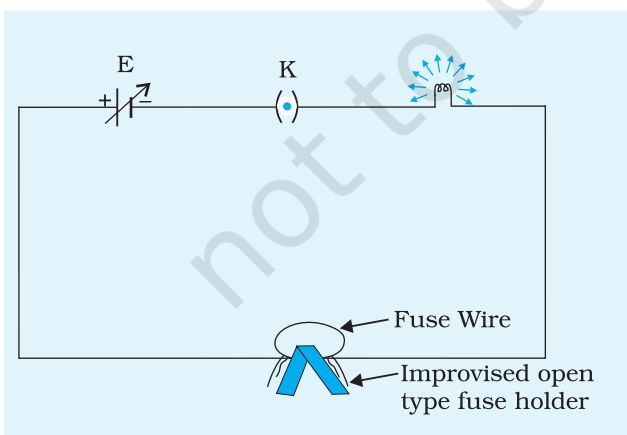
(i) **the use of an improvised fuse\* that melts with the flow of a certain current through it, and**

(ii) **different kinds of fuses used in everyday life.**

(i) *Demonstrating use of an improvised fuse that melts with the flow of a certain current through it*

Take a small piece of suitable fuse wire (say 5 A rating) and fix it across the improvised open type fuse (see Appendix 4). Connect this electric fuse in series with a 6 V lead accumulator, a 6 V (18 W or 24 W) electric bulb (fixed in a holder), and a plug key as shown in Fig. D 3.1. Plug the key and see if the bulb glows. Observe the fuse wire. See, if it remains unaffected. Next, unplug the key to break the circuit. Short circuit the bulb by joining its terminals with a thick copper wire. Again plug the key for a short duration, the bulb would not glow this time. Does the fuse wire snap quickly? Observe carefully.

(ii) *Demonstrating use of different kinds of fuses used in everyday life*



**Fig. D 3.1** Circuit to demonstrate the working of a fuse

Collect different types of fuses (i) used for different electrical appliances (ii) those used in the mains having 5 A current rating and (iii) those having 15 A current rating. Observe these and record your findings about the wire thickness. Take a switch board used with the electric mains. This switch board should have a fuse socket, a bulb holder (with a 100 W, 230 V electric bulb) and a switch in series with the fuse. It should also have a socket with the switch for connecting separately an electrical appliance, say, an electric heater in series with the fuse. Fix up a 5 A fuse wire in the socket for the fuse before plugging the switch board to the mains. Switch the electric bulb on by using the switch provided on the switch board. The bulb would glow. Observe the fuse wire.

\* See Appendix 4 for making an improvised open type fuse holder.

Is it intact? Switch off the bulb and unplug the board from the electric mains. Take a single strand of copper wire from the common flexible cable used as connecting lead with a table lamp and replace it in the fuse socket. Again plug the board with the mains and switch the bulb on. Does the bulb glow and keep glowing now? Unplug the board and see the effect on the improvised fuse wire. Does it change in colour? Next, connect an electric heater (1500 W or 2000 W, 230 V) to the board. Plug on the board to the electric mains. Switch on the heater. Does the improvised fuse blow off now? Unplug the board from the mains and observe the fuse. Do you find it to have melted partly (i.e. a small length of it)? Why should electric current not be passed for long duration in the circuit used in the above experiment after the 6 V bulb has been short circuited?

### Notes

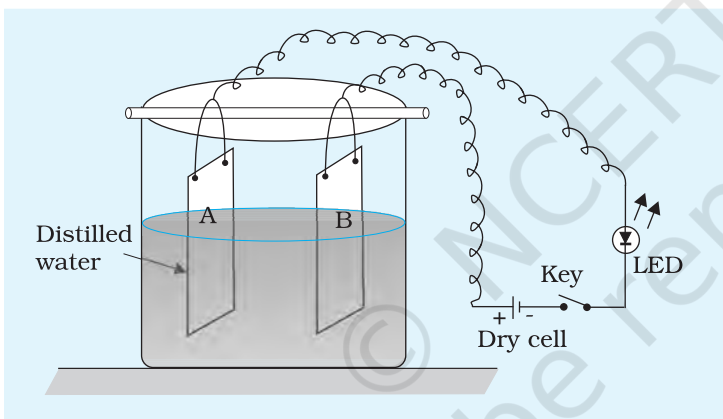
1. In case you have not made the improvised open type fuse holder, just hold the fuse wire ends in two crocodile clips. The open type fuse holder described in appendix 4 only makes a better demonstration.
2. To check the working status of fuse, you can check it using a resistance meter on “Continuity check”. If a beep is heard then fuse is ok and if no beep is heard, fuse can be assumed to be blown off.

# DEMONSTRATION 4

**To demonstrate that a higher resistance is offered by distilled water and a low resistance when sodium chloride is added to it.**

Take two electrodes A and B (aluminium strips or plates hanging from a wooden rod by naked copper wires will do) and dip them in a beaker about half filled with distilled water. Make a connection of the electrodes with a dry cell (1.5 V), a tapping key and a light emitting diode (LED), as shown in the circuit diagram (Fig. D 4.1). Check if the LED has been connected properly in the circuit as it conducts electric

current in one direction only. Ensure that its positive terminal is connected to the positive terminal of the cell to make it glow. For checking this, take the electrodes A and B out of water. Touch them with each other for a while and see that the LED glows. Next, place the electrodes A and B in the water and separate them with maximum gap of water. Does the LED glow now? Bring the two electrodes A and B nearer, so as to leave a small gap in water. See, if the LED glows? Add a pinch of common salt to the water while the plates are as far apart as when LED was not glowing. Does the LED glow now? Draw the conclusion on the basis of your observations.



**Fig. D 4.1** An arrangement to demonstrate the effect of adding salt on the electrical conductivity of distilled water

## Notes

1. If you replace the LED by a multimeter which has various ranges for measuring dc current and add salt to water in equal measured steps, then you can find concentration of salt in each case and also the resistance of the solution. Do not alter the position of the two plates during the experiment. Thus you can study how the resistance varies with concentration of salt. Students may take up this experiment as project work.
2. In general, the resistivity of an electrolyte (solution of a salt whose molecules break up into anions and cations) decreases with

increasing concentration. This is due to the fact that as concentration increases, greater number of charge carrier (+ve and -ve ions) are available, which move in the electric field created between the two electrodes when a potential difference is applied between them.

3. Whereas in a metal wire, the drift of only the negative charges (electrons) contributes to the flow of current, in case of an electrolyte the drift of negative ions as well as positive ions contribute to the flow of current. It is a zig-zag motion coupled with a slow drift in the direction of the electric field.

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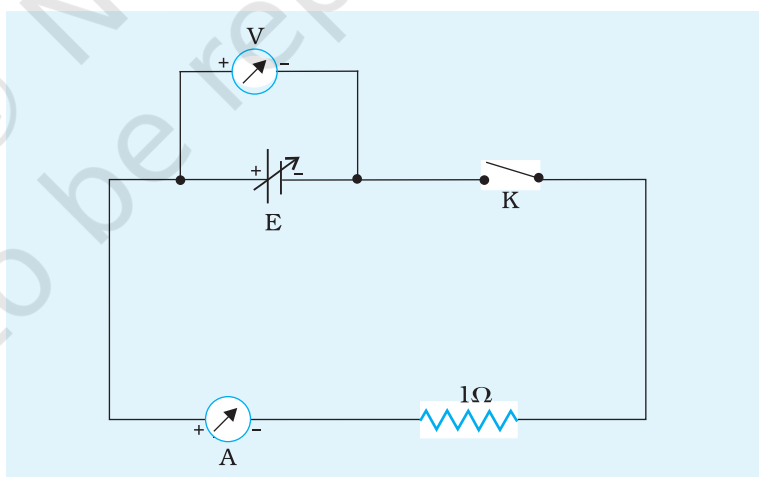


# DEMONSTRATION 5

## To demonstrate the working of a lead accumulator.

Set up the electric circuit as shown in Fig. D 5.1. Connect a resistance of  $1\ \Omega$  and an ammeter in series with the accumulator. Connect a voltmeter across  $6\ \text{V}$  accumulator. Circuit should not remain closed for more than one or two seconds. For this purpose use a tapping key in the circuit and not a plug key. When the tapping key is pressed, you will observe a minute fall in the voltage of the battery indicated by the voltmeter. Record voltmeter ( $V$ ) and ammeter readings ( $I$ ). Repeat the observation by varying the current flowing in the circuit. For this you will need to connect a rheostat in the circuit. Record your observations in the observation table and calculate internal resistance

of the accumulator  $\left( r = \frac{E - V}{I} \text{ ohm} \right)$ .

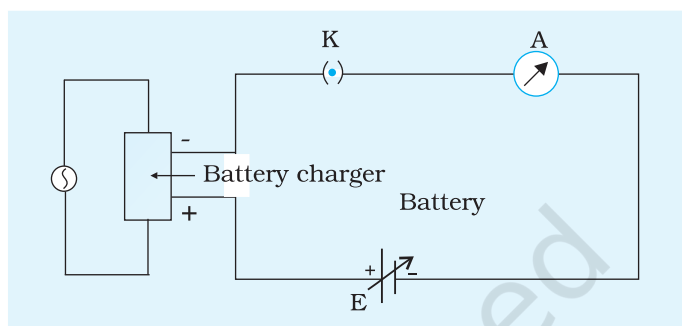


**Fig. D 5.1** Circuit to demonstrate the low internal resistance of a lead accumulator

### Notes

1. Examine the lead grid taken out from an old lead accumulator. Identify its positive and negative electrodes. Plates of lead oxide function as positive electrode and spongy lead functions as negative electrode.

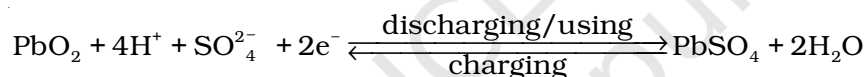
- A low resistance is connected in series with the 6 V accumulator in order to prevent it from damage. It also minimises heating up of connecting wires which may cause a burn.
- Never short circuit the battery, as life of the battery is greatly reduced. Some equipments like an ammeter of smaller range may get damaged by the heavy current produced.
- It should be recharged when voltage of any cell in it falls to 1.85 V from the normal range of 2.0 V. For this purpose it should be connected to battery charger as shown in Fig. D 5.2.



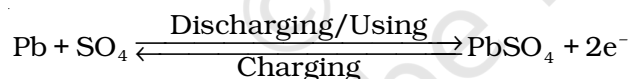
**Fig. D 5.2** Circuit for charging a battery with the help of a battery charger

- The chemical reaction during its discharging/use and during charging are as follows:

*Positive electrode*



*Negative electrode*



Thus  $\text{PbSO}_4$  is formed on both electrodes during use and an over used cell is said to become “sulphated”. Also, formation of water and consumption of sulphuric acid and consequent decrease in density of the acid takes place.

- Effect of over charging a battery is loss of water by electrolysis and hence the need to check its water level continually and bring it up by adding distilled water. This process is sometimes referred to as *topping up* with distilled water.
- Measuring emf of an acid accumulator is not the best method to test whether it needs recharging. This is because ordinary voltmeters may not measure voltage quite accurately, a voltage of 1.85 V may be read as 1.9 V.

Density of the acid inside is a much better indicator. In a charged accumulator, it is 1.26 kg/L. When it falls to 1.20 kg/L, the

accumulator needs to be recharged. Measure density of acid inside the accumulator by the special hydrometer made for this purpose and infer the condition of that accumulator. The density should be measured only after topping it up with distilled water.

8. Sulphuric acid for a new battery is made by pouring slowly the concentrated acid into distilled water, 3-times its volume. When this acid cools, it is filled in the new lead acid battery/lead accumulator and then the battery is charged overnight.

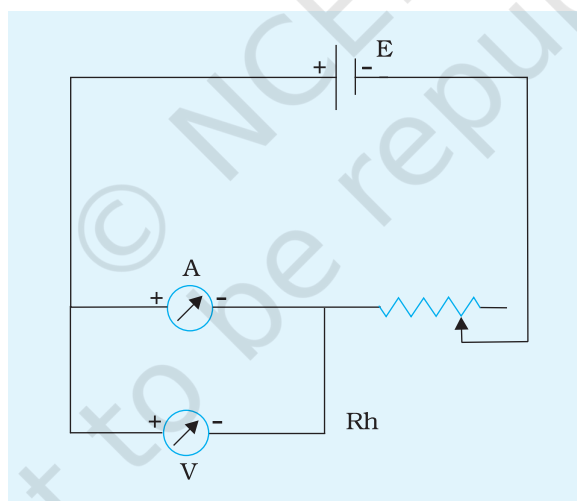
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# DEMONSTRATION 6

**To demonstrate that a current measuring device has finite non-zero resistance.**

Make a circuit using a cell, key, rheostat, ammeter and a digital multimeter (DMM) as shown in Fig. D 6.1. Close the key and then adjust the rheostat so that a current of the order of 1 A flows through the ammeter. Observe the voltage drop (V) across the ammeter with the voltmeter DMM in dc mV range. Record your observations and find the resistance of the ammeter by the ratio of the voltage drop V to

the ammeter reading,  $I \left( R = \frac{V}{I} \text{ ohm} \right)$ . Repeat the procedure for different ammeter readings and calculate mean value of the resistance.



**Fig. D 6.1** Measurement of the resistance of an ammeter

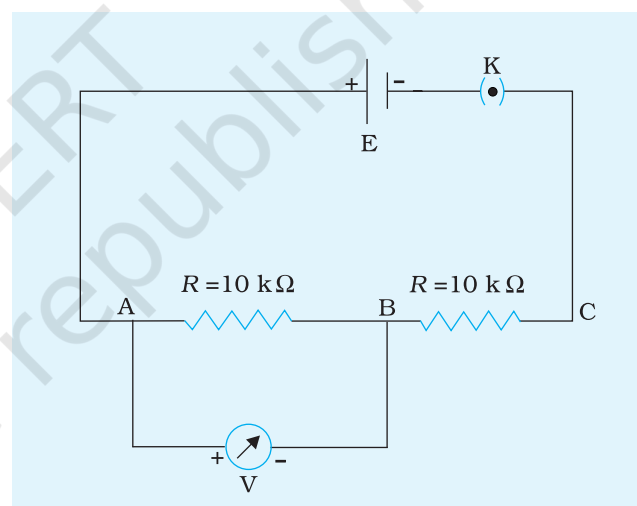
## Notes

1. Though it is commonly said that ammeters are connected in series in a circuit as they have no resistance. This is an ideal case, but in practice this is not exactly so. An ammeter has finite non-zero resistance.
2. The above experiment can be demonstrated by using a milliammeter (having resistance of the order of  $10 \Omega$ ) or a microammeter (having resistance of the order of  $k \Omega$ ) also.

# DEMONSTRATION 7

**To demonstrate that a voltage measuring device has non-infinite resistance.**

Make circuit as shown in Fig. D 7.1 using a cell, a key, a voltmeter and two carbon resistors of  $10\text{ k}\Omega$  each. Now close the key and observe the voltmeter reading by connecting it across one of the two carbon resistors. Calculate the resistance of the voltmeter by using Eq. D 7.1. Repeat the experiment using more cells varying the value of  $E$ .



**Fig. D 7.1** Measurement of resistance of a voltmeter

## Notes

It is commonly said that as voltmeter is connected in parallel, its resistance is infinitely large. But that is not so in practice as this is an ideal case. Each voltmeter, particularly the analog meters have non-infinite resistance.

Denoting resistance of the voltmeter by  $R_V$  and current by  $I$ , the circuit (Fig. D 7.1) is analysed as follows:

$$I = \left( \frac{E}{R + \frac{RR_V}{R + R_V}} \right)$$

Hence, the voltmeter reading i.e., the voltage across AB

$$V = \left( \frac{E}{R + \frac{RR_V}{R + R_V}} \right) \frac{RR_V}{R + R_V} = \frac{ER_V}{R + 2R_V}$$

$$R_V = \frac{VR}{E - 2V} \quad \text{(D 7.1)}$$

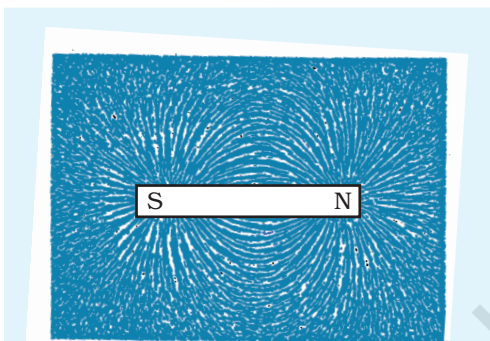
If  $R_V$  approaches infinity then from equation D 7.1,  $V = \frac{E}{2}$ . In reality,

this is much less than  $\frac{E}{2}$ .

# DEMONSTRATION 8

## To demonstrate the magnetic field lines with the help of iron filings.

Take a strong bar magnet of size 7.5 cm or 10 cm. Place the magnet under the glass sheet at the centre. Adjust the glass sheet horizontally by supporting it with four wooden blocks and by checking it with a spirit level. Sprinkle fine dry iron filings around it on the glass sheet. Now gently tap the glass sheet several times. Observe what happens. You will find that iron filings arrange themselves in a regular pattern as shown in Fig. D 8.1. This happens because under the influence of magnetic field, iron particles behave like small magnets and form long chains along the lines of the magnetic field. Therefore they align themselves along the magnetic field lines. Note that the long chains of the iron particles start from the north pole of the magnet, end at the south pole and avoid contact with middle portion. Observe the pattern of lines carefully and try to infer the relation between the gap of two adjacent lines and strength of magnetic field in this gap. Report what inference do you draw from it.



**Fig. D 8.1** Iron filings near a bar magnet align themselves along the magnetic field lines

### Notes

1. The pattern of iron filings on glass sheet may be fixed by spraying clear lacquer paint on the glass sheet. Let it become dry. It can be put up as a permanent display.
2. Suppose you perform the experiment with a magnetic compass as follows. You place the magnet below a thin glass plate (or a plane sheet of thin plywood or thick cardboard). Fix a paper on the plate and adjust it horizontal with a spirit level. Then plot the magnetic field lines with the magnetic compass. What kind of lines do you expect to get? Does any line make a complete loop through the magnet? You may refer to *Laboratory Manual Science, Class X, (NCERT, 2008 Experiment 52, pp.217-220)* for an elementary method.

# DEMONSTRATION 9

**To study the effect produced on magnetic field pattern by bringing various materials in the surrounding space of a bar magnet.**

## PROCEDURE

Take a drawing board and fix a plane sheet of paper over it using molten wax of a candle. Draw two lines perpendicular to each other say NS and EW at the centre of the sheet. Place a magnetic compass at the centre of the sheet and rotate the drawing board till magnetic needle of the compass box exactly overlaps the line NS. In this case, the needle will point along the north-south direction. During this process, tap the board gently to ensure that friction between the needle and its pivot is minimised and that it rotates freely. Draw an outline of the drawing board with a chalk. Position of the board should not be disturbed throughout the experiment. Place the magnet symmetrically in the middle of the line NS so that axis of the magnet is along the north-south direction and its north pole points towards north. In this situation magnetic axis is also coinciding with one of the lines drawn on the paper. In this way you have placed the magnet in magnetic meridian. With the help of magnetic compass, map its magnetic field lines. Find the points where horizontal magnetic field of the earth balances the magnetic field of the magnet. These are the neutral points. You get a pattern similar to that obtained in Demonstration 8. Put all magnets and magnetic substances away from the drawing board while demonstrating this experiment. Now replace the drawing paper, place the magnet in same position and place a bar of soft iron at some distance from the magnet, say near north pole of the magnet. Again map the magnetic field of the magnet. What is the pattern like now? You observe that it is quite different from the pattern of magnet alone. Many lines tend to pass through or close to the soft iron bar. Neutral points also move away from the magnet. Test the polarity at the ends of the iron bar with the help of a compass. You will find that it has become a magnet. Repeat the experiment with a bar of aluminium, copper, nickel, chromium and plastic material. Observe the pattern of lines.



**Notes**

1. The end of the iron bar where many lines starting from north pole of the magnet enter the iron bar, behaves as the south pole and the other end behaves as the north pole. Thus the iron bar becomes an induced magnet.
2. You will observe that patterns of magnetic field lines due to a bar magnet are not altered by the presence of copper, aluminium and plastic bars. These materials do not become induced magnet.
3. If you repeat the above experiment using a bar of nickel or cobalt, you will find that pattern of lines is altered, though not so much as in the case of the soft iron bar.
4. Materials by which the pattern of magnetic field lines is altered are called ferromagnetic materials.
5. If a magnetised needle is suspended to swing freely in all planes, it sets itself pointing to the Earth's magnetic North and South poles, at an angle to the horizontal. The vertical plane through the axis of such a needle is termed the magnetic meridian.

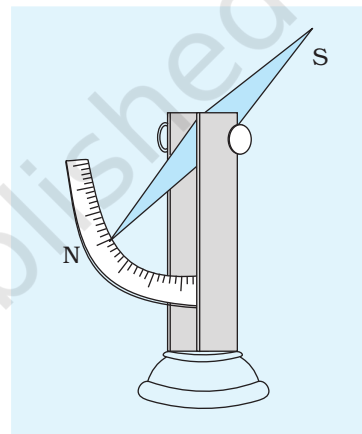
# DEMONSTRATION 10

**To show that the earth's magnetic field has both vertical and horizontal components.**

You need a dip needle and a compass needle to demonstrate this experiment.

### *Dip needle*

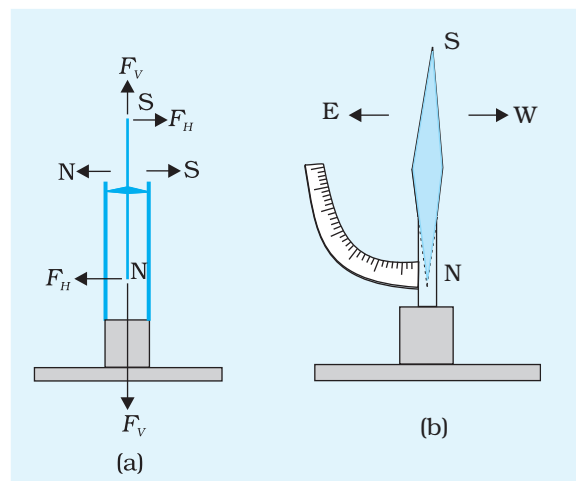
Dip needle is a compass needle free to rotate in a vertical plane. Its horizontal axle about which it rotates, passes through its centre of gravity. Thus gravitational force has no tendency to keep it in any preferred direction. The needle and its frame can rotate about a vertical axis so that its vertical plane of rotation can be set in any direction (Fig. D 10.1). A  $90^\circ$  circular scale is also attached to the frame on which you can observe at what angle to the horizontal the needle comes into equilibrium.



**Fig. D 10.1** The dip needle

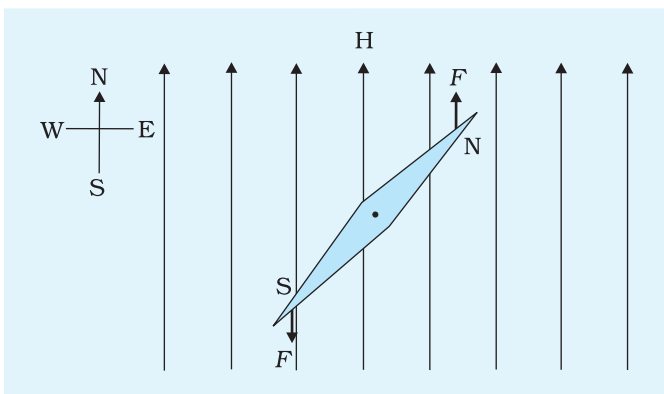
### *Vertical component*

Keeping the vertical plane of rotation of the dip needle in north-south direction (i.e. in magnetic meridian), observe the reading of the needle on the circular scale. Repeat the above observation keeping the plane of rotation at various angles to the magnetic meridian. Observe the direction of plane of rotation of the needle when the deflection in the needle is largest i.e.  $90^\circ$  and the needle becomes vertical [Fig. D 10.2(a)]. Is it along east-west direction? Now, rotate the plane of needle in magnetic meridian. Observe the reading on the circular scale. In this position the horizontal component of earth's magnetic field is fully effective and the needle points in the direction of the resultant magnetic field. The reading on



**Fig. D 10.2 (a), (b)** Dip needle becomes vertical when its plane is in East-West direction

the circular scale in this position gives angle of dip (Fig. D 10.4).



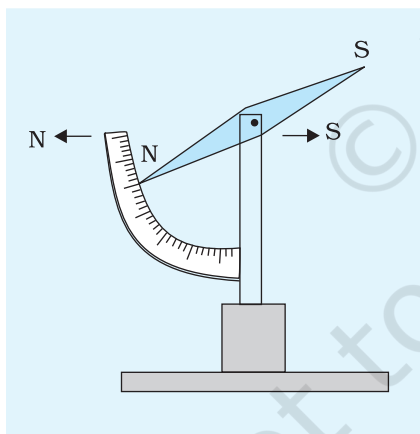
**Fig. D 10.3** A compass needle experiences forces  $F$ - $F$  in horizontal plane in the earth's magnetic field

*Horizontal component*

Take a compass needle. Place it horizontally on a pointed support so that it is free to rotate in a horizontal plane. You find that it comes into equilibrium along north-south direction only. If you leave it in any other position, it moves to north-south direction. It implies that forces are acting on its poles as shown in Fig. D 10.3. Earth's magnetic field is capable of applying a force in a horizontal plane towards north direction on the north pole of the compass needle and an equal opposite force on the south pole. Hence earth's magnetic field has a horizontal component.

**Notes**

1. When the dip needle reads  $90^\circ$ , the vertical component of earth's magnetic field pulls the north pole of needle downwards and pushes the south pole upwards. The horizontal component is ineffective because forces  $F$  applied by it on the poles of the magnetic needle are perpendicular to the plane of rotation of the needle as shown in Fig. D 10.2(b).
2. The north direction indicated by the compass is usually not the geographic north direction. The angle between the geographic north and the north shown by a compass needle is called the magnetic declination or simply declination. Only if you know this angle, you can find geographic north direction with the help of a compass.
3. The vertical component of earth's magnetic field and angle of dip can also be demonstrated with the help of a dip circle which is a more elaborate instrument.



**Fig. D 10.4** In the magnetic meridian, the dip reads the angle of dip

# DEMONSTRATION 11

## To demonstrate repulsion/attraction between two conductors carrying current in opposite/same direction.

You need following apparatus and materials to demonstrate this experiment:

A source of dc voltage (or battery eliminator) (6 V, 3 A), 2 m copper wire (18 or 20 SWG), a wooden board (8" × 12"), 2 wooden supports (1.5" × 1.5" × 12"), connecting wires, 4-5 nails, 6 screws, two thin metal strips (1.5" × 3"), a key and a low resistance rheostat (~ 10 Ω).

Figure (D 11.1) shows two long parallel conductors  $a$  (AB) and  $b$  (XY) separated by a distance  $d$  carrying current  $I_a$  and  $I_b$  respectively. According to right hand rule the direction of the magnetic field due to current in conductor AB acting on conductor XY is downward. Its

magnitude is given from Ampere's circuital law,  $B_a = \frac{\mu_o I_a}{2\pi d}$ . The

conductor  $b$  carrying a current  $I_b$  will experience a sideways force due to the field  $B_a$ . The direction of this force is towards the conductor  $a$  (Fig. D 11.2). The magnitude of this force on a segment  $L$  of  $b$  due to  $a$  is,

$$F_{ba} = I_b L B_a$$

(D 11.1)

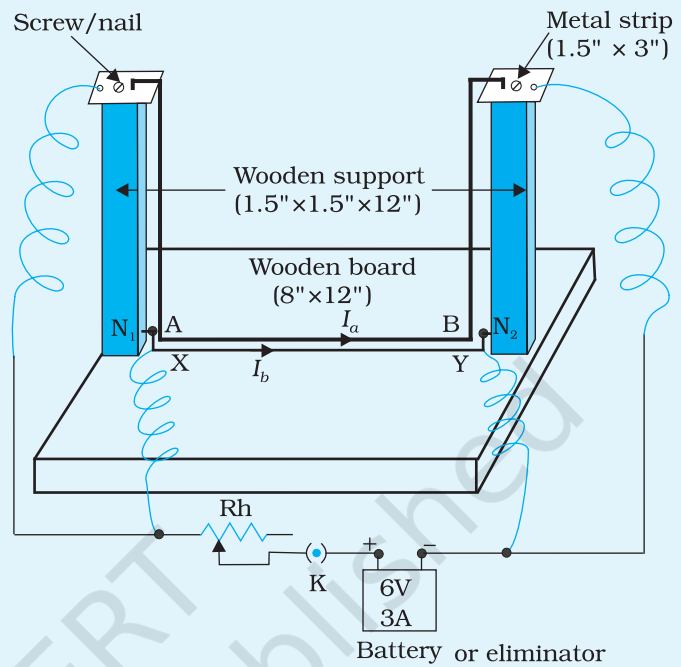
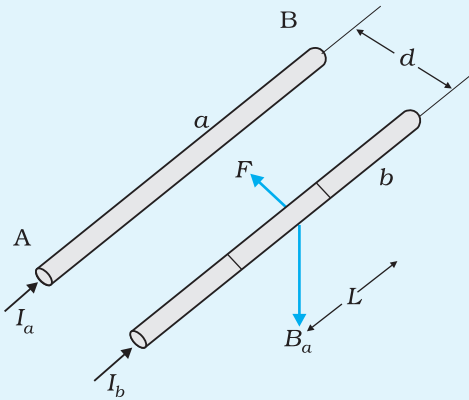
In other words, we can say that parallel conductors carrying current in the same direction attract each other with a force

$$F_{ba} = \frac{\mu_o I_a I_b L}{2\pi d}$$

(D 11.2)

Similarly, we can establish that parallel conductors carrying current in opposite direction repel each other.

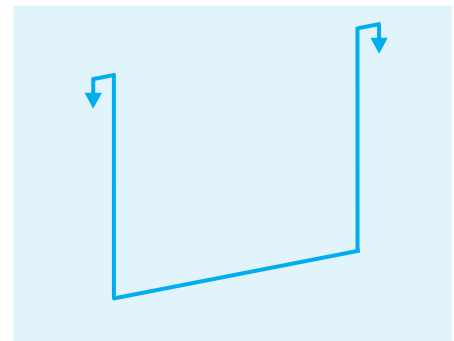
Fix both the wooden supports in vertical position near the edge of the wooden board using nails or screws. Experimental set up is shown in Fig. D 11.2. Fix metal strips (1.5" × 3") at the top of these supports using screw or nail. Take about 80-85 cm long thick copper wire and bend it as shown in Fig. D 11.3. Using sand paper or a file, make the ends of the wire sharp tipped. Now place this bent wire on pillar tops



**Fig. D 11.1** Two long straight parallel conductors carrying steady currents  $I_a$  and  $I_b$  and separated by a distance  $d$ .  $B_a$  is the magnetic field set up by conductor a at conductor b.

**Fig. D 11.2** Repulsion/attraction between two conductors carrying current in opposite/same direction respectively

as shown in Fig. D 11.2. Fix two straight nails  $N_1$  and  $N_2$  close to the lower portion AB of suspended  $\Gamma$  shape wire. Fix tightly a thick copper wire XY between the nails  $N_1$  and  $N_2$  such that the separation between AB and XY is about 1 or 2 mm. Now make electrical connections using a rheostat, a key and a battery as shown in Fig. D 11.2. When the key K is plugged, the current in the wires AB and XY flows in the same direction. We observe that wire segment AB is attracted towards the wire XY. On reversing the connections of the fixed wire XY we observe that the suspended wire segment AB is repelled away from the wire. The activity can be repeated by (i) changing the length of XY, (ii) by changing the strength of the current. We observe that currents flowing in the same direction attract each other and oppositely directed current repel each other.



**Fig. D 11.3**  $\Gamma$  shaped copper wire

**Notes**

1. If  $F_{ba}$  represent the magnitude of the force  $F_{ba}$  per unit length, then from Eq. E 11.2.

$$F_{ba} = \frac{\mu_0 I_a I_b L}{2\pi d}$$

[\(D 11.3\)](#)

Eq. 11.3 is used to define the SI unit of electric current, ampere (A), which is one of the seven base units.

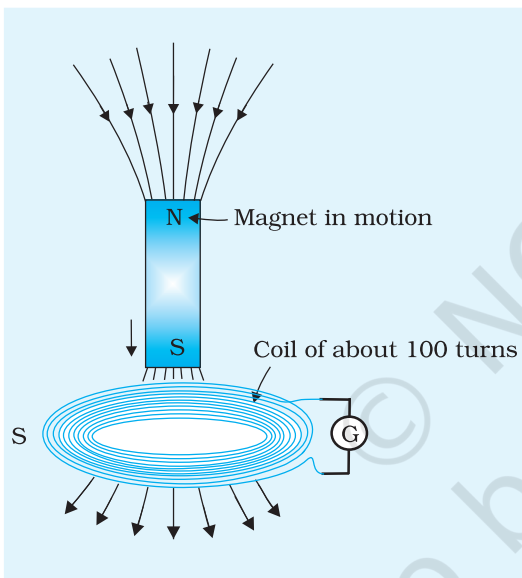
2. Care should be taken not to pass current for a longer period as it may heat the wire.

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# DEMONSTRATION 12

**To demonstrate the production of induced emf in a coil due to the movement of (i) a magnet towards and away from it (ii) similar coil carrying current towards and away from it.**

(i) *Demonstrating production of induced emf in a coil due to the movement of a magnet towards and away from it*



**Fig. D 12.1** Magnet in motion produces an induced emf in coil S

Connect the two ends of the coil of 100 turns with the terminals of a sensitive galvanometer as shown in Fig. D 12.1. Hold the magnet in your hand and bring it towards the coil with a large speed. It may be inserted right into the coil. You will observe some deflection of the galvanometer needle, which is a measure of the induced current that flows due to an induced emf generated in the coil. Now move the magnet away from the coil with roughly the same speed. You will observe the same deflection, but now in opposite direction. In the former case, the magnetic flux passing through the coil was increasing while in the latter case, it was decreasing. Note also that the deflection is observed only when the magnet is in motion. It shows that the induced current flows as long as the flux is changing. Repeat the above steps by varying the speed of the magnet. Observe and record your observations.

You will find that when you move the magnet towards the coil, the magnetic flux  $\phi_B$  passing through the coil increases and when you move it away from the coil, magnetic flux decreases. If you repeat the demonstration by moving the magnet faster, you will observe greater deflection in each case. It shows that higher the rate of variation of the magnetic flux, the greater is the induced emf in the coil. This is a qualitative demonstration of the Faraday's law which states that the induced emf is directly proportional to the rate of change of magnetic flux through the circuit.

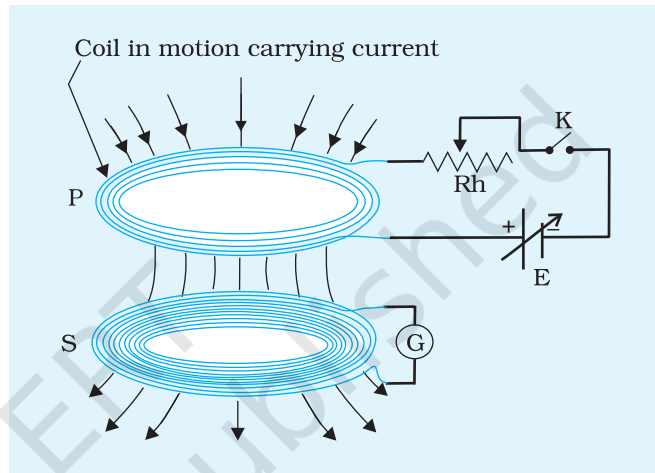
### Notes

1. In the case of closely wound coil of  $N$  turns, change of magnetic flux associated with each turn, is the same. Therefore, the

expression for the total induced emf is given by  $E = -\frac{Nd\phi_B}{dt}$ .

2. DCC wire has two layers of cotton thread wound on it for insulation and is quite convenient for low voltage experiments in the laboratory.
- (ii) *Demonstrating production of induced emf in a coil due to the movement of similar coil carrying current towards and away from it.*

Take the coil S used in Demonstration 12 (i) above and connect it with the galvanometer. Take another coil P of same diameter having 50 number of turns. Connect it with a battery and a rheostat through a key as shown in Fig. D 12.2. Move this coil towards or away from the coil S as the magnet was moved in Demonstration 12 (i). The coil P acts as a magnet due to the current flowing in it. Observe a deflection in the galvanometer. This is an evidence of production of induced emf in coil S. Note and



**Fig. D 12.2** Current carrying coil P in motion produces an induced emf in coil S

observe that the deflection in the galvanometer is larger when coil P moves faster towards coil S. Without changing the position of P change the current flowing through it using the rheostat. You will observe change in the galvanometer deflection as the magnitude of current through the coil changes. Now place the coil P on the coil S, separated by an insulator like a glass plate or cardboard sheet. Do not move coil P. Observe the deflection in the galvanometer connected to S as you switch on the current in P. Switch off the current in P. You will observe that direction of deflection in the galvanometer is opposite. Now allow a constant current to pass through the coil P. As current is not changed, magnetic field is also not changed. Coil P is just above S, so almost all the lines of magnetic field of P pass through S. Slide P on the glass plate so that common area of the two coils decreases. Observe deflection in galvanometer in the same direction as that when current was switched off in P. Next increase the common area of the coils and observe deflection in the galvanometer. It is in the same direction as that when current was switched on in P.



**Notes**

1. When the current is varying, it produces a changing magnetic field, which in its turn induces an emf in the conductors through which the magnetic field lines pass.
2. From the above observations it is clear that motion of the coil or magnet is not the important factor. It is the change of magnetic flux produced by the coil P in the area occupied by S which causes induced emf in the coil S.
3. It is the magnetic flux produced by P and passing through S, whose change causes induced emf in S, whether the change is done
  - (i) by motion of P which changes the field strength in S and thus magnetic flux through the coil S;
  - (ii) by change of current in P; or
  - (iii) by change of area of P facing the coils.
4. The above demonstration can be repeated by connecting battery, rheostat and key to the coil S and galvanometer to the coil P.

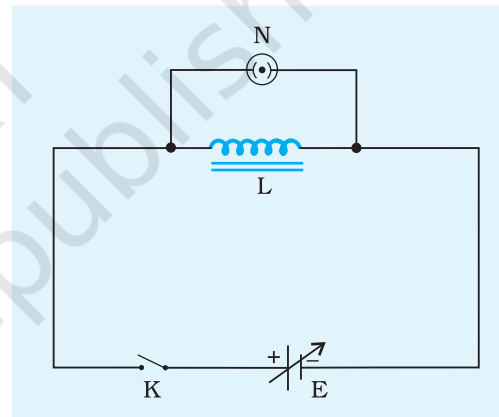
# DEMONSTRATION 13

## To demonstrate that a large emf is induced when direct current is switched off in an inductive circuit.

Make a circuit as shown in Fig. D 13.1. N is a neon lamp fitted into holder across the two terminals of the coil connected in series with the battery. Close the key K and observe that the neon lamp does not light up. Now open the key K. The lamp is seen to flash indicating that in the inductor L, a large induced emf has been generated. The induced emf tends to maintain the flow of current through the coil after the source of emf has been switched off.

### Notes

1. The back emf in an inductive coil cannot exceed the emf of the battery when the current is switched on, because the resultant of the two must pass (conventional) current from positive terminal of the battery. However when dc is switched off, the situation is different. A large emf is generated in the inductor L tending to maintain the flow of current through the coil and lamp is seen to flash.
2. According to Faraday's law of electromagnetic induction, this large induced emf is generated due to the fact that when key is opened, current through the battery instantly stops. Thus, rate of decrease of magnetic flux in the coil is very large and a large emf is induced, which passes a pulse of electric current in the lamp.
3. After switching on the circuit, neon lamp does not glow. This is because the striking voltage for neon lamp (about 150 V) is considerably larger than the modest 2 to 3 V, which battery E is capable of supplying.
4. When the source of emf (the battery) has been cut off, where does the energy which flashes the neon bulb come from? It comes from the magnetic field associated with the coil L with current passing through it. Thus this experiment also vividly demonstrates that a magnetic field contains energy.



**Fig. D 13.1** When current in the circuit is stopped then only, the neon bulb N flashes.

5. The phenomenon of induced emf existing in the same coil in which the changing current passes is called self inductance. Mathematically, the self inductance ( $L$ ) of a coil is defined by the equation

$$E = -L \frac{dI}{dt}$$

where  $E$  is induced emf and  $\frac{dI}{dt}$  is the rate of change of current

passing through the coil. Negative sign in the above equation only indicates that the direction of induced emf is opposite to the change in current and tends to maintain the current constant.

6. Mechanical analogy of self inductance:

The above equation is quite similar to the following equation in mechanics. Force exerted by a moving object on any object due

to its inertia =  $-m \frac{dv}{dt}$ , where  $m$  is mass and  $\frac{dv}{dt}$  is rate of change

of velocity i.e. acceleration of the body. Here too, the negative sign indicates only that the direction of force is opposite to the change in velocity and tries to maintain the velocity constant. Thus, the role of  $L$  in an electric system is similar to that of mass, in a mechanical system. For example, switching on a dc current in the coil is analogous to accelerating a hammer. Therefore, switching off this dc current is analogous to the hammer striking a nail when its motion is instantly stopped and it applies a large force on the nail.

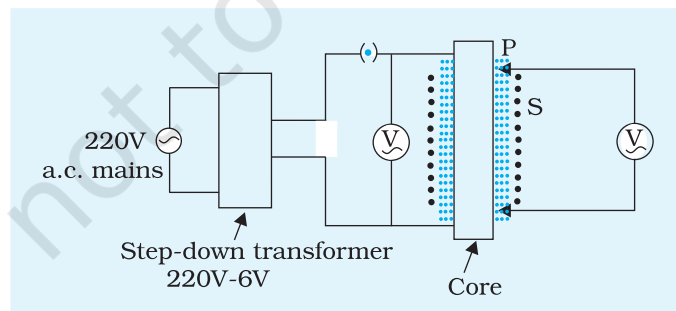
# DEMONSTRATION 14

**To demonstrate (i) the principle of transformer by winding primary and secondary on a steel rod; and (ii) removal of eddy currents by using laminated core.**

(i) *Demonstrating the principle of transformer by winding primary and secondary on a steel rod*

Take a soft iron rod of 15 cm length and 1.3 cm diameter. Wrap thick paper on it. Wind a coil P of enamelled copper wire (22 SWG or 20 SWG)\* with 200 turns. Wind another coil S of thick enamelled copper wire (18 SWG or 16 SWG) P with 50 turns as shown in Fig. D 14.1. Both coils are wound over same length of the rod, so that almost the entire flux produced by current in one is linked to the other. Connect the coil P with 6 V ac supply obtained from a step down transformer. Connect the coil S with an ac voltmeter (0-10 V). Connect an identical ac voltmeter across coil P also. Switch on the current in P and note the voltage  $V_p$  and  $V_s$  across the two coils. Find the ratio of  $V_p$  to  $V_s$ . You find that this ratio is equal to the ratio of the number of turns in the coil P to that in the coil S, i.e.,

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

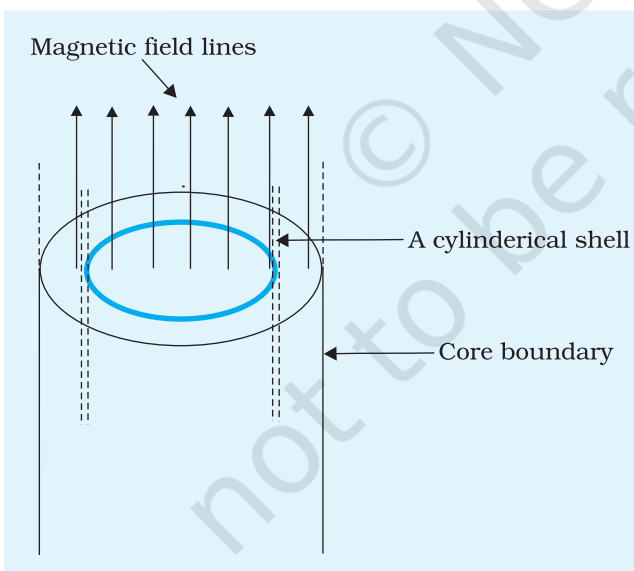


**Fig. D 14.1** A simple transformer made by winding two coils on an 'I' shaped iron core

\* See Table D<sub>s</sub>6, p 289

**Notes**

1. The coil P (on which ac voltage is applied) is called the primary and coil S (in which ac is induced) is called the secondary.
2. Since coil S is placed very close to the coil P (they are not connected to each other, rather they are separated by insulating enamel), the power in the primary is transferred into the secondary through mutual induction.
3. As it is clear from the above equation, by appropriate choice of the turn ratio i.e.  $\frac{N_P}{N_S}$ , we can obtain a higher voltage or lower voltage in S compared to that in P.
4. It should be noted that a steady dc voltage cannot be stepped up or stepped down by a transformer, because a steady dc current does not produce changing magnetic flux and therefore cannot produce induced voltage.
5. Transformer is an important application of mutual induction. Depending upon the ratio of turns in the two coils, a transformer can step down or step up ac voltage.

(ii) *Demonstrating removal of eddy currents by using laminated core*

**Fig. D 14.2** Changing magnetic flux within the core produces induced emf around any cylindrical shell within the core

In the above demonstration, connect P to 6 V ac for some time continuously and feel the hotness of the core and coil by hand. You will find that the core soon gets hot, while the windings of copper wire are comparatively cooler. Switch off the transformer when it is rather too hot to touch, otherwise the enamel coating of copper wire may burn out. The core gets hot due to eddy currents induced in it (resistive heating). Consider the core to be composed of large number of cylindrical shells and consider any one of them (Fig. D 14.2). The changing magnetic flux passing through this shell induces current in it, as in a coil. Such induced currents are produced in every shell of which the core is composed. Now instead of solid iron rod you take laminated core consisting of thin soft iron wires insulated from each other by an enamel coat and pressed together. Repeat the above demonstration using this core. You will find that the core made of wires does get hot, but much more slowly.

**Notes**

1. Insulating enamel amongst the soft iron wires reduces eddy current considerably as the current cannot flow from one wire to another. However, there are some eddy currents within each wire too.
2. It may be mentioned that this kind of core becomes useless for higher frequencies.

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