DEMONSTRATION 1

To demonstrate uniform motion in a straight line

It is rather difficult to demonstrate uniform motion of a freely moving body due to the inherent force of friction. However, it is possible to demonstrate uniform motion if a body of the forces acting on it are balanced.

(a) *Demonstration of uniform motion of a body in glycerine or caster oil in a glass or a plastic tube*

Take a glass or plastic tube one metre long and about 10 mm end diameter. Close one end of it with a cork. Fill the tube with glycerine (white) or castar oil upto the brim. Insert a steel ball or lead shot of three mm diameter in it and close it with a cork such that no air bubble is left in the tube. Take a wooden base 7.5 – 10.0 cm broad having metallic brackets near its ends. Paint the board with white paint or fix a sheet of white paper on it. Mount the tube on the wooden base with the help of metallic brackets (to rest the tube like the base of a fluorescent tube). Put marks on the base with black/blue paint or ink at regular intervals of 10 cm each [Fig. D 1.1(a)]. To demonstrate

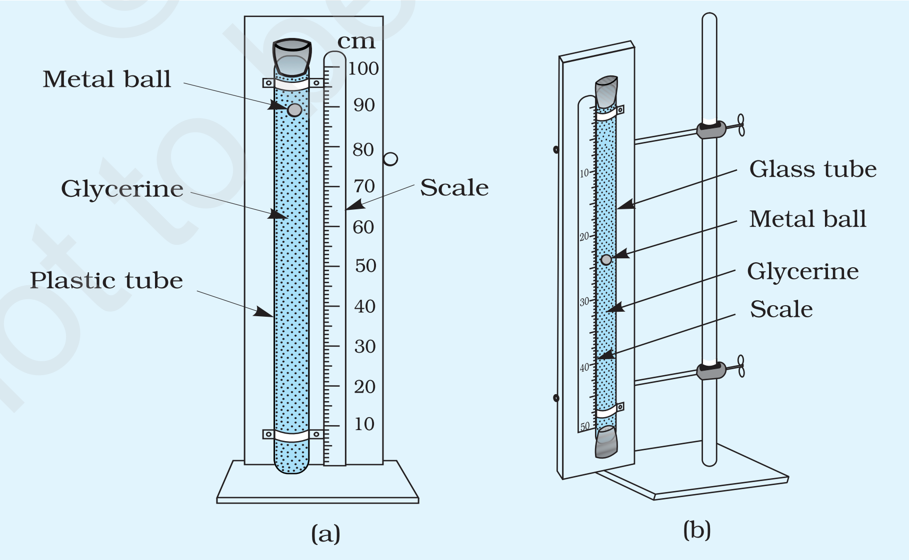


Fig. D 1.1: *Demonstration of uniform rectilinear motion of a ball under two balancing forces: (a) A demonstration apparatus 1 m long (b) A low cost apparatus 50 cm long* uniform motion keep the tube vertical and ask a student to note the time taken by the ball to travel successive segments of 10 cm. Repeat the experiment by inverting the tube a couple of times. It may be emphasised that if a 10 cm segment is further sub-divided into segments of 1 or 2 cm length, then the ball should travel successive smaller segments also is equal intervals of time*.

This demonstration can also be done with a half metre long glass tube and a half metre scale. It may be clamped vertical in a laboratory stand [Fig. D 1.1(b)]. In this case students can also be asked to note the time taken by the ball to travel successive segments of one cm.

The tube may be inclined slightly, say, at about 5 to the vertical. The advantages of this are:

(i) The ball moves closer to the scale which reduces the parallax error in observing its position on the scale.

(ii) The ball moving in contact with the wall of the tube is under identical conditions throughout its motion. If you wish it to move in the centre of the tube, i.e., along the axis of the tube, then the vertical adjustment of the tube has to done with greater precision.

In order to perform this demonstration with the half metre tube more effectively, students may be encouraged to devise their own mechanism to simultaneously record the distance moved by the ball and the time taken to do so. For example, let one student watch the falling ball at close distance and give signals by tapping the table as the ball passes successive equidistant marks at a pre-decided distance from each other.

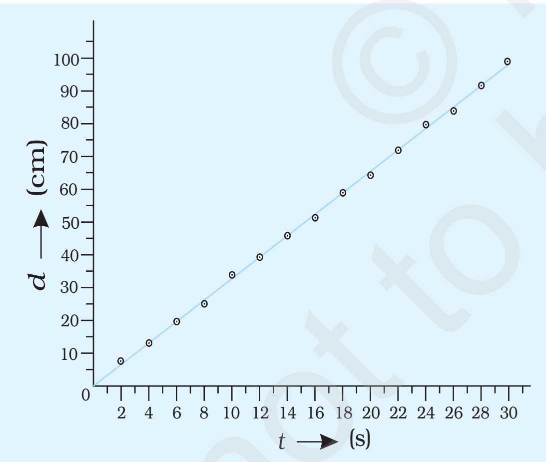


Fig. D 1.1(c): *Distance–time graph for motion of metal ball in glycerine*

A second student may start the stop-watch at the sound of any tap. Thereafter, he observes and speaks out the time shown by the watch at each successive tap, without stopping the watch. A third student may keep noting the data of distance covered by the ball and time elapsed since the measurement was started. Ask students to plot the distance versus time graph of the motion of the ball on the basis of this data and discuss the nature of this graph [Fig. D 1.1(c)].

In this coordinated activity of three students, it is likely that the first one may happen to miss giving signal at a mark when the ball passes it. He should only indicate this by saying "missed" and a few points less on the graph made with about 15 to 20 points are of no significance. Similarly, any tapping which he subsequently feels, was not made at the right instant, he may indicate

* In this experiment, the ball accelerates for some time initially and approaches the terminal velocity u_0 according to relation $u = u_0 = (1\text{-}e^{-t/T})$. For a typical terminal velocity $u_0 = 3$ cms^{-1}, the time constant $T = 0.003$s. Thus, the duration of accelerated motion is so small that one may not at all bother for it.

by saying "wrong". Two students can also record this data, if there is sufficient time between successive readings, the second one taking over the task of the third. With some practice and by keeping the watch in the left hand close to the ball, even one student can record the data and take it up as an individual activity.

By mixing water with glycerine in a suitable ratio one can make adjust the speed of motion of the ball such that it is neither too slow as to cause boredom to the class nor so fast that the data is difficult to record.

(b) *By using a burette*

The above demonstration may also be performed by using a long burette. It has its own scale too. However, it may be difficult for students sitting at the back in the classroom to see the scale. Also, the upper end is open, which implies that several balls of the same size should be available. In fact, in the demonstration (a) above, the upper end of the tube may be kept open, if several balls of the same size are available, since the most tricky part of it is to close the upper end leaving no air bubbles inside the tube.

The demonstration with the burette can also be made more effective in the same manner as discussed above.

Note:

1. In the class discussion following the demonstration of a steel ball falling down with uniformed speed, an important question will be "what are the two balancing forces under which it moves with uniform velocity?" One is the net weight of the ball acting downwards due to which its speed increases in the beginning. As its speed increases, the resistance of liquid, acting upwards, to the motion increases till it balances the weight. Then onwards, the ball acquires terminal velocity and the speed remains nearly constant.

2. There are a number of situations in everyday life where an object falls down with uniform velocity in exactly the same manner as the ball in a liquid.

   (a) When a paratrooper descends from an aeroplane with the help of a parachute, resistance of air on the parachute often balances her/his weight. In such an event she/he moves vertically down with uniform speed, except for some horizontal drift due to the wind (Fig. D 1.2).

   (b) Many children play with a toy parachute which is first thrown up. Then it moves down in exactly the same manner as the paratrooper with a parachute.

   (c) A shuttle cock, which is used in the game of badminton, may be shot vertically upwards, when it comes down,

Fig. D 1.2: Discent of a parachute is nearly uniform

players often see that it is moving down with uniform downward speed (if there is no wind) after a small initial period of increasing speed.

3. This demonstration may also be done by the apparatus used for finding the viscosity of liquid by Stoke's law. However, for demonstrating uniform motion in a straight line, the demonstration is easier and better by: (a) using a scale to read the position of the ball, and (b) keeping the tube slightly inclined towards the horizontal.

DEMONSTRATION 2

To demonstrate the nature of motion of a ball on an inclined track

Make an inclined plane of about 50 cm length with 2 – 3 cm height at the raised end. Alternately, one can use a double inclined track apparatus and make the inclined plane by joining its two arms at the base strip so that these form a single plane. Give it a low inclination by raising one end of the base strip by about two cm with the help of a wooden block, or a book, etc. (Fig. D 2.1). Now let a metronome produce sound signals at intervals of ½ seconds. Keep the ball at the higher end of one of the inclined planes. Release it at any signal (which may be called 0th signal) and let students observe its position at 1st, 2nd, 3rd and 4th signals after the release. For this purpose, divide the class into four groups. Explain to them in advance, with the help of a diagram on the blackboard, that group I will observe the 1st position of the ball, group II the 2nd position of the ball, and so on.

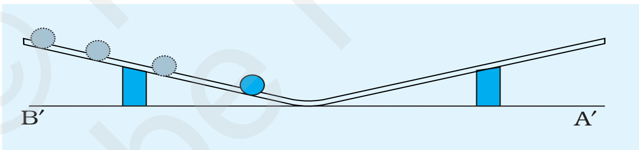


Fig. D 2.1: *Motion of a ball on a double inclined plane*

After the demonstration, there are as many observations for each position of the ball as the number of students in each group. Let one student in each group collect the observation in his/her group, calculate the mean value and record it on the blackboard. Then it can be shown that distances covered by the ball in successive intervals of ½ second go on increasing by equal amounts when the ball roll down the incline.

Note:

1. In the absence of a metronome, let a person tap on the table at a steady pace which synchronises with extreme positions of the pendulum of a clock, or a simple pendulum of 25 cm length on a laboratory stand.

2. If a strobe-light is available, use it illuminate the ball moving down the track. Then students can visually see successively longer distances moved by the ball in equal intervals of time.

DEMONSTRATION 3

To demonstrate that a centripetal force is necessary for moving a body with a uniform speed along a circle, and that magnitude of this force increases with angular speed

(a) *Using a glass tube and slotted weights*

Take a glass tube about 15 cm long and 10 mm outside diameter. Make its ends smooth by heating them over a flame. Now pass a strong silk or nylon thread about 1.5 m long through the tube. At one end of the thread tie a packet of sand or a rubber stopper and at the other a weight (*W*) (about three to 10 times the weight of the sand/cork). First, demonstrate that on lifting the glass tube, the weight stays on the table while the packet of sand or the stopper gets lifts up (Fig. D 3.1).

Now by holding the glass tube firmly in one hand and the weight (*W*) in the other, rotate the packet of sand in a horizontal circle. When the speed of motion is sufficiently fast, the weight (*W*) can hang freely without the support of your hand. Adjust the speed of rotation such that the position of the weight (*W*) does not change. In this situation, weight (*W*) provides the centripetal force necessary to keep the packet or stopper moving along a circular path (Fig. D 3.2). If the speed of motion is increased further, the weight (*W*) even moves up and vice versa. Why?

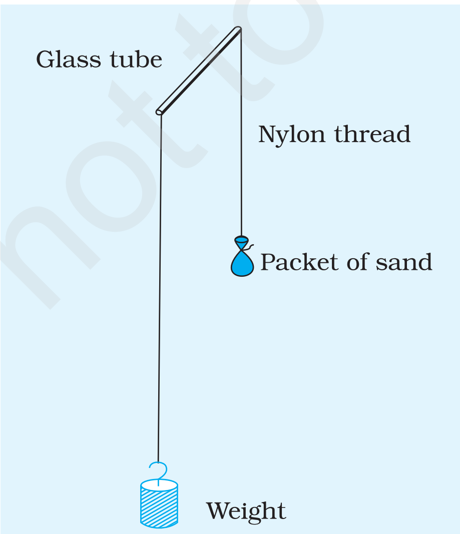


Fig. D 3.1: *The weight tied at the end passing down the glass tube is much heavier than the packet of sand*

As a safety precaution, in this demonstration, the packet to be rotated in a horizontal circle should be a packet of sand, or a packet of a few fine lead shots, or a rubber stopper, etc., lest it breaks off and strikes someone. Again, the glass tube should be wrapped with two layers of tape, lest it breaks and hurt the hand of the person demonstrating the experiment.

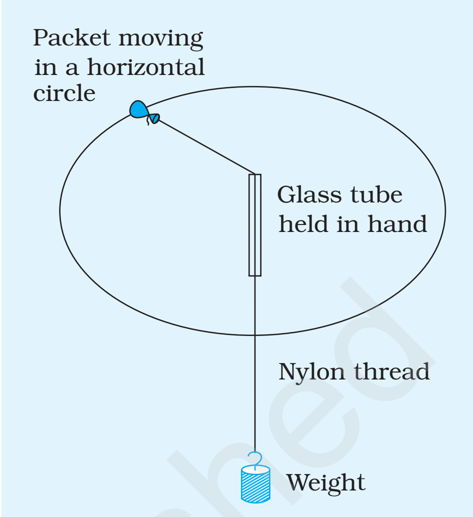


Fig. D 3.2: *On revolving the packet of sand at a suitable speed, the weight lifts off the table; its weight is just enough to provide the necessary centripetal force*

(b) *Using a roller and a turn table*

If a turn table (as you might have seen in a gramophone) or a potter's wheel is available, it can also be used to demonstrate centripetal force. A small roller is placed on the turn table and its frame is attached to the control peg by a rubber band (Fig. D 3.3). The roller is free to roll radially towards or away from the centre. The disc is set in motion first at the lowest speed of 16 revolution per minute. The stretching of the rubber band indicates that a force acts outwards along the radius. At higher speeds, 33 r.p.m., or 45 r.p.m., or 78 r.p.m., the stretching of the rubber band could seen to be larger and larger, showing that greater and greater centripetal force comes into play. Note that as the angular speed increases, the radius of circular motion of the roller also increases due to elongation of the rubber band.

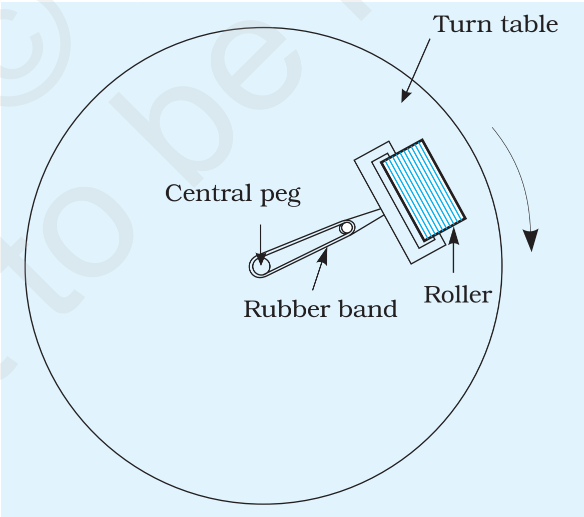


Fig. D 3.3: *Elongation of rubber band indicates that it is exerting a centripetal force on the roller*

DEMONSTRATION 4

To demonstrate the principle of centrifuge

Bend a glass tube (about 10 to 15 mm diameter) slightly at its middle to make an angle of, say, 160 . Fill it with coloured water leaving an air bubble in it and then close its both ends with rubber stoppers. Now mount it on the turn-table with both its arms inclined to horizontal say, at, 10 while keeping the turn-table horizontal. The lowest portion of the tube in the middle is attached to the central peg of the turn-table (Fig. D 4.1). The air bubble then stays at the top of one or both the arms of the glass tube.

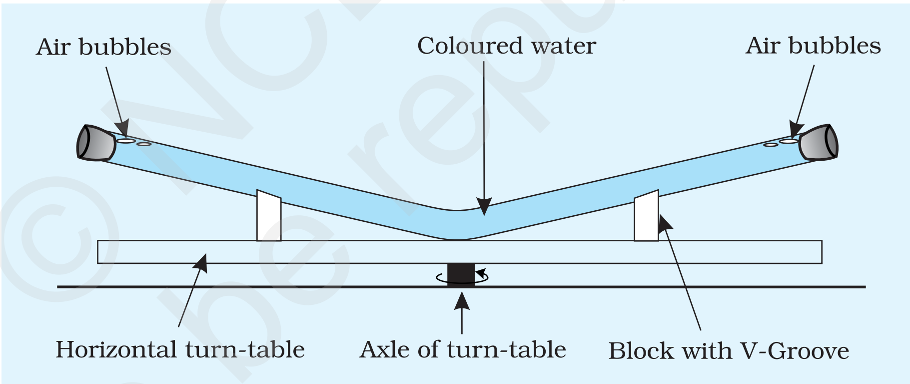


Fig. D 4.1: *A bent glass tube filled with a liquid but having an air bubble attached to the central peg of turn table at its middle*

Now rotate the turn-table and increase its speed in steps, 16 r.p.m., then 33 r.p.m., then 45 r.p.m. and then 78 r.p.m. As the speed of rotation increases, draw attention that the air bubble is moving towards the centre, the lowest part of the tube.

The rotating turn-table is an accelerated frame of reference. At every point on it, the acceleration is directed towards the centre. Thus, an object at rest in this frame of reference experiences an outward force. Every molecule of water in the tube experiences this force, just like the force of gravitation. Under the action of this force, denser matter moves outwards and the less dense inwards.

DEMONSTRATION 5

To demonstrate interconversion of potential and kinetic energy

Interconversion of kinetic and potential energies may be easily demonstrated by Maxwell's Wheel (Fig. D 5.1). It consists of a wheel rigidly fixed on a long axle passing through its centre. It is suspended by two threads of equal length, tied to the axle on two sides of the wheel. In the lowest position of the wheel, separation between the lower ends of the two threads is slightly more than that between them at the supporting at the top.

To set it in action the wheel is rotated and moved up so that both threads wind up on the axle. As the wheel moves up, it gains some potential energy. On releasing, it moves down and its P.E. is converted to K.E. of rotation of the wheel. At its lowest position when all the length of the two threads has unwound, all the energy of the wheel is kinetic due to which the threads start winding up in the opposite direction.

Thus, the wheel starts moving upwards, converting its K.E. into P.E.

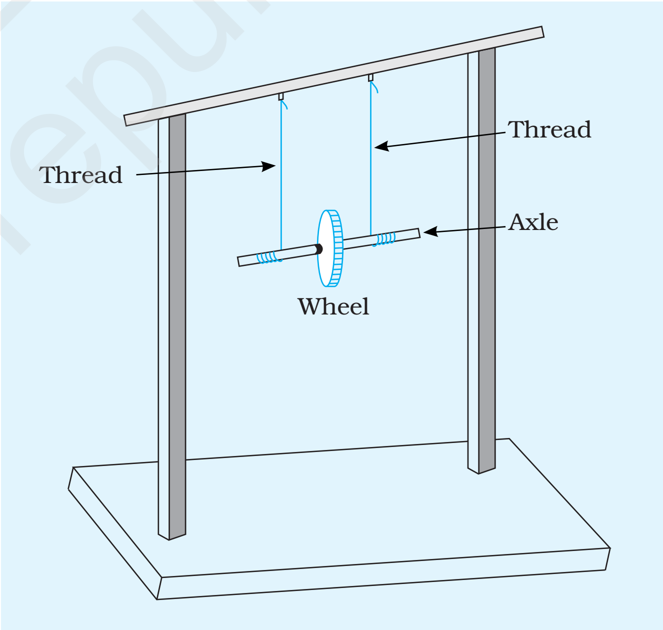


Fig. D 5.1: *The Maxwell's wheel*

Note: In order to ensure that loss of energy in successive up and down motions of the wheel be small, the threads should be quite flexible, inextensible and identical to each other.

DEMONSTRATION 6

To demonstrate conservation of momentum

The law of conservation of momentum can be demonstrated using two bifilar pendulums of the same length using bobs of different materials (Fig. D 6.1). The time period T for both pendulums is the same. Initially the two bobs A and B touch each other in their rest position. Also the suspension fibres of A and B are parallel to each other in their rest positions.

The bob A is displaced with the help of a wooden strip and allowed to touch the reference peg C and thus given a displacement, a, which is noted with the scale. The strip is then quickly removed, so that bob A moves smoothly towards the rest position and collides with the bob B. The maximum displacement a' and b' of the bobs A and B respectively after collision are noted simultaneously. On the right hand side of B, a rider is put on the scale, which is pushed by the ball B, as it undergoes the displacement b'. Then reading the displacement of A directly and of B from the displaced position of the rider becomes easier.

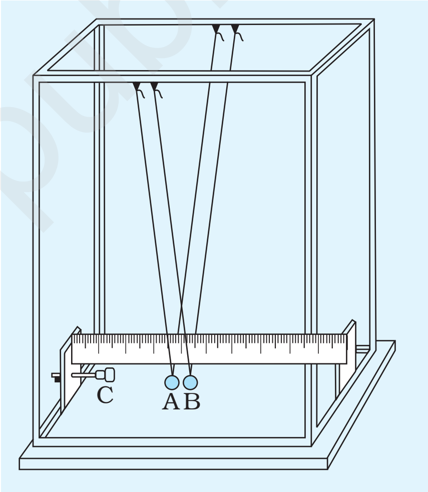


Fig. D 6.1: *The bifilar pendulums*

The masses m_A and m_B of the bobs are measured. The velocities of the bobs, just before and just after the collision are proportional to their displacements, since the time period, T, for both the pendulums is equal and the velocity of a simple pendulum in its central position is equal to (amplitude $2\pi/T$). Therefore, the equality of total momentum of the two bobs before and after their collision implies

$$m_A a = m_A a' + m_B b'$$

Having measured a, a' and b', the above equality can be checked up (a' and b' are the displacements' after the impact).

DEMONSTRATION 7

To demonstrate the effect of angle of launch on range of a projectile

The variation in the range of a projectile with the angle of launch can be demonstrated using a ballistic pistol or toy-gun and mounting it suitably so that the angle of launch can be varied. While mounting the gun care must be taken to see that the axis of the gun passes through the centre of the circle graduated in degrees (Fig. D 7.1). If a toy-gun is used, whose maximum range is more than the length of the classroom, then this demonstration may be done in an open area such as the school play ground.

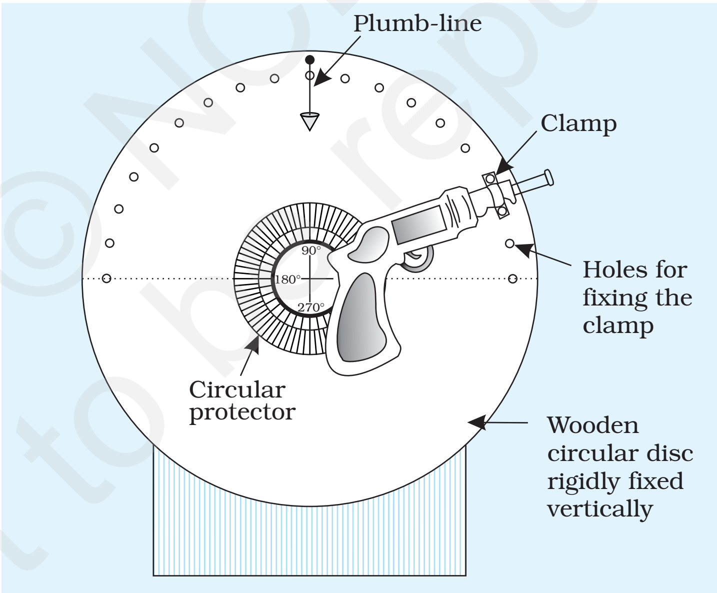


Fig. D 7.1: *A set up to study the range of a projectile fired with a toy pistol*

As the gun is fired at different angles ranging between 0 and 90 , the corresponding ranges are measured with care. A graph for the angle of projection versus the range may be drawn.

Alternately one can also study the range of water jet projected at different angles provided it is assured that water will be released at same pressure.

DEMONSTRATION 8

To demonstrate that the moment of inertia of a rod changes with the change of position of a pair of equal weights attached to the rod

Take a glass rod and hang it horizontally from its centre of gravity with the help of a light, thin wire. Take two lumps of equal mass of plasticine, roll both of them separately to get discs of same size and uniform thickness. Now attach them near the two ends of the rod (like rings) so that the rod is again horizontal [Fig. D 8.1(a)]. Make sure that the plasticine cylinders easily move along the rod. Give a small angular displacement to the rod and note the time for 10 oscillations. Find the time period for one oscillation. Now, move the rings of plasticine by equal distances towards the centre of the rod so that it remains horizontal [Fig. D 8.1(b)]. Give a small displacement to the rod and again note the time period for 10 oscillations. Find the time period for one oscillation. Are the two time periods the same or different? If you

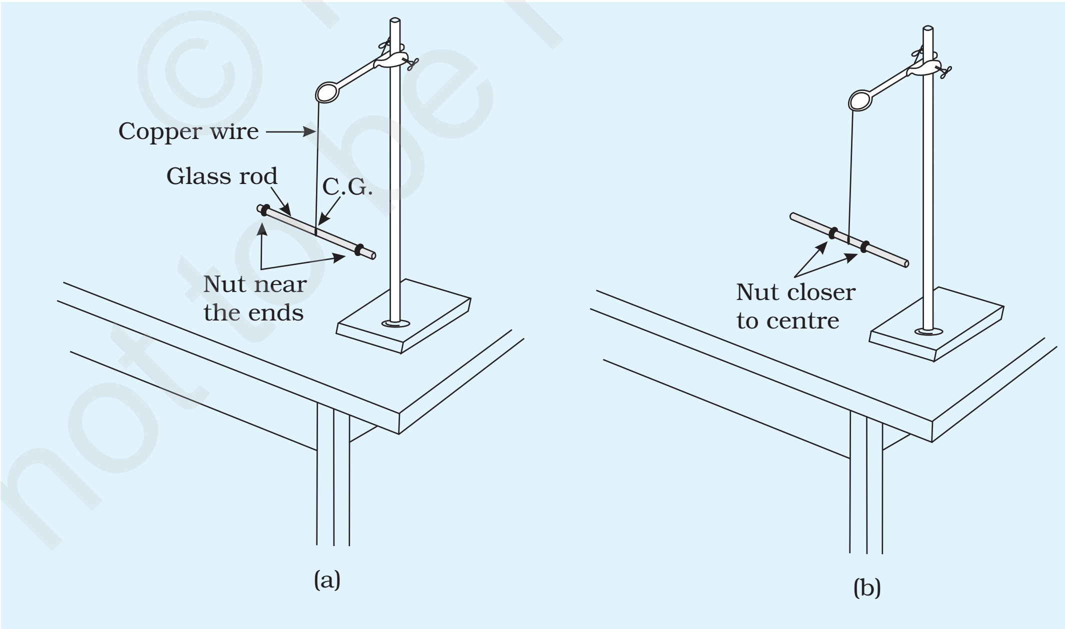


Fig. D 8.1: *Setup to demonstrate that total mass remaining constant, the moment of inertia depends upon distribution of mass. Here nuts have replaced the plasticine balls: (a) the movable mass are far apart, (b) the masses are closer to the C.G. of the rod* find that the time periods in both the situations are different, it shows that the moment of inertia changes with the distribution of the mass of a body even if the total mass remains the same.

An important caution for a convincing demonstration is that the point where a thin metal wire is attached to the glass rod (the point about which the glass rod makes rotatory oscillations) should remain fixed. The metal wire should be so tied that the rod hangs horizontally from it. It ensures that the axis of rotation passes through its C.G. The wire can be fixed tightly by using a strong adhesive. Therefore, the position of plasticine discs have to be adjusted so that the glass rod hangs horizontally.

DEMONSTRATION 9

To demonstrate the shape of capillary rise in a wedge-shaped gap between two glass sheets

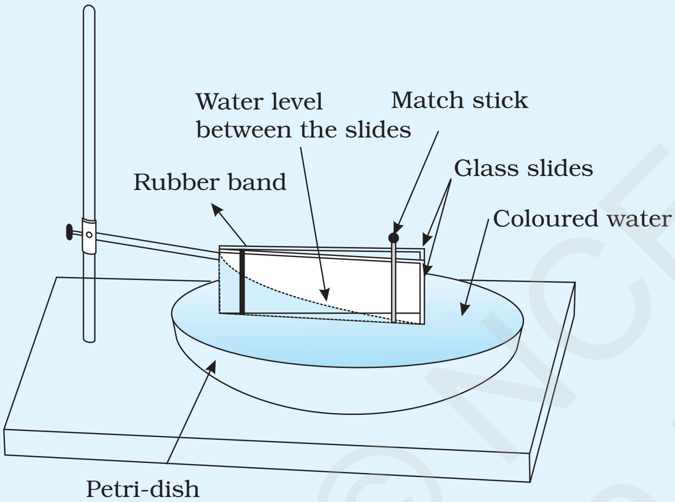


Fig. D 9.1: *Capillary rise of water is higher at the end tied by rubber band in the wedge-shaped gap between the glass slides*

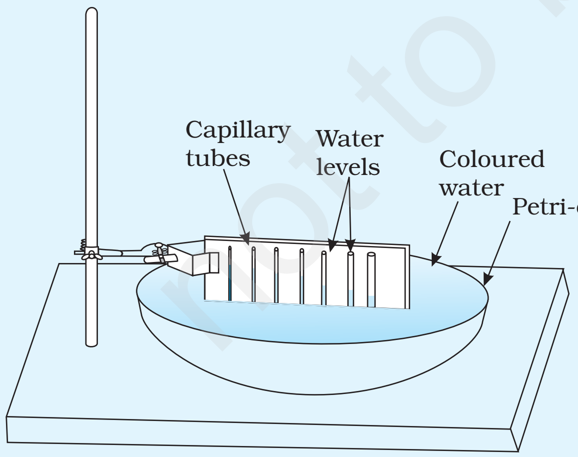


Fig. D 9.2: *Rise of water in capillary tubes of different diameters*

You would require two plane glass slides, a thick rubber band, a match stick, a petri-dish, some potassium permanganate granules and a felt-tip glass marking pen.

Clean the two slides and the petri-dish thoroughly with soap and water and rinse with distilled water. Ensure that no soap film remains on them. Fill the dish about half with distilled water coloured by potassium permangnate. Tie one end of the pair of slides together with a rubber band and put a match stick between their free ends (Fig. D 9.1). Dip this arrangement in the coloured water in the petri-dish. Water rises more at the tied end as compared to that at the match stick end because the separation between the glass slides increases linearly from the tied end to the match stick end.

Note

1. The same effect could be demonstrated by using a number of capillary tubes of different diameters arranged side by side in increasing order of diameter, as shown in Fig. D 9.2.

2. Students may take up this experiment as an activity or project work.

DEMONSTRATION 10

To demonstrate affect of atmospheric pressure by making partial vacuum by condensing steam

To perform this demonstration you will need a round-bottom flask, a glass tubing, a cork, cork borer, a long piece of pressure rubber tube just fitting the glass tubing, a pinch cock, burner, tripot stand, laboratory stand with a clamp and large water container.

Take some water in a round bottom flask. Close its mouth tightly with a rubber cork, in which a short glass tube is fitted. Attach a pressure rubber tube, about 1.5 m long, in the open end of the glass tube. Heat the water, as shown in Fig. D 10.1(a). The steam produced in the flask expels the air from the flask, the glass tube and the rubber tube. Stop heating after some time and tightly close the mouth of the rubber tube with a pinch cock immediately.

Invert the flask and clamp it as high as possible in a tall stand placed on the table [Fig. D 10.1(b)]. Dip the free end of the rubber tube in coloured water kept in the large container on the ground and release the pinch cock. As the flask cools, water from the container rushes through the glass tube into the flask. The students will naturally

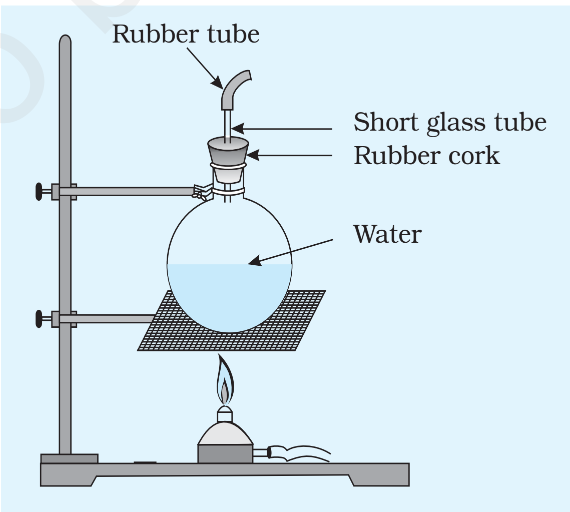


Fig. D 10.1 (a): *On heating the water in flask, steam drives air out from it*

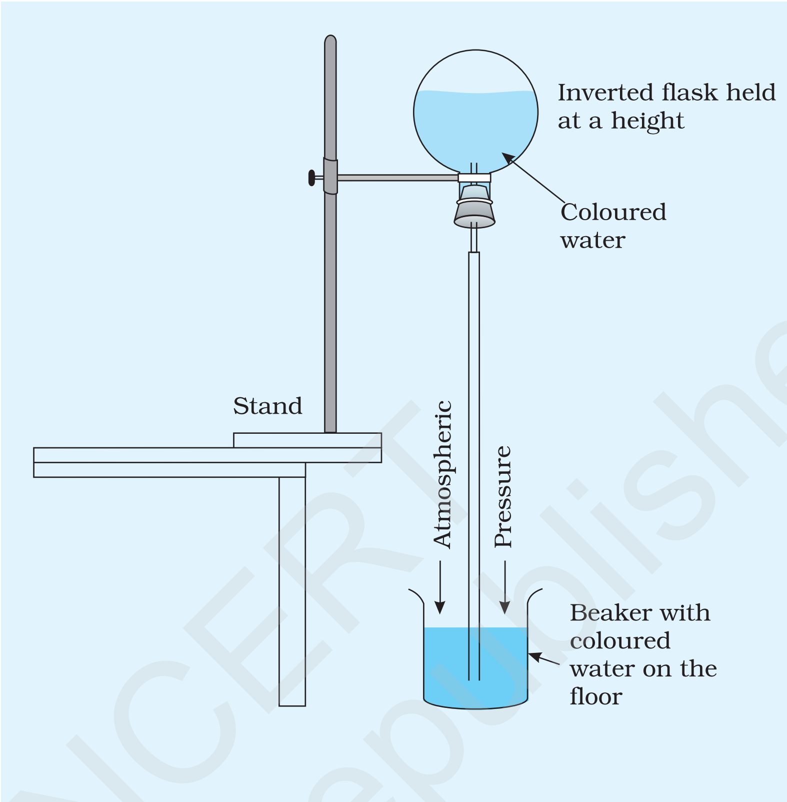


Fig. D 10.1 (b): *Atmospheric pressure pushes coloured water up into the flask as steam in the flask condenses*

become curious to know the reason why water rises through the height. It may be explained in terms of difference in pressure of air on the surface of the water in the container and inside the flask.

Note

To make this experiment more spectacular, a student may climb on the table and raise the stand by another 2 m. Then the pressure rubber tube may also have to be longer.

DEMONSTRATION 11

To study variation of volume of a gas with its pressure at constant temperature with a doctor's syringe

This demonstration can be given with the help of a large (50 mL or more) doctor's syringe (disposable type), laboratory stand, grease or thick lubricating oil, 200 gram to 1 kg weights which fit over one another, cycle value-tube, rubber band, a wooden block and a laboratory stand.

Make the piston in the syringe air tight by applying a drop of thick lubricating oil or grease into the syringe. Draw out the piston in the syringe so that the volume of air enclosed by it is equal to its full capacity. Next close the outlet tube of the syringe by fixing a piece of cycle value-tube on it and folding the valve-tube. Hold the syringe vertically with a laboratory stand with its base resting on a wooden block (Fig. D 11.1).

Press the piston downward with the hand to compress the air inside. Release the piston and observe, whether the air inside regains its initial volume by pushing the piston up. Since, the friction between the piston and the inner surface of the syringe is quite large, both

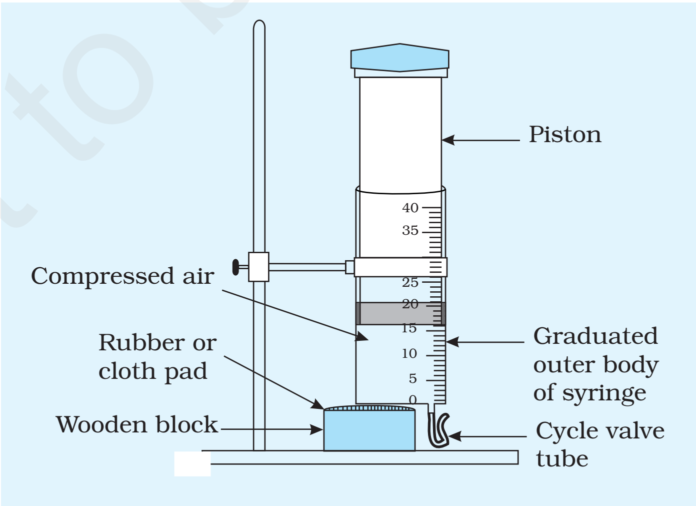


Fig. D 11.1: *The load is kept on the piston of the syringe to apply the force of its weight along the axis of the piston* being of plastic, the air inside is unable to push the piston upto its original position. When the piston comes to rest, the thrust of atmospheric pressure plus limiting friction is acting on it downwards. Note the volume of enclosed air in this position of the piston.

Next, pull the piston up a little and release. Again it does not reach quite upto its original position. This time the thrust of atmospheric pressure minus limiting friction is acting on it downwards. Note this volume of air also and check that the mean of the two volumes so measured is equal to the original volume of air at atmospheric pressure.

Now balance a 1 kg weight on the handle of the piston. Note the two volumes of enclosed air, (i) piston slowly moving up and coming to rest, and (ii) piston slowly moving down and coming to rest and find their mean. In this manner note volume, V, of air for at least two different loads, say 1 kg and 1.8 kg, balanced turn by turn on the piston. Check up, in the end that volume for no load is same as that at the beginning to ensure that no air leaks out during the experiment. Draw a graph between $1/V$ and load W for the three observations, W = 0 kg, 1 kg and 1.8 kg if a graph black-board is available. Alternately, it may be given as an assignment to students.

DEMONSTRATION 12

To demonstrate Bernoulli's theorem with simple illustrations

(a) Suspend two simple pendulums from a horizontal rod clamped to a laboratory stand (Fig. D 12.1). Use paper balls or table tennis balls as bobs. Their bobs should be close to each other and at the same height but not touching each other. Ask the students what would happen if you strongly blow into the space between the bobs. A person/ student not thinking in terms of Bernoulli's theorem would conclude that air pushed into this space will push the bobs away from each other. Now blow air between the two bobs suspended close to each other and ask them to observe what happens. The speed of air passing between them gets increased due to less space available and so the pressure there, gets decreased. Thus, the pressure of air on their outer faces of the bobs pushes them closer. That is why one observes the bobs to actually move closer.

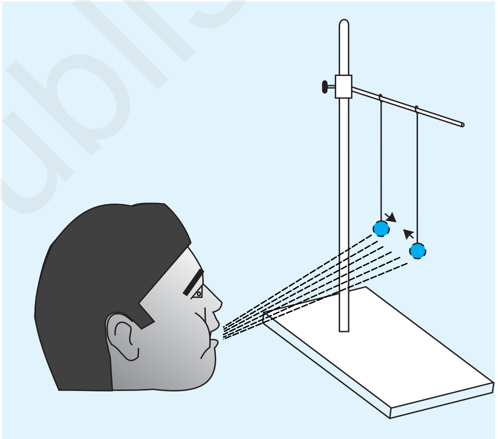


Fig. D 12.1

(b) Place a sheet of paper supported by two books in the form of a bridge. Let the books be slightly converging (Fig. D 12.2) i.e., their separation is larger on the side facing you. Now, you blow under the `bridge', the paper `bridge' is pushed down.

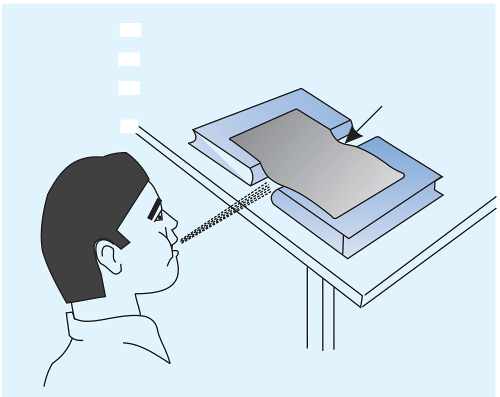


Fig. D 12.2

(c) Hold the shorter edge of a sheet of paper horizontally, so that its length curves down by its weight [Fig. D 12.3(a)]. If you press down lightly on the horizontal part of the curve with your finger the paper curves down more. Now, instead of touching with the hand hold the horizontal edge of the sheet of paper close to your mouth. Blow over the paper along the horizontal. Does the hanging sheet of paper get pushed down or

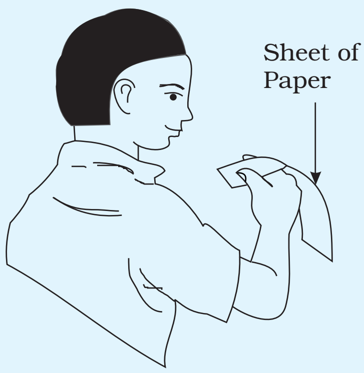


Fig. D 12.3 (a)

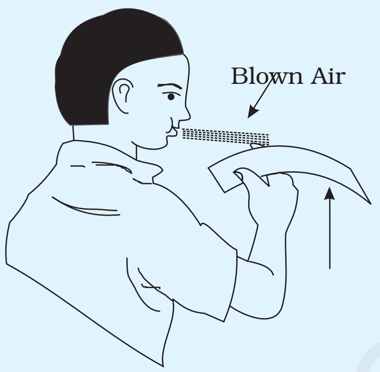


Fig. D 12.3 (b)

lifts up [Fig. D 12.3(b)]? The curved shape of paper makes the tubes of flow of the wind narrower as the wind moves ahead as shown in [Fig. D 12.3(c)]. Thereby its speed increases and pressure on the upper side of the paper decreases.

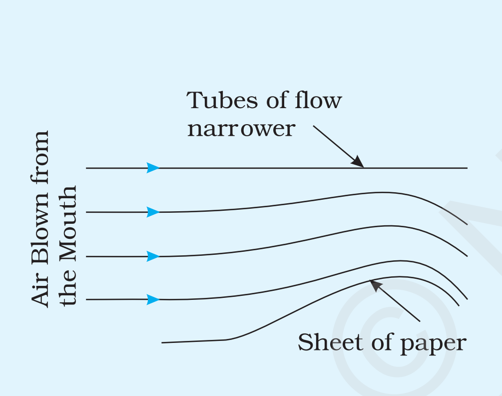


Fig. D 12.3 (c)

(d) Fill coloured water in an insecticide/pesticide spray pump. Spray the water on a white sheet of paper. Coloured drops deposit on the paper. It is evident that water from the tank rises up in the tube attached to it and is then forced ahead in the form of tiny droplets. But what makes it rise up in the tube? As the pump forces air out of a fine hole, the speed of air in the region immediately above the open end of the tube in the tank becomes high (Fig. D 12.4). Thus, the pressure of air in the region is lower than the surrounding still air (which is equal to atmospheric pressure). Right in this region, just below the hole in the pump is the upper end of the fine tube through which water rises up, due to atmospheric pressure acting on the surface of water outside the tube.

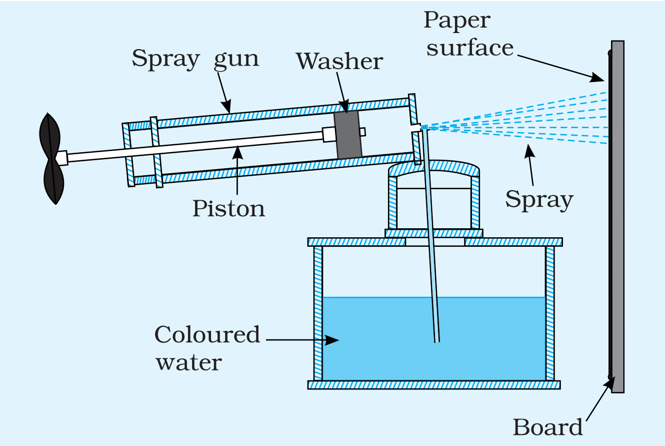


Fig. D 12.4

(e) Fig. D 12.5 shows the construction of a Bunsen burner. The fuel gas issues out of the jet J in the centre of the vertical tube. Due to the high speed of gas, its pressure gets lowered. So, through a wide opening in the side of the vertical tube air rushes in, mixes up with fuel gas and the gas burns with a hot and blue flame. If the air does not get mixed with fuel gas at this stage and comes into contact with it only at the flame level, the flame will be bright yellow-orange like that of a candle, due to incomplete combustion of the gas which gives off comparatively less heat than when it burns with a blue flame.

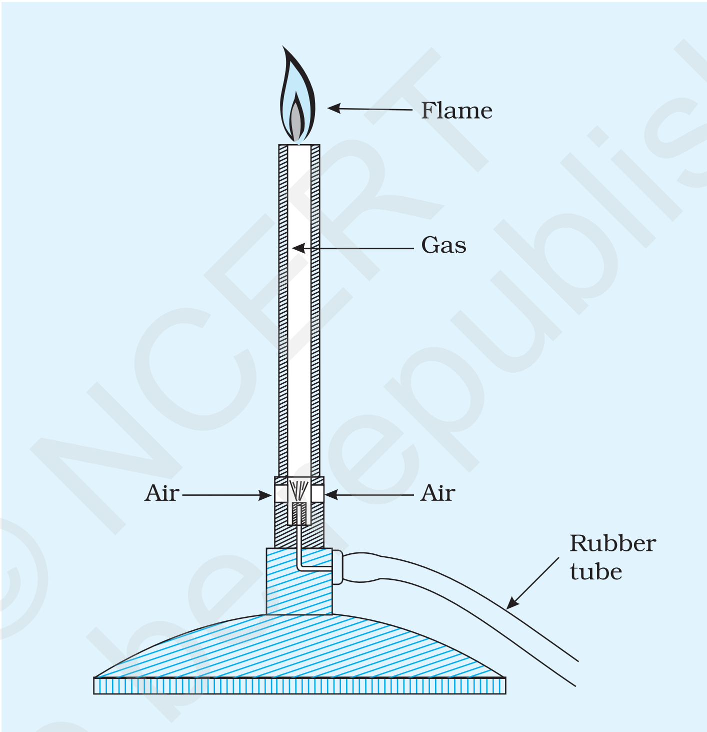


Fig. D 12.5

DEMONSTRATION 13

To demonstrate the expansion of a metal wire on heating

Stretch a length of any metal wire firmly between two laboratory stands, which are fixed rigidly on the table by G-clamps (Fig. D 13.1). Suspend a small weight at the centre of the wire and stretch the wire as tightly as possible, without significantly bending the iron stands. However, the wire cannot be made straight and some sagging is inevitable due to the weight suspended at the centre. Place a pointer on the hind side of the upper edge of the weight to serve as reference.

Heat the wire along its entire length by a spirit lamp or a candle. The wire is seen to sag more and the weight moves down. Remove the flame to let the wire cool. As the wire gradually cools, the weight ascends to its original position.

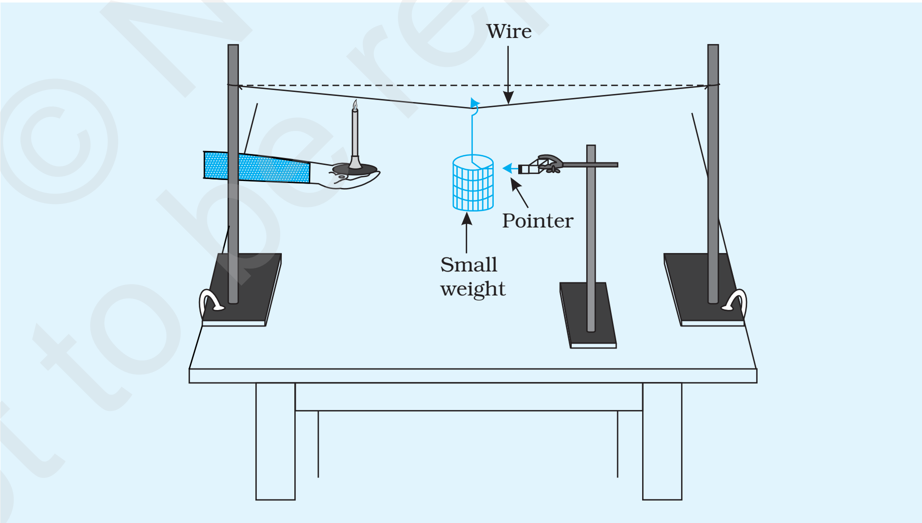


Fig. D 13.1: *A taut wire sags on heating due to its thermal expansion*

Note:

The wire can also be heated electrically, if so desired. Use a step-down transformer which gives various voltages in steps from 2 volt to 12 volt. The advantage is that heating of the wire for a certain voltage applied across it will be uniform along its whole length and the observed sagging by this heating will be repeatable.

DEMONSTRATION 14

To demonstrate that heat capacities of equal masses of aluminium, iron, copper and lead are different

This demonstration can be performed with four cylinders of aluminium, iron, copper and lead having equal mass and cross-sectional area, a rectangular blocks of paraffin wax, beaker/metallic vessel, thread, water and a heating device.

Since the four solid cylinders are having equal mass and equal cross-sectional area, their lengths are inversely proportional to their densities. Take water in a beaker or a metallic vessel and boil it. Suspend the four cylinders, tied with threads, fully inside boiling water (cautiously, if a beaker is being used). After a few minutes all have attained the temperature of boiling water [Fig. D 14.1(a)].

Take out the cylinders in quick succession and place them side by side on a thick block of paraffin wax [Fig. D 14.1(b)]. The cylinders sink to different depths in the paraffin wax. They all cool from temperature of boiling water to melting point of wax during the process of sinking. Although all the cylinders have the same mass, but the amount of heat they give out are different.

An alternative (and more convenient to do) method is to have a wooden board with semi cylindrical grooves resting against a block. Equal length of each groove is initially filled with wax. Hot cylinders are placed on this wax in the grooves, instead of on the wax block.

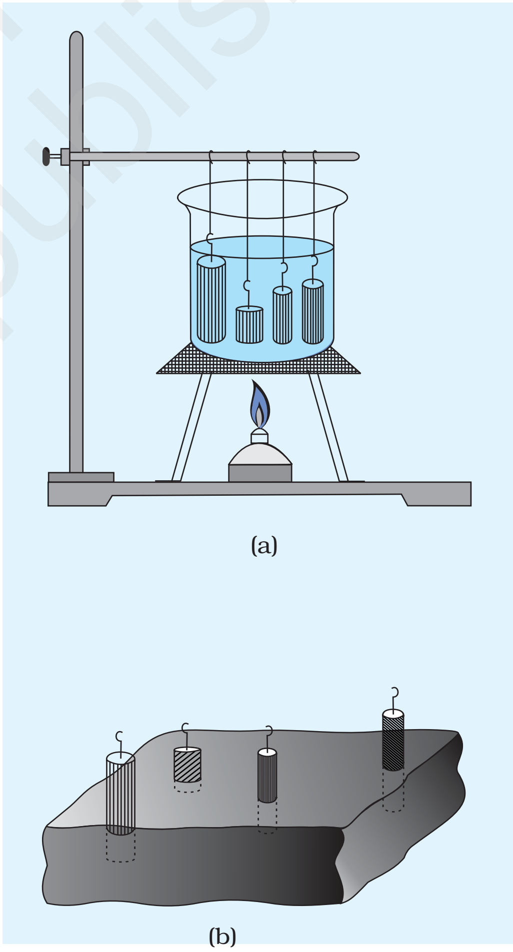


Fig. D 14.1: *Qualitative comparison of heat capacities of different metals*

Note

A substantial portion of heat given out by each cylinder is radiated into the atmosphere. Moreover, they radiate at different rates because of the difference in their surface areas. Therefore, by this experiment we only get a qualitative comparison of the heat capacities of these solids.

DEMONSTRATION 15

To demonstrate free oscillations of different vibrating systems

A number of demonstrations involving vibrating systems are presented through (a) to (j). Demonstrate as many vibrating systems as possible and discuss the following in each case:

(i) What are the energy changes that occur during vibrations?

(ii) How can the frequency of vibration be altered?

(iii) Can the damping of the system be reduced? If so, how?

(iv) How does the force acting on the oscillating body vary with its displacement from the mean position?

(a) *Simple pendulum*: Make a rather long and heavy simple pendulum following the steps described in Experiment 6. One may tie a brick or a 1kg weight at one end of a strong thread about 1.5 m in length. Suspend the pendulum from a stand having a heavy base so that it does not topple over. The base can be made heavy by putting a heavy load on it, say a few bricks. Alternatively, the stand may be clamped on the table with a G-clamp. The vertical rod of the stand may be further supported by tying it to three G-clamps fixed on the table (Fig. D 15.1). A sturdy stand will help in keeping the pendulum oscillating for quite a long time with very small damping.

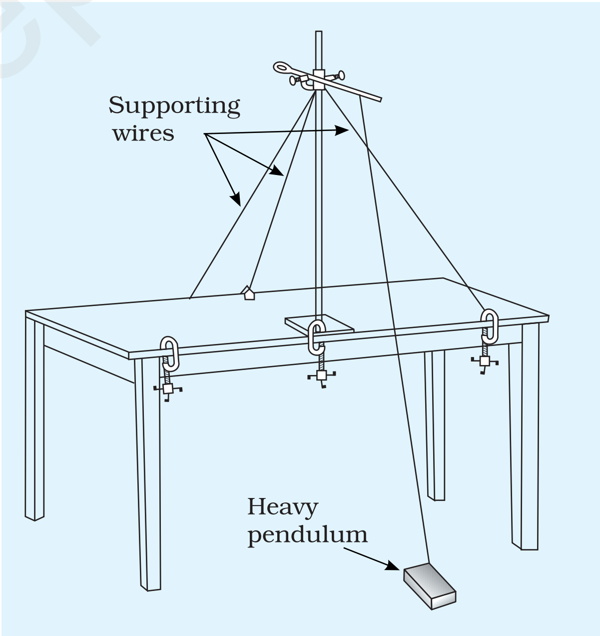


Fig. D 15.1: *Set up to study oscillations of a heavy pendulum*

(b) *Vibrating hacksaw blade*: Clamp a hacksaw blade (or a thin metal strip) with its flat surface horizontal at the edge of the table by a

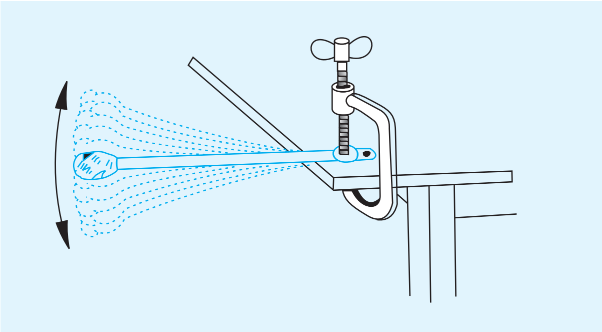


Fig. D 15.2: *A hacksaw blade clamped at one end vibrates up and down*

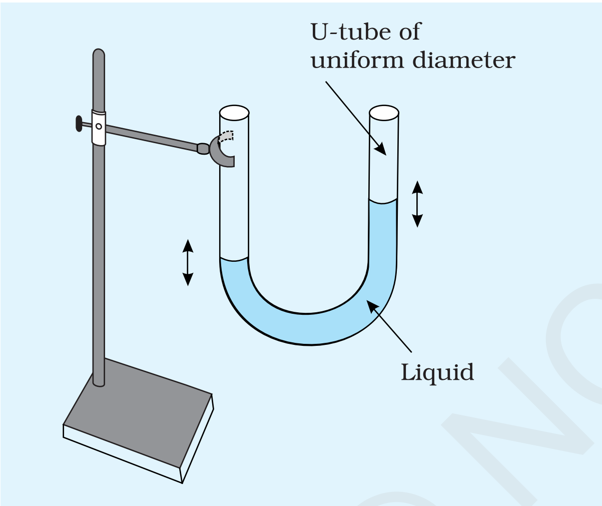


Fig. D 15.3: *Set up to demonstrate oscillations of liquid column in a U-tube*

G-clamp (Fig. D 15.2). Load the free end by about 20 g of plasticine or by putting a 20 g weight on the flat free end and fastening it to the blade with a thread. Let the free end of the blade vibrate up and down. Repeat the demonstration with a smaller load and then with no load on the blade. Compare the oscillations with different loads.

(c) *Oscillating liquid column:* Fix a U-tube of large diameter (about 2cm) on a stand with its arms vertical. Fill liquid of low viscosity e.g., water or kerosene or methylated spirit in it. Let the liquid column oscillate up and down in the tube (Fig. D 15.3). For this purpose blow repeatedly into one arm of the U-tube with your mouth as soon as the liquid column in the arm you are blowing attains maximum height so as to generate a small air pressure in it each time so as to oscillate the liquid column by resonance. Another method is to slightly tilt the stand to one side repeatedly, with the U-tube fixed on it so as to oscillate the liquid column by resonance.

A low cost U-tube can be improvised with two straight tubes of about 3.5 cm to 4 cm diameter and each of length about 50 cm. Fix the tubes vertically on a wooden board about 20 cm to 30 cm apart. Join their lower ends with a piece of a rubber tube, or a piece of hose pipe made of plastic. A plastic hose pipe is better because it bends to the U-shape easily. Fill this U-tube with coloured water upto about 10 cm below the two open ends. Oscillate the liquid in the tube by either of the two methods described above.

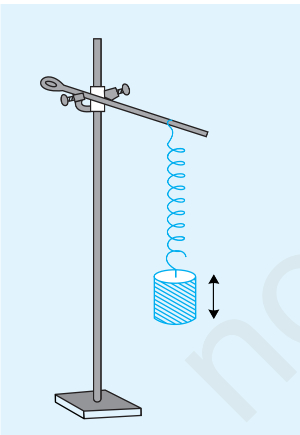


Fig. D 15.4: *A load attached to the lower end of a helical spring oscillates up and down*

(d) *Helical spring :* Attach a suitable mass, say 1kg, at one end of a helical spring (Fig. D 15.4). Suspend the spring vertically. Pull the weight down through a small distance and let it go. Observe and study the vertical oscillations of the mass suspended by the lower end of the spring.

(e) *Oscillations of a floating test-tube :* Take a test tube and fill at its bottom about 10 g of lead shots or iron filings or sand. Float the tube in water and adjust the load (lead shots or iron filings or sand) in the tube till it floats vertically. Keeping the tube vertical push it a little downwards and release it so that it begins to oscillates up and down on the surface of the water (Fig. D 15.5).

(f) *Oscillations of a ball along a curve* : Take about 30 cm length of aluminium curtain channel and bend it into an arc of a circle. Put it on a table and provide it proper support by two rectangular pieces of thick card board or plywood to keep it standing in a vertical plane. Let a ball–bearing or a glass marble oscillate in its groove (Fig. D 15.6). Alternatively place a concave mirror (10 cm or 15 cm aperture) or a bowl or a *karahi* on a table with its concave side facing up. Let a ball bearing or a glass marble oscillate in it along an arc passing through its lowest point as shown by point P in Fig. D 15.6.

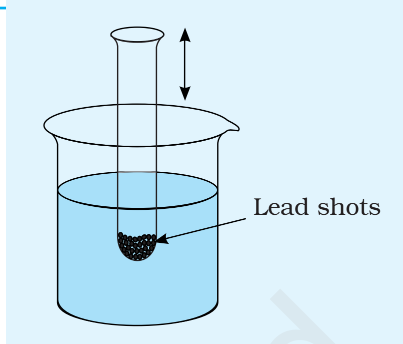


Fig. D 15.5: *A test tube floating in vertical position due to a load in it, oscillates up and down, when it is pushed a little and then released*

(g) *Oscillations of a ball on the double inclined track:* Adjust a double inclined track on a table with its arms equally inclined to the horizontal (Fig. D 15.7). Release a steel ball–bearing (2.5 cm diameter) from the upper end of one of the arms and let it oscillate to and fro between the two arms of the double inclined plane.

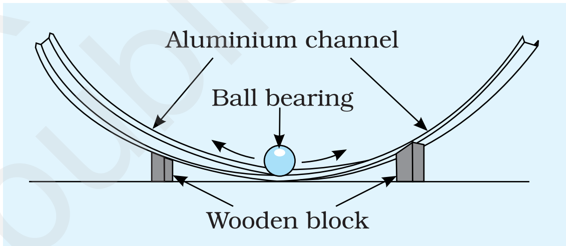


Fig. D 15.6: *Arrangement to demonstrate the to-and-fro motion of a steel ball in a channel in the form of an arc of a circle*

(h) *Oscillations of a trolley held between two springs on a table:* Take a trolley and attach two identical helical springs at each of its ends such that the springs are along a straight line. Place the trolley on a table and fix the free ends of the springs to two rigid supports on opposite ends of the table so that the springs are under tension along the same straight line [Fig. D 15.8(a)]. Displace the trolley slightly to one side keeping both springs under tension. Release the trolley and observe its to and fro motion along the length of the springs. Find the time period of oscillations and also make a note of damping.

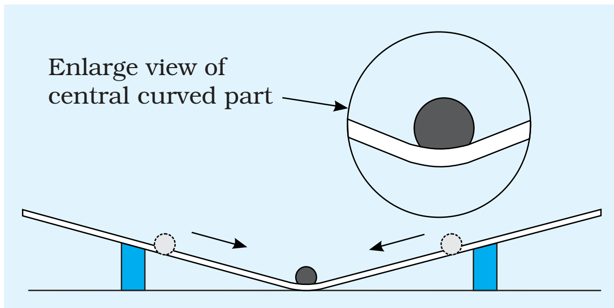


Fig. D 15.7: *Arrangement to demonstrate the to-and-fro motion of a ball along a double inclined track*

(i) *Oscillations of a trolley attached to a spring:* Remove one of the springs from the set up arranged for demonstration (h) shown in Fig D 15.8 (a). Displace the trolley to one side and release it. Compare the time period of oscillations affect of damping with the earlier case.

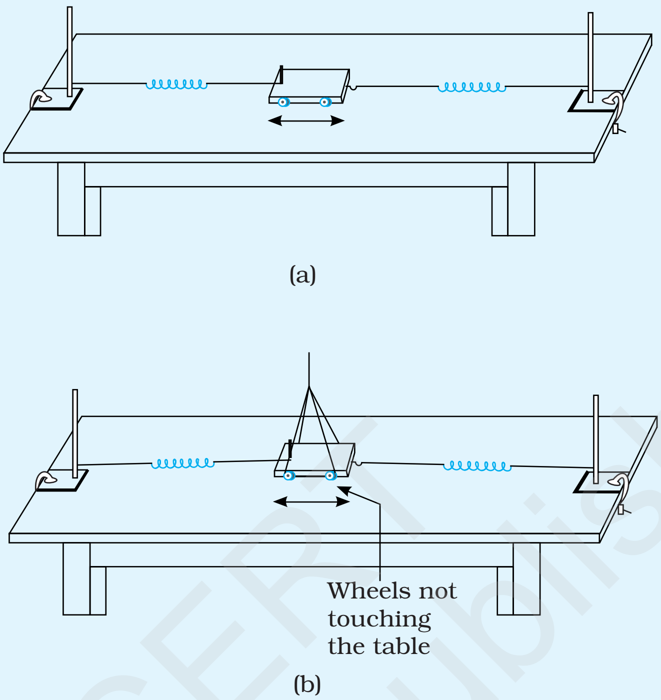


Fig. D 15.8: *(a) Set up for demonstrating the to-and-fro motion of a trolley held between two identical springs (b) Arrangement to demonstrate the to-and-fro motion of a trolley suspended from a high support while it is held between two springs on either side*

(j) *Oscillations of a trolley suspended from a point and held between two springs:* Set up the trolley with two springs on a table as described in demonstration (h) above. Attach an inflexible string to the trolley as shown in Fig. D 15.8(b). Fix the other end of the string to a stand kept on a stool placed on the table or to a hook on the ceiling such that the trolley remains suspended just above the table. Set the trolley in oscillation by displacing it slightly to one side. Study how the time period of oscillations and damping get affected as compared to the case when the trolley was placed on the table, as in demonstration (h).

DEMONSTRATION 16

To demonstrate resonance with a set of coupled pendulums

Take two iron stands and keep them on the table at about 40 cm from each other. Tie a half metre scale (or still better a straight strip of wood about 1.5 cm wide) between them so that it is horizontal with its face vertical and free to rotate about its upper edge (Fig. D 16.1). Near one edge of the scale suspend a pendulum with a heavy bob (say, approximately 200 g). Also suspend four or five pendulums of different lenghts with bobs of relatively lower masses. However, one of them should be exactly of the same length as the one with the heavy bob, as described.

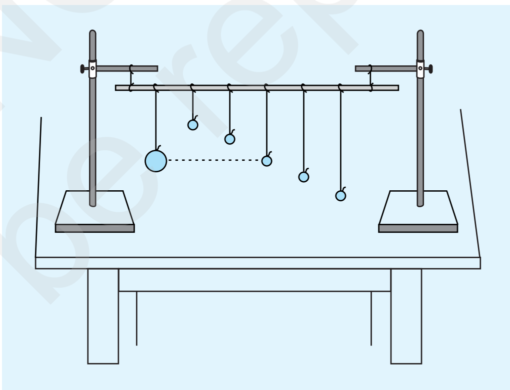


Fig. D 16.1: *A set up to demonstrate resonance*

Let all the pendulums come to a rest after setting up the arrangement described above. Gently pull the bob of the heavy pendulum and release it so that it starts oscillating. Make sure that other pendulums are not disturbed in the process. Observe the motion of other pendulums. Which of the pendulums oscillates with the same frequency as that of the heavy pendulum? How does the amplitude of vibrations of different pendulums differ?

DEMONSTRATION 17

To demonstrate damping of a pendulum due to resistance of the medium

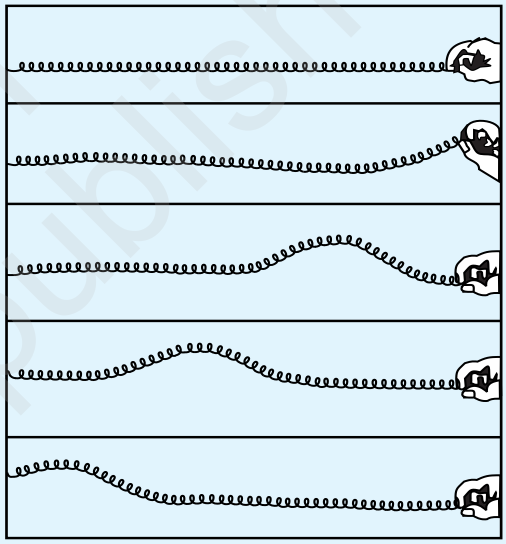
(a) *Damping of two pendulums of equal mass due to air:* Set up two simple pendulums of equal length. The bob of one should be small in size say made of solid brass. The bob of the other should be of the same mass but larger in size — either of a lighter material like thermocole or a hollow sphere. Give them the same initial displacement and release simultaneously. Observe that in the pendulum with the larger bob the amplitude decreases more rapidly. Due to its larger area, air offers more resistance to its motion. Though both pendulums had the same energy to start with, the larger bob looses more energy in each oscillation.

(b) *Alternative demonstration by comparing damping due to air and water:* Set up a simple pendulum about half metre long with a metal bob of 25 mm or more diameter. In its vertical position the bob should be about 4 cm to 5 cm above the table. First, let the pendulum oscillate in air and observe its damping. Now place a trough below the bob containing water just enough to immerse the bob in water. Let the pendulum oscillate with the bob immersed in water and note the effect of changing the medium on damping.

DEMONSTRATION 18

To demonstrate longitudinal and transverse waves

A few characteristic properties of transverse and longitudinal waves can be demonstrated with the help of a slinky, which is a soft spring made of a thin flat strip of steel (about 150 to 200 turns) having a diameter of about 6 cm and width 8 cm to 10 cm. Nowadays slinky shaped spirings made of plastics are also available. Let two students hold each end of the slinky and stretch it to its full length (at least 5 metres) on a smooth floor. Give a sharp transverse jerk at one end and let the student observe the pulse as it moves along the spring [Fig. D 18.1(a)].

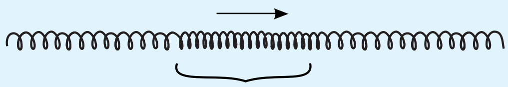


(a)

Fig. D 18.1(a): *Motion of a pulse through a slinky*

Find the speed of the pulse by measuring the time taken by it to move from one end to the other along the stretched length of the spring. For more accuracy, instead of measuring time taken by the pulse to move from one end to the other, measure the time taken by it to make three to four journeys along the entire length of the spring. This would be possible because each pulse moves back and forth along the spring a few times before it dies.

Repeat the experiment by decreasing the tension in the spring (by stretching it to a smaller length) and find the speed of the pulse. Does the speed depend on tension?



(b)

Fig. D 18.1(b): *A compression moving along the length of a slinky*

The slinky can also be used to demonstrate propagation of longitudinal waves. To do so, give a longitudinal jerk at one end of the slinky, keeping the slinkly stretched on the floor to about half the length (2.5 m) than while demonstrating movement of a transverse pulse [Fig. D 18.1(b)]. Ask the students to observe the motion of the pulse in the form of compression of the spring.

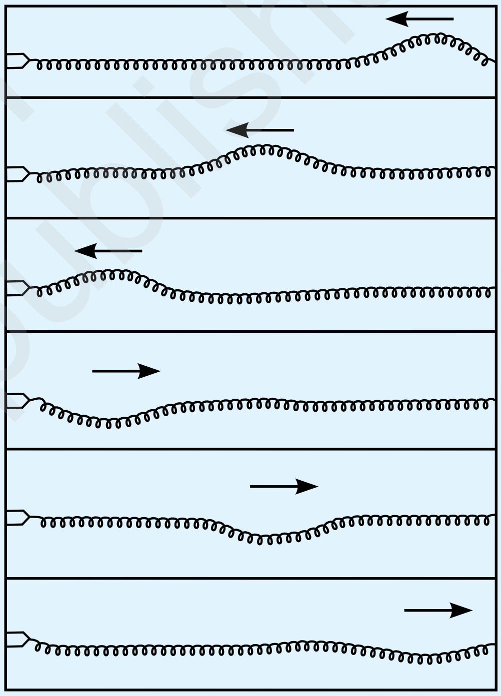
The damping may be too high if the floor is not very smooth. In that case the experiment may be performed by suspending the slinky from a steel wire stretched between two pegs firmly fixed on opposite walls of the room. In order to minimise the effect of sagging of the spring in the middle, support the spring by tying it to the wire with pieces of thread spaced at about 25 cm from each other. All pieces of thread must be equal in length.

The transverse waves may also be demonstrated with the help of a flexible clothes line or a rubber tubing or a rope instead of a slinky. Tie one end of the rubber tubing or the clothes line to the knob of a door and give it a jerk at the other end while keeping it stretched. If the rubber tube is heavy (fill water in it) and is held loosely, the pulse would move slowly to make better observation.

Instead of a single pulse, a series of pulses one after the other creating an impression of a continuous wave propagation may also be demonstrated. This can be done by using a slinky or a flexible clothes line. Stretch the slinky on the ground and ask one of the students to hold one end firmly. Instead of giving just one jerk at the other end, move the hand to and fro continuously to make waves of wavelength about 0.5m which can be seen to move continuously along the spring.

DEMONSTRATION 19

To demonstrate reflection and transmission of waves at the boundary of two media



(a)

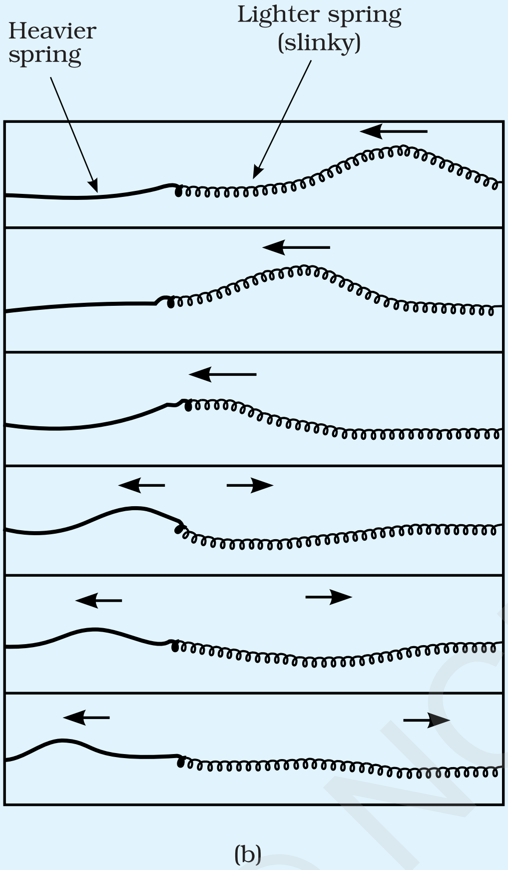
Fig. D 19.1 (a): *A pulse reflected at a fixed end undergoes phase change of π*

Stretch the slinky on a smooth floor or suspend it from a stretched steel wire as described in Demonstration 18.1. Keeping one end fixed, send a pulse from the other end. Note the size and direction of displacement of pulse before and after it gets reflected at the fixed end. Note that the reflected pulse is upside down with little change in its size in comparison to the incident pulse [Fig. D 19.1(a)].

Next join the coil spring (slinky) with another long helical spring of heavier mass end to end [Fig. D 19.1(b)]. Stretch them by holding the free end of each spring and produce a pulse at the free end of the lighter spring (slinky). Observe what happens when the pulse arrives at the joint of two springs. In what way (i.e., with respect to size and direction of displacement) does the reflected pulse undergo a change? Does the pulse transmitted to the heavier spring also undergo any change?

Repeat the demonstration by sending the pulse from the end of the heavier spring. Note how the reflected and transmitted pulse undergo a change at the boundary of the two springs as compared to the incident pulse [Fig. D 19.1(c)].

How do these changes differ from those in case of incident pulse going from lighter to heavier spring?



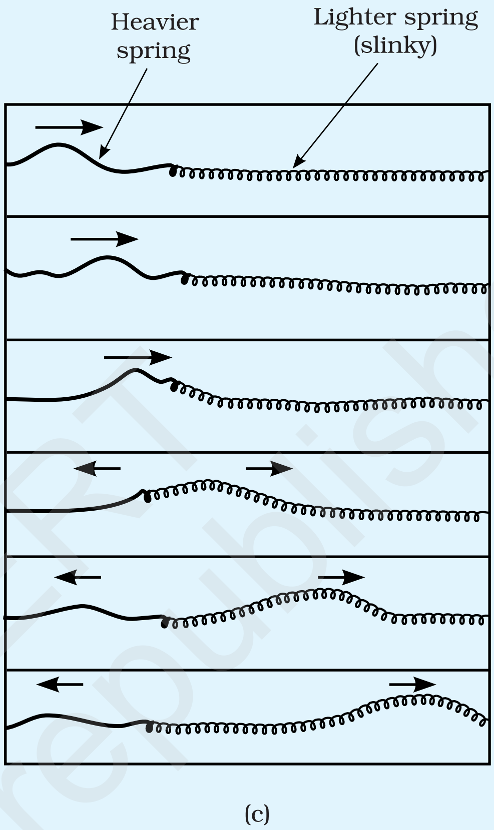


Fig. D 19.1 (b): *Reflection and transmission of a pulse moving from a rarer medium to a denser medium*

Fig. D 19.1 (c): *Reflection and transmission of a pulse moving from a denser medium to a rarer medium*

Now join the slinky (coil spring) to a fine thread instead of a heavier spring. Stretch the spring and the thread and produce a pulse at the free end of the spring. Note what happens to the pulse at the boundary of the spring and the thread.

DEMONSTRATION 20

To demonstrate the phenomenon of beats due to superposition of waves produced by two tuning forks of slightly different frequencies

Take two tuning forks of identical frequency. Attach a small piece of plasticine or wax to the prongs of one of the tuning forks. This will slightly lower the frequency of the tuning fork. Now holding them one in each hand strike both the tuning forks simultaneously on two rubber pads. Place them close to each other.

Carefully listen to the combined sound produced by the two tuning forks. Gradual increase and decrease in the intensity of sound will be heard. It is due to beats produced by the superposition of waves of slightly different frequencies. You can also count the number of beats produced per second if their frequency does not exceed two or three beats per second. The person who is listening to the beats, gives a silent signal at each minimum intensity or maximum intensity, e.g., by shaking his head in the manner we say 'yes'. Then a second person with a stop-watch, either finds the time taken by 10 beats or counts the number of beats in 5 seconds. The person with the stop-watch will also listen to the beats, though less loudly and may measure the frequency without the aid of a signal by the first person.

If two tall tuning forks of the same frequency mounted on resonating wooden boxes are available, all the students in a classroom may be able to listen to the beats. Place them on a desk in the centre of the classroom. Let there be pin-drop silence in the classroom. Then strike the tuning forks with a rubber hammer in quick succession, with roughly equal force. Make their frequencies slightly different by loading one with plasticine or wax or by tightly attaching a small load with adhesive tape. Both tuning forks must be of rather good quality and must give audible sound for about 8 to 10 seconds in spite of dissipation of energy in the resonating box.

DEMONSTRATION 21

To demonstrate standing waves with a spring

Stretch the wire spring (heavier one and not the slinky) to a length of 6 m to 7 m, by tying its one end to a door handle. It may sag in the middle but that will not affect the demonstration. Give a transverse horizontal jerk at the free end, a pulse will travel along the spring, and get reflected back and forth. If instead of stretching the spring in air it is stretched along the ground, then due to large damping, the results will not be so clear and convincing.

Now generate a continuous transverse wave in the spring by giving series of jerks to the spring at fixed time intervals. Change the frequency of the waves by changing the time period of oscillating your hand till stationary waves are set up. You will find that stationary waves are produced only when an integral number of loops, i.e., 1,2,3 etc. are accommodated in the entire length of the spring. In other words, stationary waves are produced corresponding to only some definite time periods.

Ask one of the students to measure the time period of standing waves when one loop, two loops, three loops, and so on are formed in a given length of stretched spring. For the same extension of the spring, and thus for the same tension in the spring, how are the time periods of stationary waves of one loop, two loops, and three loops related to each other?

While producing stationary waves, suddenly stop moving your hand to and fro and thus stop supplying energy to the spring. This is best done by taking the help of a stool on which your hand rests while producing the waves as well as when you stop your hand. Observe that the spring continues to vibrate for some time with the same time period and the same number of loops. Thus, it can be demonstrated that the stretched spring is capable of making free oscillations in several modes—with one loop, two loops, three loops, etc. The various time periods with which you can produce stationary waves in it, are also the natural time periods of the spring.

Thus, when you are producing and observing stationary waves in the stretched spring, you can consider it as a resonance phenomenon. However, in this case, the object being subjected to forced oscillations (i.e., the stretched spring), is capable of oscillating freely with one of the several time periods, unlike the simple pendulums with which you experimented earlier to study the phenomenon of resonance.

One can also demonstrate stationary waves with a spring when its both ends are free to move. Tie a thread, 3 – 4 m in length, at one end of the spring. Tie other end of the thread to a hook on the wall or a door handle. Stretch the spring by holding it at its free end and send a continuous transverse wave in the spring by moving the end in your hand. Do you observe that the stationary waves now produced are somewhat different than those produced when one end of the spring was fixed. Note the difference in the pattern of stationary waves in the two situations and discuss the reason for the difference. Also ask to note the number of loops produced when a stationary wave is set in the spring.

Change the time period of the wave by adjusting to and fro motion of your hand to produce ½ loop, 1½ loop, 2½ loop and so on for same extension of the spring.

How are these time periods related to the various time periods of vibration when the end not in your hand was kept fixed and extension of the spring was the same?

Note

> Mathematically, it can be shown that superposition of two waves of the same frequency (and thus moving with same velocity) travelling in opposite directions in an infinite medium, produce stationary waves. In this mathematical treatment, there is no need of specific frequencies at which the stationary waves are produced. However, it is not possible to translate that mathematical result into a simple experimental demonstration. In an experiment we have to take a finite medium, like the stretched spring of finite length. A finite medium with boundaries has its natural frequencies and thus experiment is done at those frequencies. In the above demonstrations one wave is produced by hand and the other (travelling in the opposite direction) is the reflected wave and their superposition produces stationary waves, exemplifying the above referred mathematical result.