

Making a simple electroscope and using it to detect charges on bodies

Bend a metal wire with a knob at one end (you can make such a knob by twisting the wire several times at end A) into the shape shown in Fig. A_x1(a). Take about 8 cm long and 1/2 cm broad strip of thin aluminium foil. Fold it round the middle. Gently place it on the horizontal arm B of the wire. Take a tall glass jar or a tumbler. Stick two aluminium foils C and D, 2 cm broad and 10 cm long, on opposite sides of the glass tumbler. Gently lower the copper wire having the folded aluminium strip on its arm B. Orientation of the wire must be such that C faces one half of the folded aluminium strip and D faces the other half [Fig. A_x1(b)]. E is a cardboard disc to support the wire. This is your electroscope.

In order to test whether a given body is charged or not the body (say a glass rod) is brought near the electroscope and made to touch its end A. If the body is charged you will notice the aluminium strip will diverge.

With the help of this electroscope, you can show that bodies acquire charge on

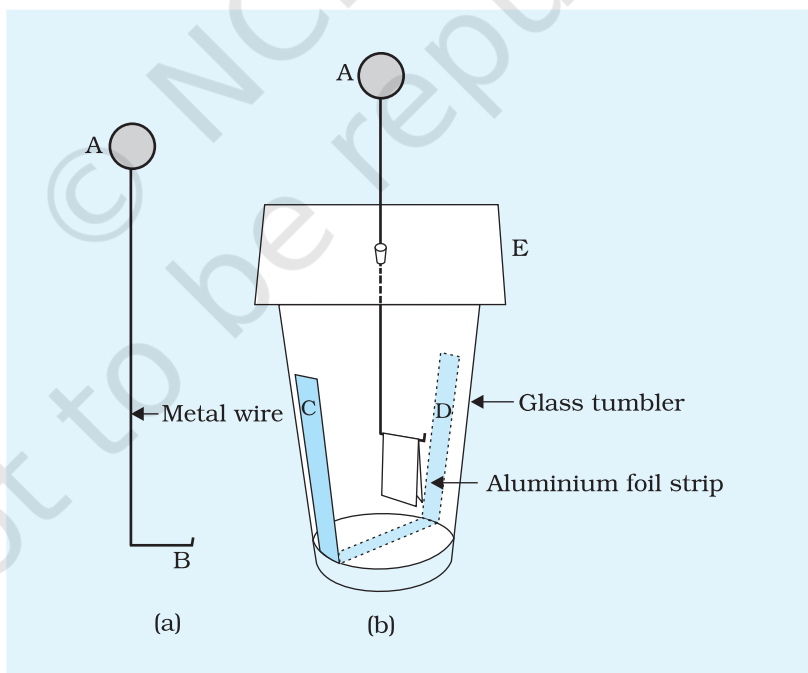


Fig. A_x 1(a),(b) An improvised aluminium foil electroscope

rubbing. You can also show that during the process of rubbing, the two bodies involved in rubbing acquire opposite kinds of charges.

APPENDIX 2

Guideline for making a mechanical model of “Electron Drift” in a metal wire

Take a straight aluminium channel AB, about 3 cm wide and 50 cm long [Fig. A_x 2(a)]. The atoms/ions(+ve) are to be represented by fixing the smallest size of bicycle steel balls (about 3 mm diameter) and the free electrons by the small beads (used in electrostat machines) free to move when the channel is given a slant. The steel balls are to be fixed after putting, carefully, small quantity of a strong adhesive, (say araldite) on each ball just enough to stick the lower tip of the ball to the aluminium surface. Adhesive should not provide any resistance to the drifting tiny beads when these collide with the steel balls. Therefore, before putting the adhesive, points have to be marked all along the channel by repeating the pattern of a crystal lattice network [Fig. A_x 2(b)]. This pattern can be achieved more accurately by sticking a strip of graph paper equal in size to that of the channel. Mutual gap among balls should be about twice the size of the beads representing electrons.

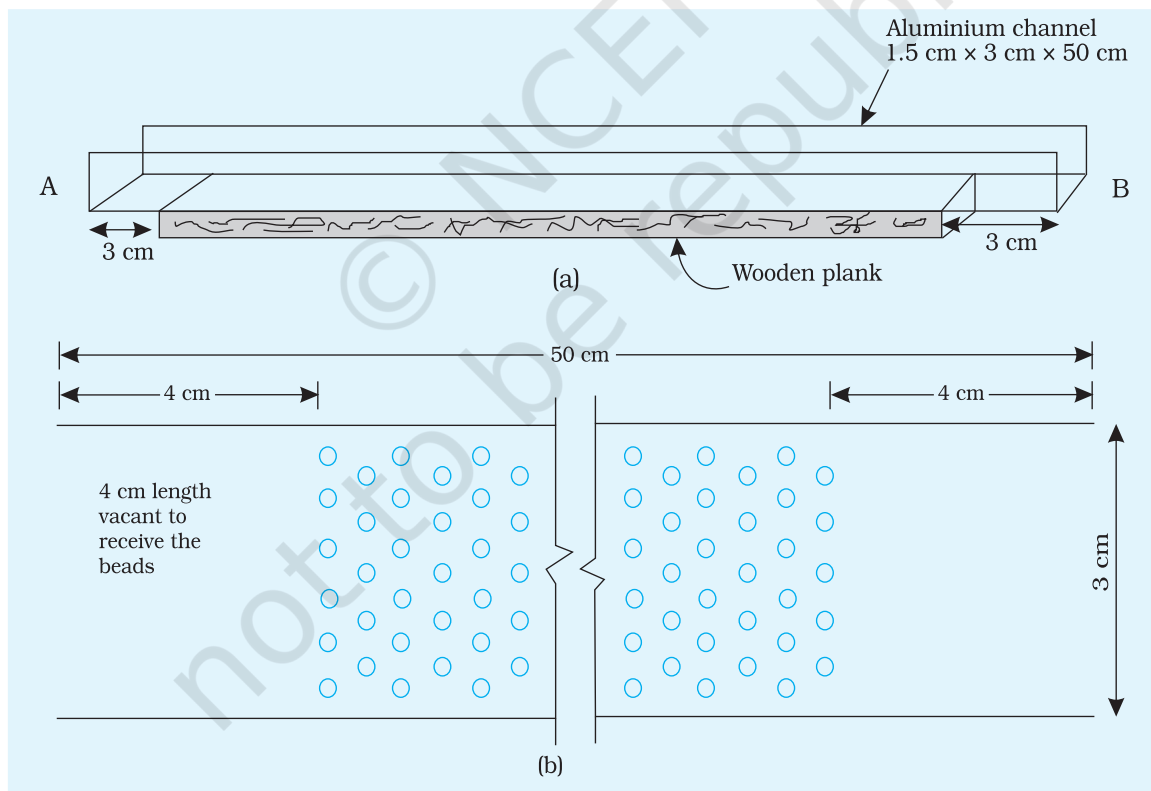


Fig. A_x 2 Making mechanical model of “electron drift” (a) Fixing up aluminium channel on a wooden plank (b) Fixing ball bearings on the channel in the pattern of face-centred crystal lattice.

Note : This figure is not to scale.

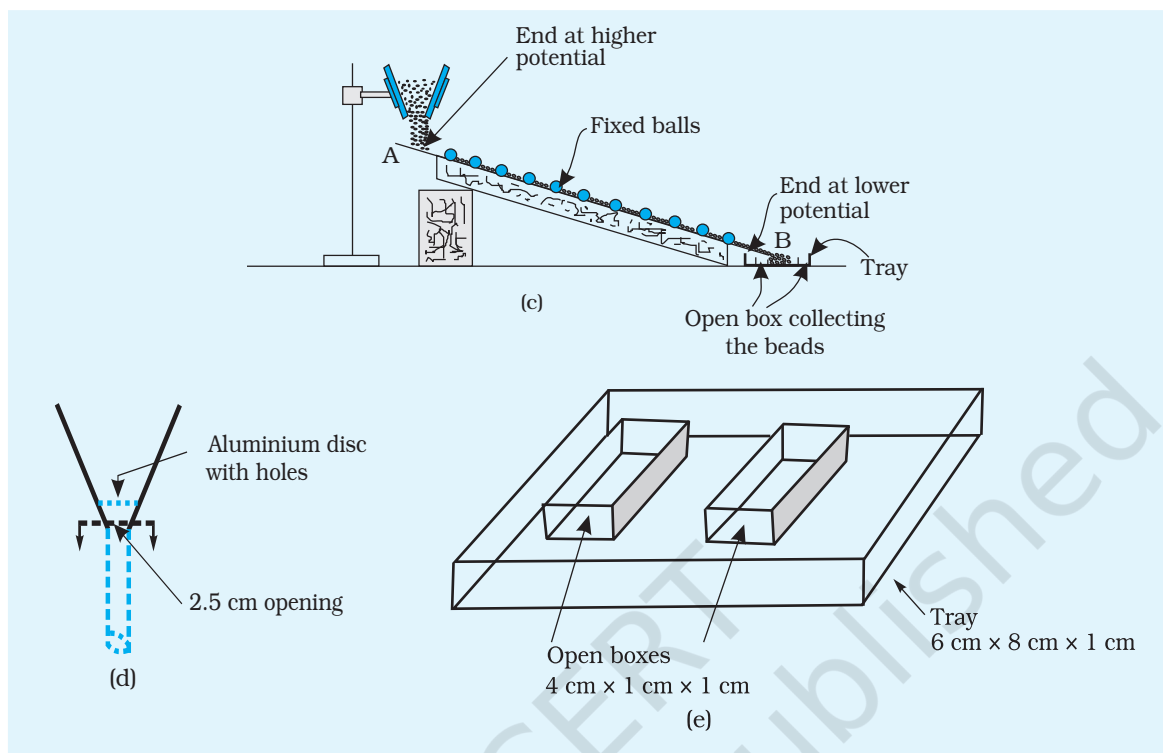


Fig. A_x 2 Making mechanical model of “electron drift” (c) Complete set up of the demonstration (d) Making the device which constantly feeds the small beads at upper end of the channel (e) Open and dry boxes for collecting the beads at lower end of the channel.

To make the base of the channel stable, it is good to fix it over a wooden plank of the same width but 6 cm smaller in length, having a thickness of about 2.5 cm by using a strong adhesive (and not by fixing screws).

For the tiny beads to keep adding at upper end of the channel and colliding with balls and drifting along the channel a suitably modified plastic funnel, filled with beads may be kept close to this end. It may be supported on a ring stand [Fig. A_x 2(c)]. The modification to be done to the funnel is by a way of cutting it carefully so that its lower side has an opening of about 2.5 cm diameter. Inside its lower end is placed a circular aluminium disc with about ten holes in it, which are of size just sufficient to allow one bead each to fall from a hole [Fig. A_x 2(d)]. You would also need a few blocks/wedges, 2 to 3 cm thick, to provide a desired slope to the channel for the tiny balls to keep drifting and colliding with the balls; a tray with a pair of small open boxes would be needed for collecting the beads at the other end of the channel [Fig. A_x 2(e)]. The box filled, say upto 3/4th, with the beads would help in transferring 3 cubic cm of the beads at a time to the end at higher potential, after the other box is kept to collect the beads reaching the end at lower potential.

Resistors and codes to indicate their values

Carbon resistors are made from mixtures of carbon black (a conductor) clay and resin binder (non-conductor). The mixture is pressed and moulded into rods by heating. The resistivity of the mixture depends on the proportion of carbon. The stability of such resistors is poor and their values are usually only accurate to within $\pm 10\%$ but they are cheap, small and good enough for many jobs. The value of a resistor is usually shown by colour markings, as shown in [Fig. A_x 3(a)]. Figures associated with different colours are as under:

TABLE A_x 3.1

Figure	Colour	Figure	Colour
0	Black	5	Green
1	Brown	6	Blue
2	Red	7	Violet
3	Orange	8	Grey
4	Yellow	9	White

The tolerance colours are gold $\pm 5\%$, silver $\pm 10\%$, no colour $\pm 20\%$.

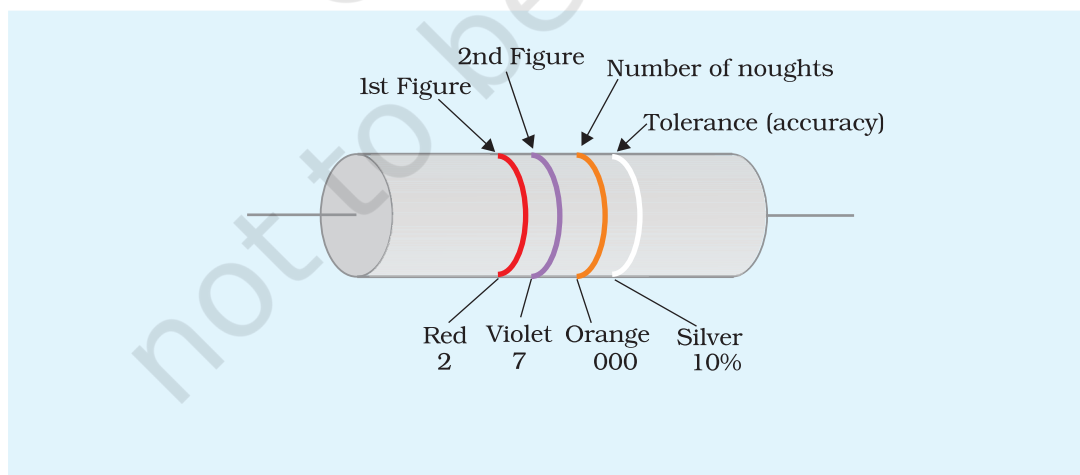


Fig. A_x 3(a) A carbon resistor with colour code marking

This colour code is now being replaced by code with simpler marking, which may be understood by following examples.

TABLE A_x 3.2

Value	0.27Ω	1Ω	3.3Ω	10Ω	220Ω	1000Ω
Mark	R27	1R0	3R3	10R	K22	1K0
Value	1200Ω	68KΩ	100KΩ	1MΩ	6.8MΩ	470KΩ
Mark	1K2	68K	M10	1M0	6M8	M47

In this system the tolerances are indicated by adding a letter:

F = ± 1%, G = ± 2%, J = ± 5%, K = ± 10%, M = ± 20%

Examples: 5K6K = 5.6 KΩ ± 10%

M47J = 470 KΩ ± 5%

K10F = 100 Ω ± 1%

Carbon film resistors have recently gained popularity. The stability and accuracy of this type of resistor is commonly ± 2% and the power rating 1/8 to 1/2 watt. Its construction is as shown in [Fig. A_x 3(b)].

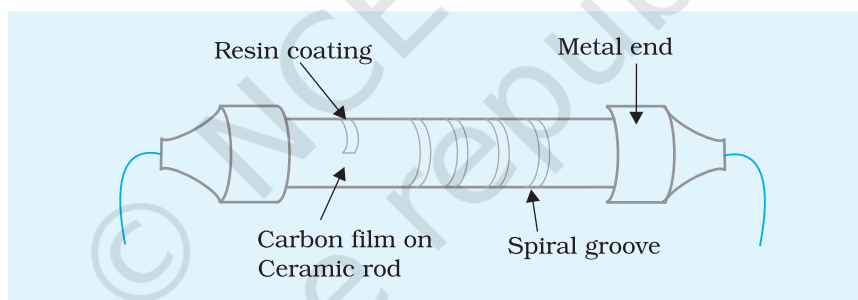


Fig. A_x 3(b) A carbon-film resistor

A ceramic rod is heated to about 1000°C in methane vapour which decomposes and deposits a uniform film of carbon on the rod. The resistance of the film depends on its thickness. Resistance of the film can further be manipulated by increasing it by cutting a spiral groove in it. The thinner and longer the resulting spiral of carbon film connecting the two metal ends, the larger is its resistance. After cutting spiral groove, the film is protected by a layer of epoxy resin coating.

For high accuracy and stability, resistors are always made of wires, as are those required to have a large power rating (i.e. over 2 watt). They use the fact that the thinner and longer the wire, the larger its resistance. Manganin (manganese, copper, nickel alloy) wire is used for high precision standard resistors because of its low temperature coefficient of resistance ($\approx 10^{-5}$ per °C). Constantan (or eureka), an alloy of copper and nickel is used for several purposes (temperature co-efficient $\pm 2 \times 10^{-5}$ per °C, unpredictable). Nichrome (nickel, chromium alloy) wire is used for commercial resistors and heating elements (temperature coefficient 10×10^{-5} per °C).

An improvised open-type fuse holder

To demonstrate the function of a fuse, this type of fuse holder is quite useful in the class room. The fuse wire is quite visible to students against a white background. The burnt out fuse wire can be replaced in just about 5 to 10 seconds.

Take two equal wooden strips each about 5 cm long, 6 mm thick (1/4"), 25 mm broad. Grind one end slightly on a sand paper for tapering each strip. Stick the tapered ends together with a strong adhesive to make an inverted V-shape [Fig. A_x (4)]. On two crocodile clips solder about 1 meter each of flexible electric cable as lead. It should be of 15 A capacity, made of tinned copper wires. Stick the two crocodile clips on the two sloping arms by a strong adhesive (like araldite). The fuse holder is now ready.

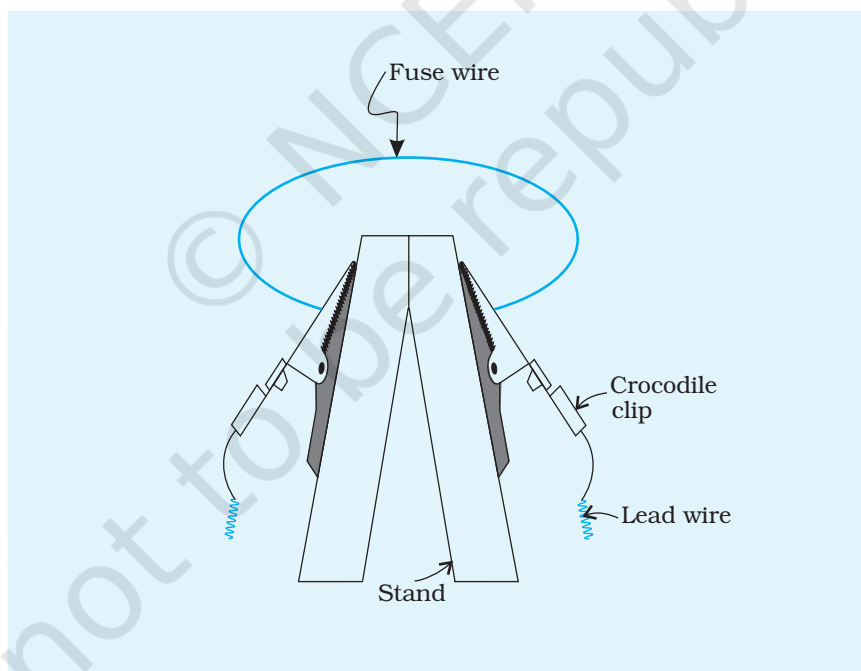


Fig. A_x 4 An open type fuse holder

To attach a fuse wire in the fuse holder, take about 12 cm length of fuse wire. On the outer jaw of a crocodile clip, wind two turns of one end of the wire. Similarly, attach other end to the other crocodile clip, leaving a loop of about 5 to 6 cm of wire in the middle.

Making a square coil for study of magnetic field produced by a straight conductor using only two dry cells as current source

Take an aluminium curtain-channel available in 366 cm length. Make a square of it with each side being $\frac{1}{4}$ th of the total length i.e. 91.5 cm [Fig. A_x 5(a)]. Width of channel should be 6 mm or 9 mm, as is available. Each corner of the square is round. To further strengthen the corners, a 90° bracket of appropriate shape is fixed at each corner.

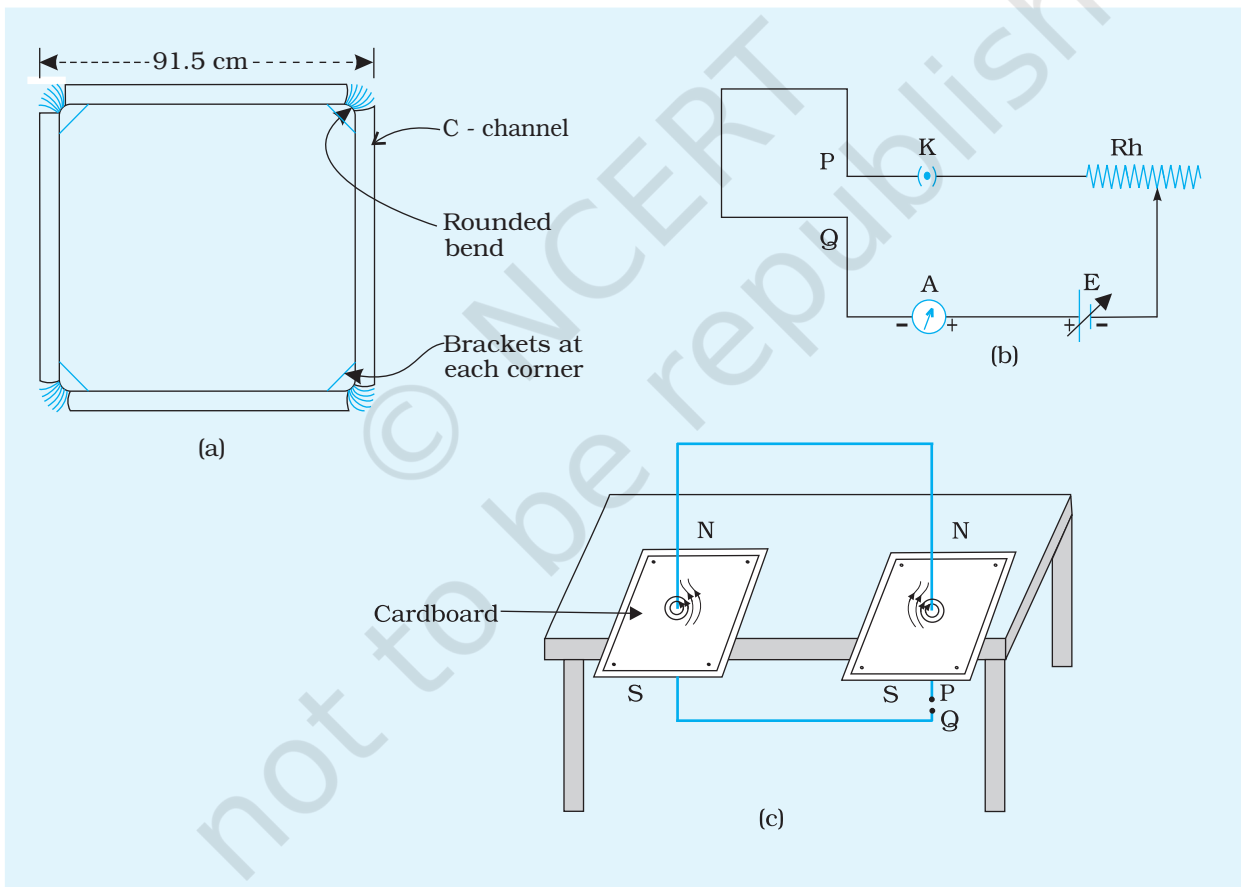


Fig. A_x 5 Study of magnetic field produced by a straight conductor (a) Large square coil (b) The electric circuit for mapping the magnetic field (c) Mapping the magnetic field due to a straight conductor carrying current using the square coil

In this square wind 40 turns of 24 SWG enamelled copper wire. Resistance of this coil at 20°C is about 11 ohm. Hence even by a battery of 2 dry cells in the common battery box, which gives an emf of 3 V, you may pass a current of upto 250 mA in the coil. This makes total current in all the conductors of one arm taken together equal to 10 amperes, which gives a neutral point at a distance of about 6 cm in the presence of earth's magnetic field. A 12 volt dc power supply or a lead accumulator can be used to supply total current in one arm equal to 40 ampere to demonstrate the field pattern by iron filings.

Fix the coil vertically in the table as shown in [Fig. A_x 5(c)]. Complete the circuit as shown in circuit diagram [Fig. A_x 5(b)]. Let its vertical arm pass through the centres of two horizontal boards fixed on the table. Sprinkle fine iron filings on the cardboards. Pass a current of 1 A in the coil by a 12 volt power supply and tap the cardboards. The iron particles arrange themselves in circular loops around the vertical arms of the coil carrying current.

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Making a solenoid for study of its magnetic field

Take copper wire (16 SWG), commonly used for earth connection in domestic electric wiring. Enamelled wire will be better. On a glass bottle of cylindrical shape and diameter between 5 to 5 ½ cm, wind 42 turns of this wire close to each other. When you take it off the bottle, it unwinds by 4 turns, leaving only 38 turns. At the same time, its diameter increases to between 55 mm to 61 mm.

Now take a strip of 6 mm thick plywood, between 16 to 20 cm long and breadth equal to external diameter of the solenoid [Fig. A_x 6(a)]. Along its longer edges, make 1.5 mm deep grooves at 4 mm spacing (i.e. 38 grooves in 152 mm length). Insert it into the solenoid such that its upper surface is the horizontal plane passing through the axis of the solenoid (i.e. height of loops below the lower surface is 6 mm less than height of loops above the upper surface). Put a drop of araldite (or similar adhesive) in each groove and let it harden for 24 hours, thus fixing the solenoid in correct position on the strip.

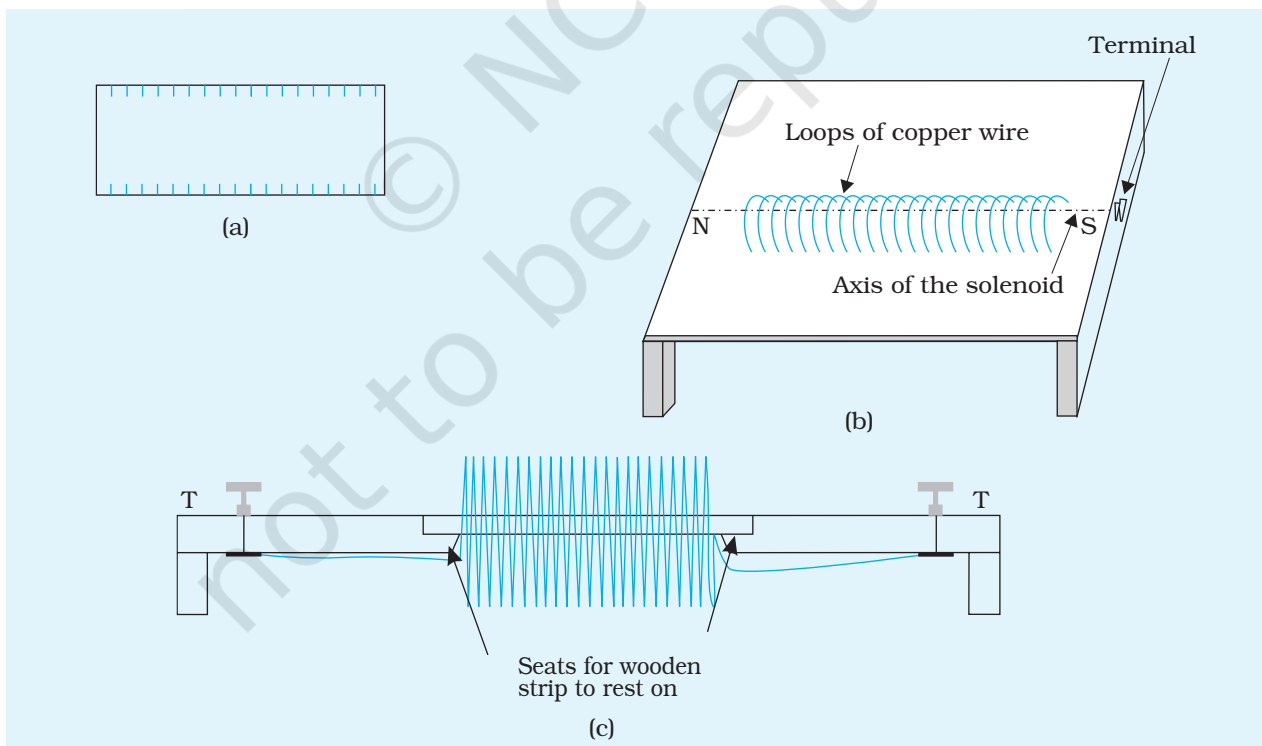


Fig. A_x 6 Solenoid for study of its magnetic field (a) The strip to fix the horizontal plane through its axis (b) Solenoid mounted on a horizontal board (c) Sectional view of the mounted solenoid

Make a wooden board (30 cm × 40 cm) in the centre of which is a window whose size is equal to the wooden strip. At the two ends of this window there are seats for the wooden strip to rest on. Fix the wooden strip on these seats along with solenoid wound on it [Fig. A_x 6(b),(c)]. Fix terminals T,T at the ends of the board and connect the two ends of the solenoid to the terminals.

Your solenoid is ready. Connect the solenoid in series with a rheostat, a key, a battery and an ammeter. You can pass a current 0 to 10A through it and its temperature rises by only 3°C or 4°C above room temperature. Then a magnetic field of 30×10^{-4} T is produced in it, which is enough to demonstrate field pattern by iron filings. You can pass merely 300 mA by a dry cell to plot the field pattern by a plotting compass. A plotting compass can be manipulated inside it by a short length of 16 SWG copper wire, which can be introduced through the 2.5 mm spacing among the turns of the solenoid. You can plot the points inside for mapping the magnetic field by a ball point refill or a short length of pencil lead plugged at the end of the plastic tube of a used ball point refill.

Making a fine slit of uniform width equal to thickness as a razor blade

On a glass sheet of at least 60 mm × 60 mm, place another glass plate of same size, which has been cut into two parts A and B [(Fig. A_x 7(a))]. A and B separated by a distance equal to thickness of blade C, which stands vertically between them with its sharp edges vertical. Stick end portions of A and B together by adhesive tape so that these are not pushed apart during subsequent work. About 50 mm length of A and B is clear from the adhesive tape [(Fig. A_x 7(b))]. Next place two new blades D and E, one sharp edge of each touching the blade C. Now stick the end portions of D and E together by adhesive tapes T, T.

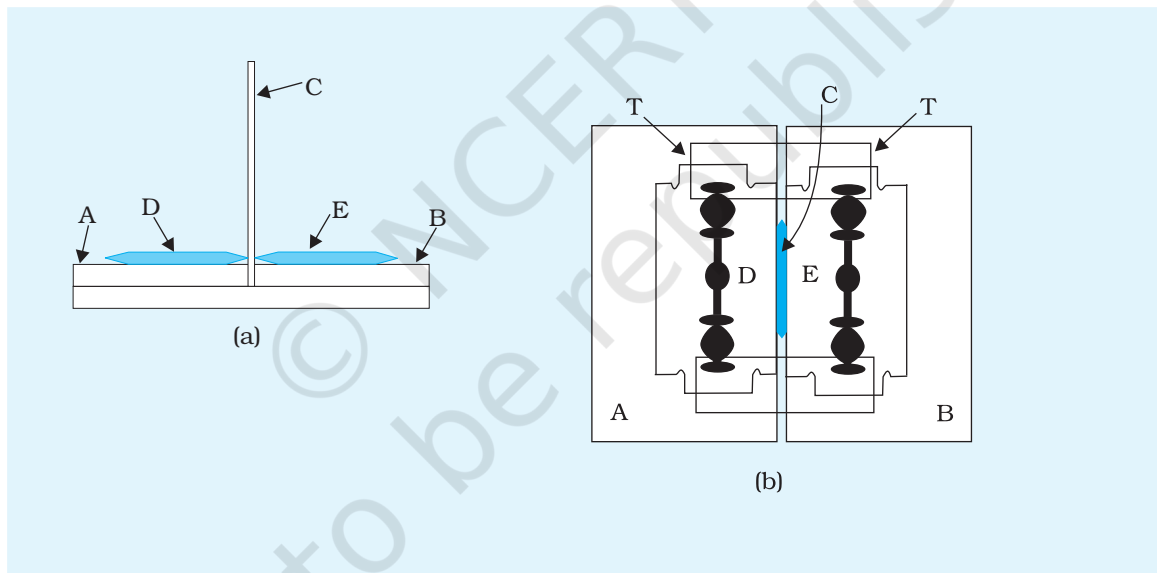


Fig. A_x 7 (a),(b) Making a fine slit of uniform width equal to thickness of a razor blade

Remove blade C and put the assembly of D and E upside down. Fold the extra breadth of tapes T, T on the side which is now upwards. If this assembly is to be made permanent then, instead of folding the adhesive tape, use small pieces of blade coated with a strong adhesive (like araldite) on this side of the assembly. Then this assembly of D and E has a slit of uniform width equal to thickness of blade C and length more than the width of blade C. You can observe diffraction pattern of a clear glass electric bulb preferably with a straight filament with this single slit [refer Physics Textbook for Class XII Part-II (NCERT, 2007, p.371)]

Making a simple double slit for Young's experiment

Take a microscope slide. Clean it with soap and water and let it dry. Check that the glass has no ripples visible with naked eyes. (Look at a distant object through it and move it in its own plane. If the distant object is seen shaking, the slide has ripples, and is not made of good glass).

Now paint the slide with graphite colloidal suspension, or black water proof ink used by the artists, or just deposit soot by keeping over a candle flame. Take two razor blades. Hold them together with thumb and fore-finger, close to the corner and make a pair of lines on the slide by this corner. The separation between the two lines, A and B [Fig. A_x 8(b)] is equal to thickness of one blade. If you hold far from this corner, then while drawing the lines, the blade may separate out and separation between the lines may increase at some places, wherever the blades separate out.

You must draw the lines in a single effort and with such a pressure that the glass becomes transparent at the lines. For this reason it is advisable to start with four to five slides, make lines on each and then select the best one by viewing through each at a line source of light. Arrangement shown in [Fig. A_x 8(a)] is helpful for drawing a pair of lines straight and in correct place and direction. The slide S is held between two slightly thicker glass plates P, P. The three are stuck together by an adhesive tape on their lower faces which are in contact with working table. Then a small straight edge E (it can be another glass plate with edge ground or a plastic scale) is supported on the plates PP, so that it remains clear above the coated surface.

the pair of lines is drawn by the blades along the edge E.

A slide coated with graphite colloidal suspension or water proof ink may be viewed from any side. However, the slide on which soot is deposited must be held with uncoated side towards the eyes, lest contact with your face may spoil the slide.

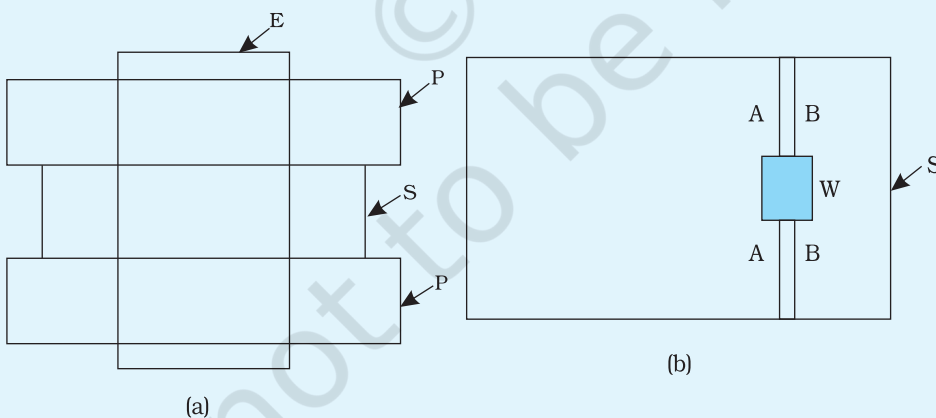


Fig. A_x 8 (a),(b) Making a simple double slit

through it, along with the diffraction pattern, make a clear window, W, of about 5mm × 5mm (or a circle of about 5mm diameter) in the middle of the pair of lines A and B [Fig. A_x 8(b)]. The best way to make the window is to stick a small piece of adhesive tape on the slide before painting it. After painting it, peel off the piece of tape carefully by the tip of a knife. The tape must be of good quality, so that it leaves no spot on the glass after it is peeled off.

In order to be able to see a metre-scale

Mechanical analogue of scattering of α -particles by atomic nuclei

Principle

The potential at a point of an inverse square force-field (as is that of the nucleus of an atom) is inversely proportional to the distance from the point source of field. If the force is repulsive (as it is between the nucleus and an α -particle), the potential is positive and a graph of h versus r represents the variation of potential with distance [Fig. A_x 9(a)]. If we revolve this curve about the y-axis [Fig. A_x 9(b)] the solid of revolution of this curve is obtained. Top surface of this

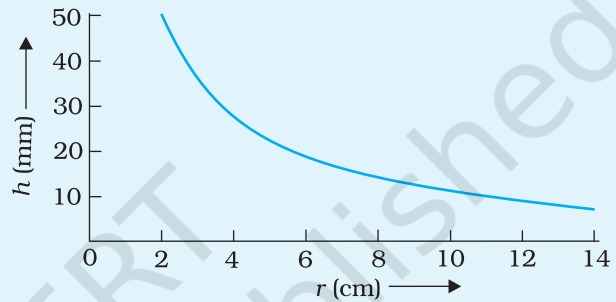


Fig. A_x 9 (a) Variation of potential with distance

solid of revolution of this curve is obtained. Top surface of this

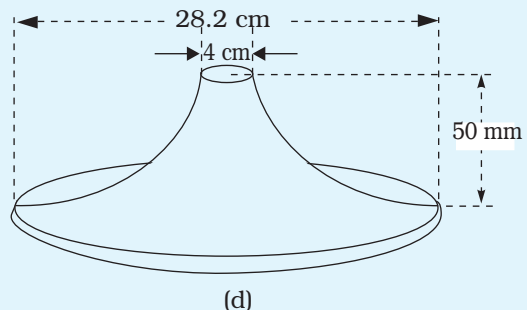
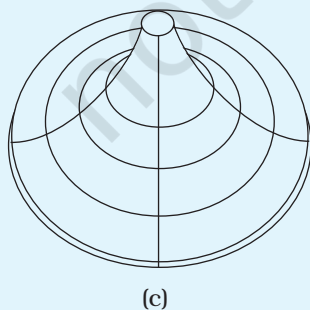
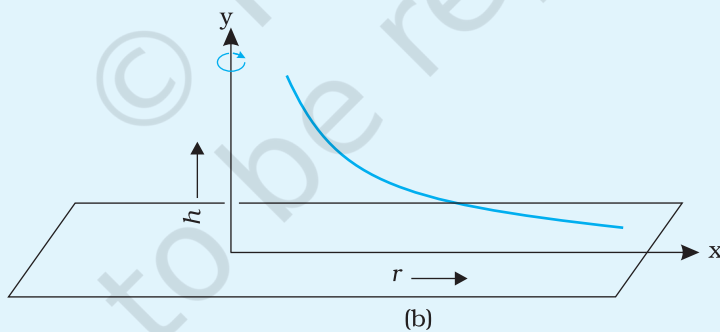


Fig. A_x 9 (b),(c),(d) Mechanical model of a potential hill

solid, the surface of revolution of the curve, gives a mechanical model of the potential hill [Fig. A_x 9(c)]. The potential hill is so constructed that the height h of any point on its surface is proportional to $1/r$, where r is the distance on the plane from the centre.

A ball rolling up this potential hill acquires a gravitational potential energy proportional to h and, therefore, proportional to $\frac{1}{r}$. Thus its motion simulates

the motion of particle moving in 2-dimensions under a repulsive inverse square force-field. Thus it simulates the motion of a charge moving on the plane in the electric field of the nucleus.

Construction of the Model

A typical model of potential hill can have a base diameter of 28.2 cm, and a top diameter of 4cm and height of 50mm. [Fig. A_x 9(d)]. The model can be turned out of wooden plank 30cm × 30cm × 5cm. First, a curve between h and r [Fig. A_x 9(a)] is drawn on a graph sheet (of size larger than 10 cm × 15 cm) with the following points.

TABLE A_x 9

x (r) cm	14.1	12.5	11.1	10.0	9.0	8.0	7.0
y (h) mm	7.0	8.0	9.0	10.0	11.1	12.5	14.1
	6.0	5.0	4.0	3.3	3.0	2.5	2.0
	16.7	20.0	25.0	30.0	33.3	40.0	50.0

The graph is shown in [Fig. A_x 9(a)] for reference. To make an accurate and smooth curve, it is better to use the instrument “FLEXIBLE CURVE” used by artists. A template is cut to fit this curve. Using this template, the solid of revolution is cut on the wooden plank fixed to a lathe.

Accessories

1. Steel balls of 12.7 mm diameter.

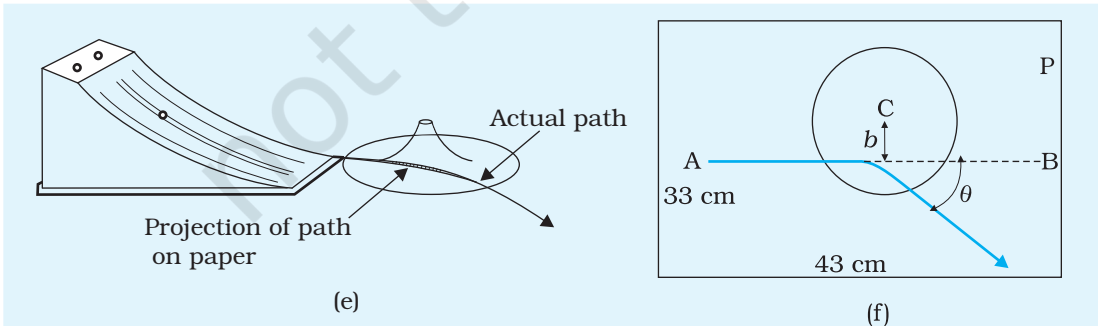


Fig. A_x 9 (e) The ramp is placed along a direction off the centre C

Fig. A_x 9 (f) b is impact parameter

2. A ramp to roll down the balls from different heights (accelerator). A 30 cm plastic scale will be suitable. Height of lower end of ramp must be equal to height of the lower boundary of the potential hill, so that a ball rolling down the ramp smoothly rolls onto the potential hill without any jump. In order that the rolling ball represents high energy α -particles, upper end of the ramp should be of height 12 cm or more. The scale must be fixed in a curved shape, with its lower end horizontal, so that the ball leaving the lower end after rolling down, smoothly rolls on to the potential hill without any significant change in the angle of its motion with respect to horizontal plane.

Experiments with the Potential Hill

In the two experiments described below, the model is to be used as a potential hill to demonstrate the different aspects of alpha scattering. The ramp should be kept with its edge touching the surface of the hill at its lower boundary [Fig. A_x 9(e)]. The ball should be held on the ramp at the desired height with a stopper (a flat scale will do). The ramp should be placed along a direction off the centre C, such as along AB in [Fig. A_x 9(f)]. To trace the path of the ball a paper P, of size 33 cm × 43 cm with a carbon sheet of same size above it is fixed on a large drawing board or plane and smooth table top, which is adjusted horizontal. The model and the ramp can be placed on this paper for both experiments.

Experiment 1: To study dependence of the scattering angle (θ) on the initial energy of the particle.

Release the ball from different heights on the ramp and show that the scattering angle (θ) increases as the initial energy decreases.

Experiment 2: To study the relation between the scattering angle and the impact parameter for a given energy of the alpha particle.

Release the ball from a specified height and determine the scattering angle θ . Measure also the impact parameter b [see Fig. A_x 9(f)]. Repeat the experiment for different values of b but always releasing the ball from the same height. Measure

the scattering angle in each case and show that $b \propto \frac{\cot \theta}{2}$.