PROJECT **1**

A_{IM}

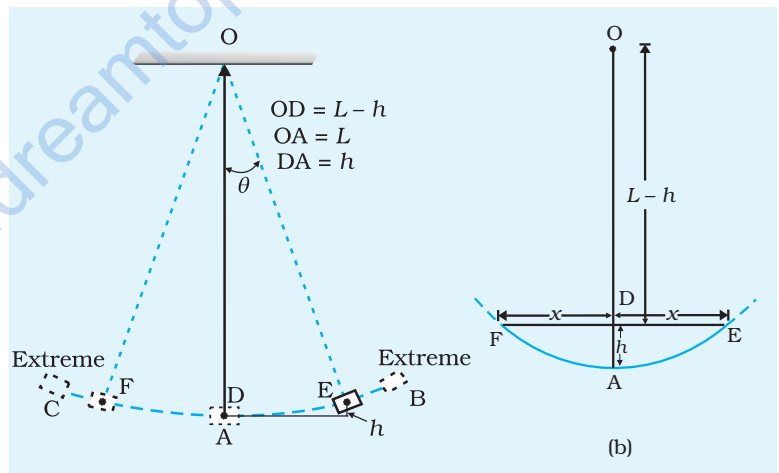To investigate whether the energy of a simple pendulum is conserved.

A_{PPARATUS AND MATERIAL REQUIRED}

A tall laboratory clamp stand with clamps, a split cork, a brick (or any heavy metallic weight) to be used as bob, strong cotton thread/ string (about 1.5 m to 2.0 m), stop-watch, ticker timer, paper tape, balance, wooden block, cellotape, metre scale and graph paper.

P_{RINCIPLE}

Energy can neither be created nor destroyed, though it can be transformed from one form to another, and the sum of all forms of energies in the universe remains constant (Law of conservation of energy). In any isolated mechanical system with practically negligible/no dissipation of energy to overcome viscous drag/air resistance / friction, (as in case of a pendulum), the sum of the kinetic and potential energies remains constant. For small angular

Fig. P 1.1: *An oscillating pendulum*

amplitude ($\theta \leq 15°$), the pendulum executes simple harmonic motion (SHM) with insignificant damping, i.e., loss of energy. Hence, an oscillating simple pendulum provides a convenient arrangement to investigate/ validate the law of conservation of energy for a mechanical system.

The oscillations of a simple pendulum of effective length L with mean position at point A and extreme positions at points B and C, are shown in Fig. P 1.1. In the extreme positions, i.e., at B and C the oscillating bob is raised to a certain height h (= AD) above the mean position where it possesses maximum potential energy but minimum kinetic energy. In the mean position, at A, it possesses maximum kinetic energy and minimum potential energy. At any intermediate position i.e., at E and F the bob will possess energy in the form of both kinetic and potential energies. The effective length L (= $l + r$) of the pendulum is taken from the point of suspension O to the centre of gravity of the bob (Fig P 1.1; also refer Experiment E 6). For small angular amplitudes (θ) (about 8° to 10°) the arc length EA = (FA) is about the same as linear distance ED = (FD) = x, the points E and F are symmetrically above point D.

From the geometry of the Fig. P 1.1, it follows

DF. DE = OD. DA

$x \times x = (L - h) h$

For small values of x and h (and $x \ll L$ and $h \ll x$)

(P 1.1)
$$h = \frac{x^2}{L}$$

Then the potential energy of the bob (brick) of mass m at point E (or F)

(P 1.2)
$$= mgh = \frac{mg}{L} x^2$$

The kinetic energy E possessed by the bob moving with velocity v at

(P 1.3)
point E (or F) is $= \frac{1}{2} mv^2$

Then total energy of the bob is given by

(P 1.4)
$$E = \frac{1}{2} mv^2 + \frac{mg}{L} x^2$$

Using this relation, now investigate whether the total energy E of the oscillating simple pendulum remains constant.

DEVICE FOR MEASURING SHORT TIME INTERVALS IN THE LABORATORY: TICKER TIMER

Ticker-timer is a device used for the measurement of short time-intervals in the laboratory. It can measure short time intervals of about 0.02s to much higher degree of accuracy as compared to that of a stop-watch (with least count of 0.1s). Ticker-timers are available in different designs.

A simple type of ticker-timer, as shown in Fig.P1.2, consists of a steel/metallic strip T which can be made to vibrate at a known frequency with the help of an electromagnet. The pointed hammer of the vibrating steel strip, T strikes a small carbon paper disc C under which a paper tape, is pulled by the oscillating object. The dot marks are marked on the paper tape by the pointed hammer when the strip vibrates.
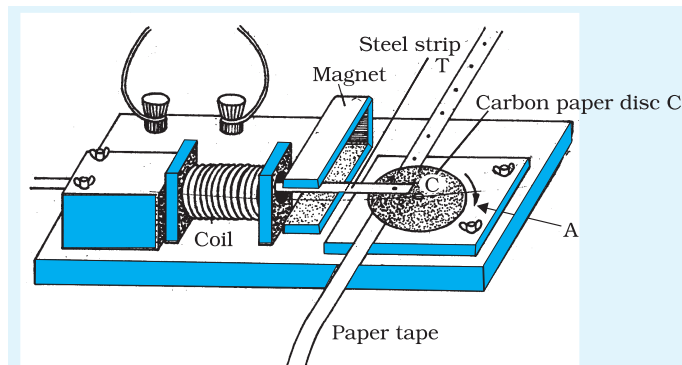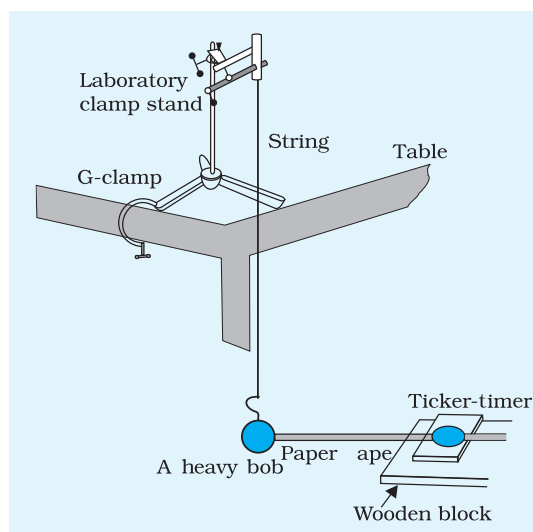

Fig. P1.2: Ticker-timer

The dot marks are obtained on the paper tape at regular (or equal) intervals of time. Each dot mark refers to a complete vibration of the vibrating steel strip. The time interval between the two consecutive dot marks can be taken as a unit of time for a tick. The time period of the vibrating strip is obtained from its given (known) frequency of vibration. When it is run on 6V step-down ac supply, its frequency is the same as that of ac mains (50 Hz, in India).

In this way, the measured time interval for one tick (between the two consecutive dot marks) can be converted into the basic unit, second, for time measurement. Thus, the ticker-timer can be used to measure accurately time interval of the order of 0.02 s in the laboratory.

PROCEDURE

1. Find the mass of the pendulum bob.

2. Determine *r* and *l* by metre scale. The length of the pendulum *L = l + r*.

3. Take the ticker-timer and place it at about the same level as the centre of the bob as shown in Fig. P 1.3. Fix the ticker-timer on a wooden block with tape, to ensure that its position is not disturbed when tape is pulled through it.

4. Attach the tip of the paper tape of the ticker-timer to the bob with the help of cellotape such that it is horizontal and lies in the plane in which centre of gravity of the bob lies in its rest position.

Fig. P 1.3: Experimental setup for studying conservation of energy

5. Pull the bob towards the timer such that its angular displacement ($\theta < 10°$) is about one tenth of its length from the vertical position. Take care that the ticker tape is sufficiently light and is so adjusted that it easily moves by the pull of bob as soon as it begins to move.

6. Start the ticker-timer carefully and let the bob oscillate. While the bob moves towards the other side, it pulls the paper tape through the ticker-timer. Ticker timer, thus, records the positions of the bob at successive time intervals.

7. Switch off the ticker-timer when the brick reaches the other extreme end. Take out the paper tape and examine it. Extreme dot marks on the record of the tape represent the extreme positions B and C of the pendulum. The centre point A of this half oscillation is the centre of the two extreme dot marks, and may be marked by the half metre scale, as in Fig. P1.4.
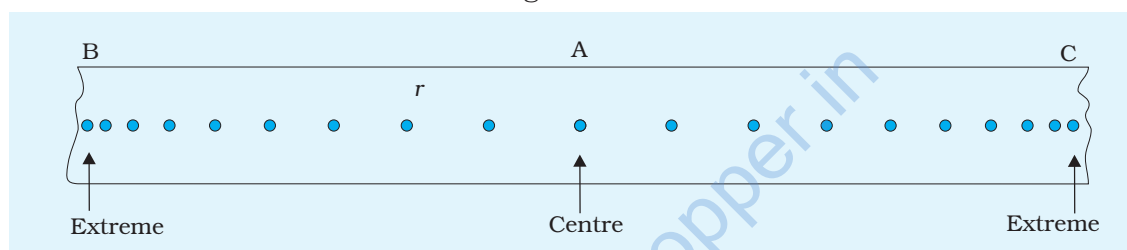
Fig. P 1.4: *Position of the oscillating bob marked on paper tape*

8. Measure the displacements of the bob corresponding to each dot (about 10 to 12) on either sides from the centre marked A as x_1, x_2, x_3, ... Find the time t_1, t_2, t_3, ... when each selected dot was made by counting the number of dots from the central point A, representing the mean position of the pendulum. If central point A is not coinciding with a dot marked by the ticker-timer, appropriate fraction of time-period of ticker-timer has to be added for finding correct t_1, t_2, t_3, ...

9. Record observations in the tabular form in SI units and proper significant figures.

10. Calculate the corresponding velocity for each selected position of the dot as v_i (= $\Delta x_i / \Delta t_i$). For this take one earlier and one later dot. The distance between these two dots is Δx_i and Δt_i is time to cover this distance. Then find magnitude of kinetic energy $\frac{1}{2}mv^2 \left[= \frac{m}{2}\left(\frac{\Delta x_i}{\Delta t_i}\right)^2\right]$ and potential energy

mgh_i [= $mg\,(x_i^2/L)$] of the pendulum bob. Find the sum of kinetic and potential energies in each case. Express the result in SI units and proper significant figures.

11. Plot a graph between the displacement (x_i) of the pendulum bob (distance of dots from the central dot) against the time.

12. Find the velocity (v) from the slope of the graph at five or six points on the left and also on the right of the mean position. Calculate the corresponding kinetic energy ($mv^2/2$) for each position of the points on the graph.

13. Plot another graph between kinetic energy and the position (x) of the bob. Find out the position of the point for which kinetic energy is minimum.

14. Calculate also the potential energy, PE $\left(= mg\dfrac{x_i^2}{L}\right)$, at the corresponding points at which you have calculated the kinetic energy. Plot the graph of potential energy (PE) against the displacement position (x) on the same graph on which you have plotted kinetic energy versus position graph.

15. Find the total mechanical energy E as the sum of kinetic energy and potential energy of the pendulum at each of the displacement positions x. Express the result in SI units with proper significant figures. Plot also a graph between the total mechanical energy E against displacement position (x) of the pendulum on the same graph on which you have plotted the graphs in Steps 13 and 14, i.e., for K.E. and P.E.

OBSERVATIONS

Measuring the mass of bob and effective length of simple pendulum

(a) Effective length of the simple pendulum

Least count of the metre scale = ... mm = ... cm

Length of the top of the brick from the point of suspension, l = ... cm = ... m

Diameter of the bob, $2r$ = ... cm

Effective length of the simple pendulum L = ($l + r$) = ... cm = ... m

(b) Mass of the ... g

Time period (T) of ticker-timer = ... s

Fraction of T to be added for finding corrected T_i on left = ...

Fraction of T to be added for finding corrected T_i on right = ...

Table P1.1: Measuring the displacement and time using ticker-timer and the recorded tape

S. No.	S. No. of dot on tape (i)	Displacement (Distance of dot from centre, x_i) (cm)	Number of vibrations of ticker-timer between central and i^{th} point	T_i (s)	Velocity v (m s^{-1})
1	2nd left				
2	4th left				
3	6th left				

	2nd right				
	4th right				
	6th right				

(c) Plotting a graph between displacement and time

Take time t along x-axis and displacement x along y-axis, using the observed values from Table P1.1. Choose suitable scales on these axes to represent t and x. Plot a graph between t and x as shown in Fig. P1.5. What is the shape of x-t graph?

CALCULATION
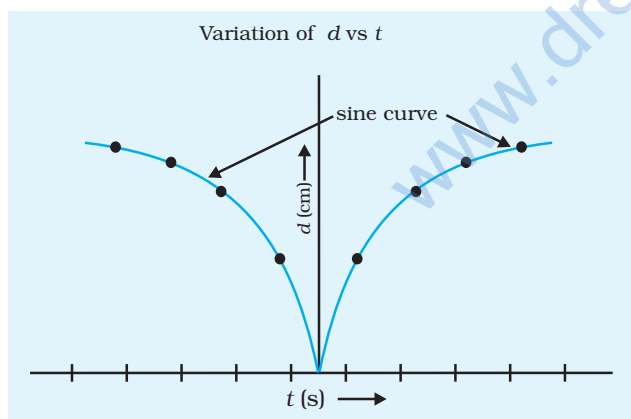
Fig. P1.5: *Graph between displacement and time of the oscillating bob*

(i) Find out from the graph (Fig. P1.5), the velocity of bob at five or six different points on the either side of the mean position O of the graph.

Compute the values of kinetic energy, using Eq. (P1.3), corresponding to each value of velocity obtained from the graph. Record these values in Table P1.2.

(ii) Plot a graph by taking displacement (distance) x along x-axis and kinetic energy (K.E.) along y-axis using the values from Table P1.2 as shown in Fig. P1.6.

(iii) Compute the values of potential energy using Eq. (P1.2), for each value of displacement in Step (ii) above.

Table P 1.2: Finding potential, kinetic and total energy of the oscillating bob

S. No.	Velocity, v (ms^{-1})	Kinetic Energy, $\frac{1}{2}mv^2$ (J)	Potential Energy, $mg\dfrac{x^2}{L}$ (J)	Total Energy = Potential Energy + Kinetic Energy (J)
1				
2				
3				
4				

(iv) Plot a graph by taking displacement (distance) x along x-axis and potential energy (P.E.) along y-axis on the same graph (Fig. P1.6).

(v) Compute the total energy E_T as the sum of the kinetic energy and potential energy at each of the displacement positions, x. Plot a graph by taking the displacement along x-axis and total energy E_T along y-axis on the same graph Fig. P1.6).
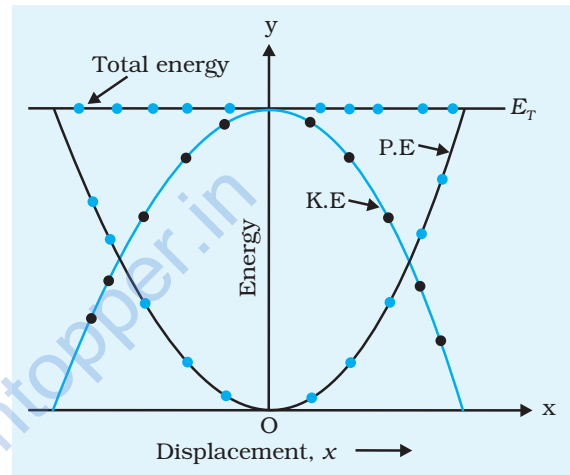
Fig. P 1.6: *Graph between displacement and energy of the oscillating bob*

RESULT

The total energy, as the sum of kinetic and potential energies, of the bob of the simple pendulum is conserved (remains the same) at all the points along its path.

DISCUSSION

1. Refer to points 3 to 5 under discussion given in Experiment E 6 on page 65.

2. Eq. P1.1 that expresses the relation between x, h and L for a simple pendulum, holds true under the conditions $h \ll x \ll L$ for small angular amplitudes ($\theta < 10°$) of the pendulum.

3. Linear displacement x of the bob, about (1/8)th to (1/10)th of the effective length of the pendulum corresponds to angular displacement (θ) of about 8° to 10° for small angular amplitudes,

the displacement (distance) of a dot mark on the paper tape from the central point/position truly represent corresponding displacement of the pendulum bob from its central (mean) position.

4. The shape of the graphs shown in Fig. P1.5 and Fig. P1.6 correspond to ideal conditions in which no energy is lost due to friction and air drag. The graph drawn on the basis of observed data may differ due to error in data collection and friction.

Self assessment

1. Identify the shape of displacement time graph, you have drawn for the oscillating simple pendulum. Interpret the graph.

2. Identify the shape of kinetic energy-displacement and potential energy-displacement graphs, you have drawn for the simple pendulum.

   Study the change in potential energy and kinetic energy at each of the displacement positions. Interpret these graphs and see how these compare.

3. What is the shape of the graph between the total (mechanical) energy and displacement you have drawn for the simple pendulum? Interpret the graph to show what it reveals?

A_{IM}

To determine the radius of gyration about the centre of mass of a metre scale used as a bar pendulum.

$A_{PPARATUS\ AND\ MATERIAL\ REQUIRED}$

A metre scale with holes at regular intervals, knife edge shaped axle, a rigid support, two glass plates (to be used for suspension plane), spring balance, spirit level, telescope fixed on a stand, stop-watch and graph paper.

$P_{RINCIPLE}$

A rigid body oscillating in a vertical plane about a horizontal axis passing through it is known as compound pendulum. The point in the body through which the axis of rotation passes is known as centre of suspension.

The time period of a compound pendulum is given by

$$T = 2\pi\sqrt{\frac{I}{mgl}}$$

(P 2.1)

where m is the mass of the rigid body, l is the distance of the point of suspension from the centre of gravity, I is the moment of inertia of the body about the axis of oscillation and g is the acceleration due to gravity.

If K is the radius of gyration of the body about an axis through the centre of gravity, then the moment of inertia about the centre of suspension is

$$I = m\ (K^2 + l^2)$$

$$= m\ l\left(l + \frac{K^2}{l}\right)$$

(P 2.2)

Hence $$T = 2\pi\sqrt{\dfrac{ml\left(l+\dfrac{K^2}{l}\right)}{mgl}} = 2\pi\sqrt{\dfrac{\left(l+\dfrac{K^2}{l}\right)}{g}}$$

(P 2.3)

or $$T = 2\pi\sqrt{\dfrac{L}{g}}$$

(P 2.4)

where $L = (l + K^2/l)$
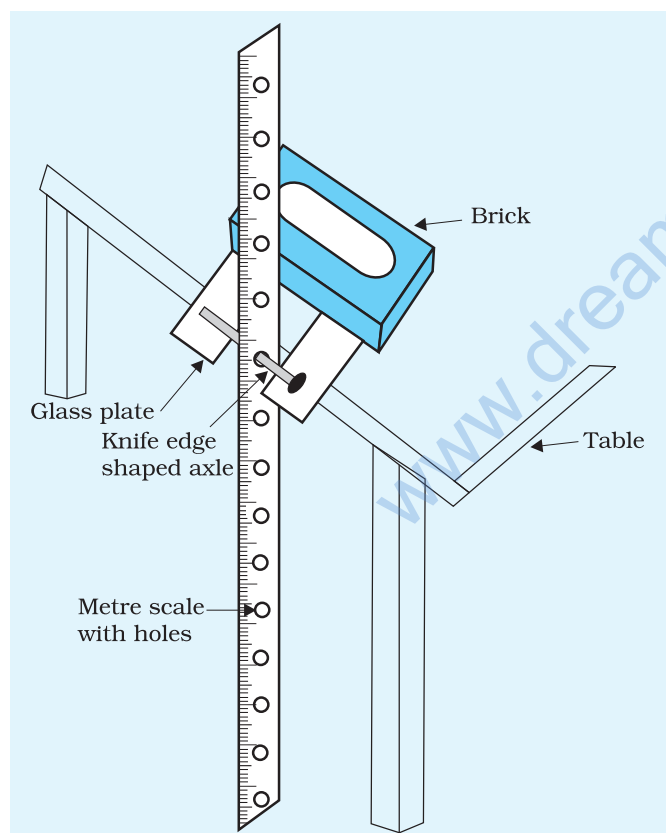
Eq. (P 2.4) can be written as

(P 2.5)

$$l \cdot L = (l^2 + K^2) \qquad l^2 - lL + K^2 = 0$$

Eq. (P 2.5) is quadratic in l and therefore has two roots, say l_1 and l_2 then

$$l_1 + l_2 = L \qquad \text{and} \qquad l_1 l_2 = K^2$$

or $$K = \sqrt{l_1 l_2}$$

PROCEDURE

Fig. P 2.1: *A metre scale oscillating about a point close to C.G.*

1. Take a metre scale. Draw a line in the middle along its length. Drill holes of about 1.6 mm diameter on this line separated by a distance of 2 cm, starting from one end to the other.

2. Determine the centre of gravity of the scale by balancing it over a wedge.

3. Pass the knife edge shaped axle in the hole near one of the ends of the metre scale and let it rest on the suspension base having glass plates at its top.

4. Ensure that the glass plates fixed on the suspension plane be horizontal and in the same level so that when we suspend the metre scale by placing the knife edge we may be sure that the scale hangs vertically (Fig. P2.1).

5. Make a reference line, drawn on the paper strip, near the lower end of the pendulum and focus it with a telescope. Adjust the telescope until its vertical crosswire focuses on the reference line.

6. Displace the lower end of the scale horizontally through a small distance from its equilibrium position and then release it. The pendulum (metre scale) will begin to oscillate. Take care that the angular amplitude of oscillation is within 5° or 6° and pendulum oscillates in a vertical plane without any jerk.

7. Count zero when the reference mark on oscillating pendulum passes across the vertical crosswire of telescope and start the stop-watch at that instant (The counting of oscillations could be done visually, in case a telescope is not available).

8. Continue counting 2, 3, 4,... successively when the reference line progressively passes the vertical crosswire from the same side and note the time for 20 oscillations. Repeat the observations at least three times.

9. Measure from the lower end, the distance of the point of suspension.

10. Repeat Steps 7 and 9 after shifting the knife edge to the successive holes leaving two holes on either side of the centre of gravity of the pendulum. Take length of pendulum on one side of C. G. as positive while on the other side as negative. Record your observations in tabular form.

OBSERVATIONS

Table P. 2.1: Measurement of time period of compound pendulum

Hole No.	One side of C.G.				Hole No.	Other side of C.G.			
	Distance from C.G., l_1 (cm)	Time for 20 oscillations		Time period $T = \dfrac{t_1 + t_2 + t_3}{3}$ (s)		Distance from C.G., l_2 (cm)	Time for 20 oscillations		Time period $T' = \dfrac{t_1' + t_2' + t_3'}{3}$ (s)
		t_1	t_2	t_3				t_1'	t_2'	t_3'	

CALCULATION

1. Plot a graph between l and T by taking the l along x-axis and T along y-axis. The graph will consist of two symmetrical curves Fig. P 2.2. The point on the x-axis about which the graph is symmetrical is the centre of gravity of the metre scale pendulum.
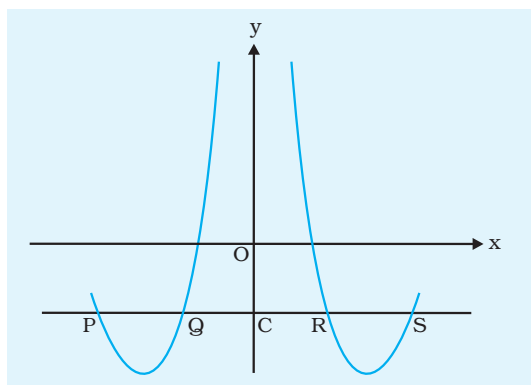
Fig. P 2.2: *Graph between distance from C.G. and time period*

2. Draw a line parallel to x-axis cutting the graph at points, *P*, *Q*, *R* and *S*

   (a) From the graph,   CP= … cm, CS= … cm

$$l_1 = \frac{CP + CS}{2} = … \text{cm}$$

   (b) From the graph,   CQ = … cm, CR = … cm

$$l_2 = \frac{CQ + CR}{2} = … \text{cm}$$

   (c) The radius of gyration $K = \sqrt{l_1 l_2}$

RESULT

The radius of gyration about the axis passing through the centre of mass of the metre scale is found as *K* = … cm.

PRECAUTIONS

1. Pendulum should be hung vertically and knife edge be kept horizontal so that the pendulum oscillates in a vertical plane.

2. Note the time by the stop-watch leaving 5 or 6 initial oscillations so that effect of any irregularities in the oscillations get subsided.

3. Increase the number of observations for a given length of pendulum if time for 20 oscillations is to be measured without using a telescope.

4. Keep the fans off or else air droughts will shift the position of the scale and its oscillations will not remain in the same plane.

SOURCES OF ERROR

1. The metre scale may not have uniform mass distribution.

2. The wedge may not be sharp.

3. The holes drilled may not be colinear or have equally smooth inner surface.

DISCUSSION

1. If a metallic bar is used in place of wooden scale we would have better results as its inertia will hold it in position in a better way.

Moreover a metallic bar of homogeneous material and uniform cross-section can be easily made.

2. To draw smooth symmetrical graphs, we may make use of curved surface on the inside of set squares or by suitably bending plastic tongue cleaners or broomsticks.

SELF ASSESSMENT

1. How would you establish that the compound pendulum executes SHM?

2. By knowing the radius of gyration of the metre scale about its centre of mass, determine the moment of inertia of the same scale about an axis passing through the centre of mass.

3. Why do we get two L – T plots symmetrical about y-axis?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Increase the angular amplitude slowly and see how your result changes.

2. Note the angular amplitude at which variation in your results is appreciable. How will you explain the changes?

A_{IM}

To investigate changes in the velocity of a body under the action of a constant force and to determine its acceleration.

A_{PPARATUS AND MATERIAL REQUIRED}

Ticker-timer, a horizontal table, a bumper (a heavy rectangular block of wood), a trolley, three G-clamps, long paper tape, a pulley, strong thread, a few bricks, hanger, slotted weights, plug-key and a spring balance.

P_{RINCIPLE}

The acceleration of a moving body is constant when force acting on it is kept constant. The principle and working of a ticker-timer has already been discussed in Project P1. Suppose the experimental arrangment allows you to mark the position of a moving object as a dot on the tape of the ticker-timer. The time interval between two successive dots is the same but the dots may not be necessarily equally spaced. Equally spaced dots would represent uniform motion while unequally spaced would represent non-uniform motion.

For calculation of speed of a given object from the tape, take one of the tapes used in the experiment. Let S_1, S_2, S_3, ... be the distances between two successive dots, say of ten dots, on the tape measured from point A by a metre scale as shown in the Fig. P 3.1.
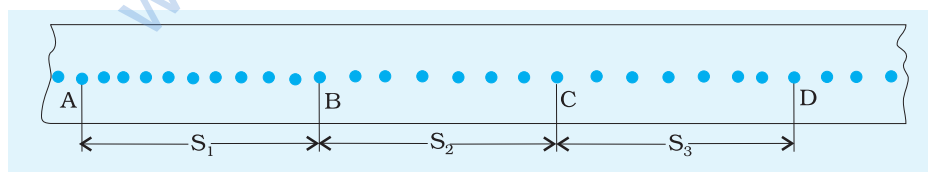
Fig.P 3.1: *Dots on tape*

The frequency of the vibrator of ticker-timer

= Frequency of the A.C. supply

= 50 Hz.

The time interval between two successive dots = $\dfrac{1}{50}$ s

The time taken for covering 10 dots i.e., for displacements $S_1, S_2, S_3, \ldots$

$$= \dfrac{1}{50} \times 10 = 0.2 \text{ s}$$

The average speed v_1 over the distance $S_1 = \dfrac{S_1 (\text{cm})}{0.2 \text{s}} = \ldots \text{ cm s}^{-1}$

The average speed v_2 over the distance $S_2 = \dfrac{S_2 (\text{cm})}{0.2 \text{s}} = \ldots \text{ cm s}^{-1}$

So, the increase in speed in the time interval of 0.2 s

$$= \dfrac{S_2}{0.2 \text{s}} - \dfrac{S_1}{0.2 \text{s}} = \ldots \text{ cm s}^{-1}$$

The average acceleration $= \dfrac{(S_2 - S_1)}{0.2 \times 0.2} = \ldots \text{ cm s}^{-2}$

PROCEDURE

1. Setup the ticker-timer at one end of a long horizontal table and fix the bumper at its other end with the help of G-clamps as shown in Fig. P 3.2.

2. Place the trolley between the timer and the bumper. Attach one end of a strong thread of suitable length to the trolley and pass it over a frictionless pulley fixed on the bumber. Attach a hanger at the free end of the thread.

3. Adjust the length of the thread in such a manner that when the trolley is brought near the timer, the hanger stands at its highest position near the pulley.

4. Bring the trolley near the ticker-timer and release it, observe its motion.

5. Place one or two small bricks on the trolley if it moves too fast. Adjust the weights on the hanger so that the trolley moves with a moderate speed.

6. Hold the trolley in position near the timer. Check that the tape is passing under the carbon paper disc. Switch the ticker-timer on and release the trolley. Ensure that the trolley gains speed till the pan touches the ground, thereafter it is stopped by the bumper.

7. Encircle the mark on the tape which was under the point of the vibrator of the timer at the instant when the pan touches the ground because there after the force ceases to act on the
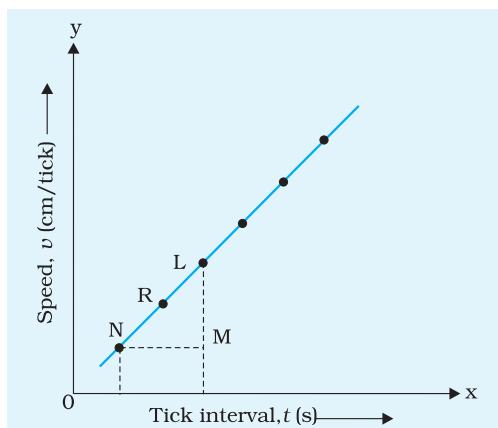
Fig. P 3.3: *Graph between speed and time under a constant force*

trolley, label this mark as P. Encircled mark P is the limiting position upto which the trolley was accelerated by constant force before it touched the ground.

8. Remove the part of tape where dots are marked, from the timer.

9. Choose a dot, close to the starting point, mark it as A and take it as the reference point for measurement of displacements.

10. Divide the entire motion of the trolley in about 10 equal intervals of time. To do this, count the total number of dots marked on the tape during the motion of trolley. From A, mark the positions as B, C, D etc. at the end of 10 ticks on the paper.

11. Measure the distance AB, BC, CD etc. and record them as shown in Table P 3.1. Compute average speed between different time intervals (Table P 3.1). This can be taken as instantaneous velocity at the mid point of the time interval tabulate. The computed values of the average speeds against the mid point of the time intervals.

12. The instantaneous speed at the mid point of time intervals would be nearly the same as the average speed during the interval in each case.

13. Plot a graph showing the values of speed against time which depicts the motion of the trolley under a constant force. Find the slope of speed-time graph to calculate the instantaneous accleration (Fig. P 3.3).

OBSERVATIONS

(a)   Mass of the pan ... g.

(b)   Mass of the pan + Mass of the weights in the pan = ... g.

(c)   Mass of the trolley + mass placed in the trolley = ... g.

Table P 3.1: Instantaneous speed of the body

S. No.	Time interval (in units of tick interval) (s)	Distance, s (cm)	Average velocity $v_{av} = s/\underline{t}$ (cm s^{-1})	Time (in mid of interval), t (tick interval) (s)
1	0 – 10	S_1	...	5
2	10 – 20	S_2	...	15
3	20 – 30	S_3	...	25

Table P 3.2: Acceleration of the body

S. No.	Point chosen	Time, t (No. of ticks)	Interval		Slope, $\dfrac{ML}{NM}$ = acceleration cm/ tick^{-2}
			ML (cm/ tick)	NM (tick)	

RESULT

1. The speed of the trolley increases with time as constant force acts on it.

2. The acceleration of the trolley is found to be ... roughly constant within the limitations of the experiment.

PRECAUTIONS

1. Make sure that the ticker-timer and bumper are rigidly fixed.

2. The ticks in the beginning when the trolley just begins to move and at the time when the force ceases to act, be encircled properly for the purpose of measurement of distances and calculation of velocity and acceleration.

SELF ASSESSMENT

Is the acceleration calculated equal to 'g'? If not, why? With increase in mass in the pan, does the acceleration approach to acceleration due to gravity?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Study the variation of acceleration for different masses placed on the trolley for constant force.

2. Study the variation of acceleration for different forces, by changing the mass placed on the pan.

AIM

To compare the effectiveness of different materials as insulators of heat.

APPARATUS AND MATERIAL REQUIRED

A cylindrical metallic container, a cylindrical plastic container (with height same as that of metal container but having a much larger radius), a thermometer, an insulating lid for plastic container with a hole for inserting a thermometer, different insulating materials in powder or liquid forms.

TERMS AND DEFINITIONS

Insulators of heat are those substances, which do not allow the flow of heat through them easily.

PRINCIPLE

The underlying principle of comparing the effectiveness of different materials as insulators of heat is to compare their thermal
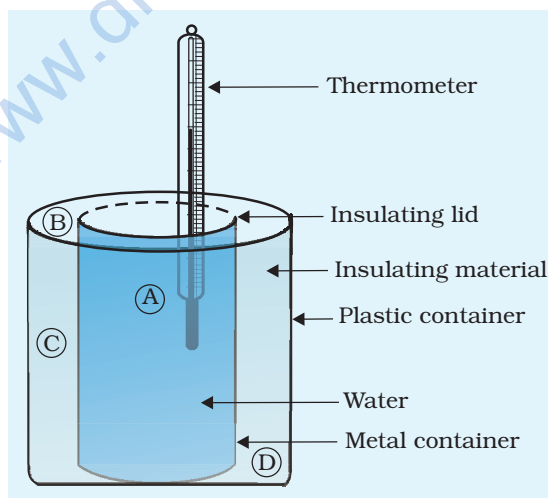
Fig. P 4.1:

conductivities. A material having a lower thermal conductivity will be more effective as an insulator.

PROCEDURE

1. Place the metal container A inside the plastic container B leaving equal gap all around it. Fill the gap, between the two containers with the insulating material you want to study (Fig P4.1).

2. Pour in container A hot water (having temperature nearly 60 °C).

3. Cover both the containers with a non-conducting lid.

4. Fix a thermometer, in a hole provided in the lid, in such a way that the thermometer bulb is well within the water.

5. Record time for every 5 °C fall in temperature.

6. Repeat the above procedure for different insulating materials.

7. Plot temperature v/s time graph for different materials on the same graph paper.

OBSERVATIONS

Least count of the thermometer = ... °C

Table P 4.1: Fall in temperature with time for different materials as insulators

S. No.	Name of the Material	Variation of temparature with time								
1.		Temparature								
		Time								
2.		Temparature								
		Time								
3.		Temparature								
		Time								
4.		Temparature								
		Time								

PLOTTING OF GRAPH AND INTERPRETATION

Plot a graph between time t and temperature θ for different materials on the same graph paper, taking time on x-axis and temperature on y-axis.

Steeper the graph, faster the rate of cooling of water thereby implying lower efficiency of the material used as thermal insulator.

RESULT

From the cooling curves of water drawn for different insulating materials surrounding it can be inferred that the effectiveness of different materials as insulators of heat in decreasing order is

(a)

(b)

(c)

(d)

PRECAUTIONS

1. Make sure that the gaps C and D are kept the same for all the materials.

2. This method can be used only for the insulating materials available in the powdered/liquid form as the effect of trapped air can be minimised for them.

3. Packing of insulating material in the gaps C and D should be equally uniform in all the cases.

4. Insulating lid should fit tightly to minimise heat loss.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Repeat the same procedure with the cold water (instead of hot water).

2. Repeat the same procedure with other insulating materials other than the ones you have used in this Activity.

Aim

To compare the effectiveness of different materials as absorbers of sound.

Apparatus and Materials Required

An audio frequency oscillator, cathode ray oscilloscope (CRO), two transformers, a microphone, a speaker (8 Ω), absorbing materials such as glass sheet, cardboard, plywood and fibre board having roughly the same thickness, 4 cardboard sheets of different thicknesses, screw gauge, vernier calipers and a metre scale.

Principle

When sound waves travel through a material, part of its mechanical energy is absorbed by the material. The degree of absorption of sound energy by a material depends upon

(i) the nature of material and

(ii) the thickness of the material through which sound waves are made to pass.

Procedure

1. Take sheets of different absorbing materials such as glass sheet, cardboard, plywood and fibre board sheets.

2. Measure the thickness of each material with the help of screw gauge/vernier calipers/metre scale.

3. Make the circuit arrangement of various components as shown in Fig. P 5.1. High impedence coils L_1 and L_4 of the two transformers are to be connected to an audio frequency oscillator and a CRO respectively. Speaker and the microphone are to be connected to the low resistance coils L_2 and L_3 of the two transformers in order to achieve impedence-matching of the coils.
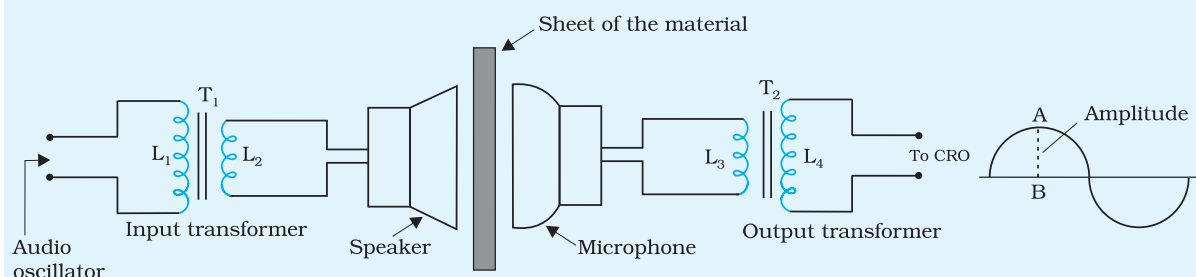
Fig. P. 5.1: *Circuit arrangement for comparing effectiveness of different materials as absorbers of sound*

4. Adjust the CRO such that a suitable wave form appears on the screen.

5. Feed an audio signal of known frequency from the audio oscillator to the speaker and note the amplitude of the corresponding audio signal on the CRO, without any sheet between the speaker and microphone.

6. Without changing the distance between speaker and microphone, insert one by one sheets of different materials, i.e., glass, cardboard, plywood, fibreboard (having same thickness) in between the speaker and the microphone and each time note the amplitude of the corresponding audio signal on the CRO graduated screen.

7. Record the observations in tabular form to analyse the relation between the degree of absorption of sound energy and the nature of the absorbing material.

8. Insert four sheets of different thicknesses of the same material (say cardboard) one by one in between the speaker and the microphone.

9. Repeat Steps 5 and 6 of the experiment.

10. Record the observations in tabular form to analyse the degree of absorption of sound with the thickness of the absorbing material.

OBSERVATIONS

1. Least count of screw gauge/vernier valipers = ... mm

2. Thickness of cardboard   = ... mm

   Thickness of glass sheet = ... mm

   Thickness of fireboard   = ... mm

   Thickness of plywood   = ... mm

3. Frequency of the audio signal used = ... Hz

Table P 5.1: Degree of absorption of sound in different absorbing materials of same thickness.

No. of observations	Name of absorbing material	Amplitude of wave on CRO (mm)		
		Before insertion of absorbing material A_0	After insertion of absorbing material A_1	$\dfrac{A_1}{A_0}$
1.	Glass			
2.	Card board			
3.	Fibre board			
4.	Plywood			

Table P 5.2: Variation in degree of absorption of sound for different thicknesses of the same absorbing material

No. of observations	Thickness of absorbing material	Amplitude of wave on CRO (mm)		
		Before insertion of absorbing material A_0	After insertion of absorbing material A_1	$\dfrac{A_1}{A_0}$
1.				
2.				
3.				
4.				

CALCULATION

1. Find the ratio of amplitude of the waveform before and after insertion of the absorbing material from the experiment data recorded in Table P 5.1.

2. Find the ratio of amplitude of the waveform before and after insertion of the absorbing material of different thicknesses and infer its dependence on absorption of sound.

RESULT

1. Degree of absorption of sound waves is maximum in …. (material) and minimum in … (material).

2. Degree of absorption of sound waves increases/decreases with increase in the thickness of absorbing material (cardboard).

PRECAUTIONS

1. The amplitude of the input audio signal is kept constant while performing the experiment, with different absorbing materials of same thickness.

2. The thickness of absorbing material should not be so high that the corresponding output signal on the screen of CRO is no longer measurable.

3. The respective positions of the speaker, microphone and absorbing material sheets for all sets of experiment should be kept unchanged.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Plot a graph between the density (along x-axis) and the ratio of the amplitudes of the waveform (along y-axis) after and before insertion of the absorbing material (Table P 2.1). Study the nature of the graph and interpret it.

2. Plot a graph between the thickness (along x-axis) of the absorbing material and the ratio of the amplitude of the wave form (along y-axis) after and before insertion of the absorbing material (Table P 5.2). Study the nature of the graph and interpret it.

AIM

To compare the Young's modules of elasticity of different specimen of rubber and compare them by drawing their elastic hysteresis curve.

APPARATUS AND MATERIAL REQUIRED

Two samples of rubber bands of about 10 cm length, a rigid support, number of slotted weights (10 g), a hanger (10 g), a scale and a fine pointer.

TERMS AND DEFINITIONS

1. **Elastic hysteresis:** When the stress-strain curve is not retraced on reversing the strain, the phenomenon is known as elastic hysteresis.

2. **Residual strain:** On removing the deforming force, if the length of the specimen does not reduce to its original length, this results in residual strain.

PRINCIPLE

1. The graph of stress versus strain (or elongation) for rubber is not a straight line. Hence, the Young's modules of elasticity for rubber cannot be defined uniquely. For a given stress, it is defined as the slope of the stress-strain curve at particular stress-strain point.

2. The area enclosed by the hysteresis curve is a measure of energy loss during the loading and unloading cycle.

PROCEDURE

1. Suspend a rubber band from a rigid support and attach a hanger of mass (10 g) along with a fixed pointer at the lower end.

2. Fix a scale S vertically such that the pointer moves freely on the scale and note the reading on the scale.

3. Place 10g slotted weight in the hanger and wait till the rubber band becomes stationary. Read the position of the pointer.

4. Repeat Step 3 by increasing load in Steps of 10 g till the total weight is 80-100 g.

5. Start removing the weight in Steps of 10 g and note the corresponding reading of the pointer (Give time for the rubber to stabilise before taking the reading).

6. Repeat Steps 1 to 5 for different samples of rubber bands.

OBSERVATIONS

(i) Least count of the scale = ... cm

(ii) Original length of unstreched rubber band, L = ... cm

Table P 6.1: Extension of rubber band on loading

	S. No.	Load suspended = applied force = F (N)	Reading of pointer r (cm)		Extension (cm)	
			Loading	Unloading	Loading	Unloading
Specimen A	1					
	2					
	3					
Specimen B	1					
	2					
	3					

CALCULATIONS

1. Plot a graph between the load and extension by taking extension along x-axis and load along y-axis for loading and unloading.

2. The area of hysteresis loop for specimen A = ...

The area of hysteresis loop for specimen B = ...

(This can be done by counting the squares enclosed in the hysteresis loop).

RESULT

Hysteresis of specimen A ... is (greater or less than the) hysteresis of specimen B.

PRECAUTIONS

1. The weights must be added or removed gently.

2. One should wait for some time after adding or removing the weights before reading is taken.

EVALUATION

1. What does the area of hysteresis curve depict?

2. Interpret the hysteresis curves obtained for the specimen A and B.

3. When do the curves obtained while loading and unloading coincide?

4. When do the curves obtained while loading and unloading not coincide?

5. For which purpose is the rubber with large hysteresis loop used?

6. For which purpose is the rubber with small hysteresis loop used?

7. Is the stress-strain graph for rubber a straight line as expected by Hooke's law? What would happen if the elastic limit is exceeded?

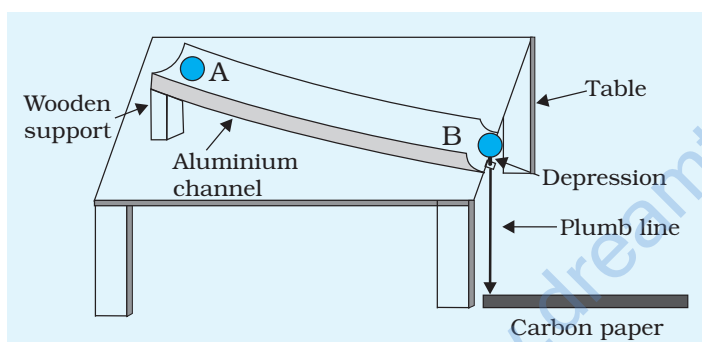8. How would you known that elastic limit has been crossed?

A<small>IM</small>

To study the collision of two balls in two-dimensions.

A<small>PPARATUS AND MATERIAL REQUIRED</small>

Apparatus for collision in two dimensions, metre scale, tracing paper, carbon paper, G-clamp, a screw, cellotape, protractor, two identical steel spheres or marble spheres and a plumbline.

D<small>ESCRIPTION OF APPARATUS</small>

Fig. P 7.1: *Setup to study the collision of two balls in two-dimensions*

A scale or ruler with a groove (or an aluminium channel) which is bent to act as a ramp so that a steel ball can be rolled from the top. At the lower end of the ruler a set screw is fixed that has a depression on its top. This is the resting place for the target steel ball. The ruler rests on a metal base which can be clamped at the edge of a laboratory table. From the set screw, a plumbline is suspended as shown in Fig. P 7.1.

P<small>RINCIPLE</small>

When two steel spheres of mass m and m′ moving with velocities $\boldsymbol{u}$ and $\boldsymbol{u}'$ respectively collide, their velocities change after collision. If their velocities after collision are $\boldsymbol{v}$ and $\boldsymbol{v}'$ respectively, then according to the law of conservation of momentum

$$m\boldsymbol{u} + m\boldsymbol{u}' = m\boldsymbol{v} + m\boldsymbol{v}'$$

In this Activity, we study collision of two balls in two-dimensions using the apparatus described above and verify the law of conservation of momentum in two-dimensions. We allow one steel ball to roll down

the ramp and collide with a target ball (at rest) placed at the lower end of the ramp. For simplicity, we take two identical balls.

After collision the two balls moving in different directions fall down and strike the ground. The horizontal velocity of each sphere is proportional to the horizontal distance travelled by each sphere (Why this should be so?). The horizontal distance is the distance from point on the floor just below the initial position of the stationary ball to the point where it lands. This same horizontal distance can also be used to represent the magnitude of the momentum of each ball as they have the same mass.

PROCEDURE

1. Arrange the apparatus as shown in Fig. P 7.1. Adjust the set screw so that the depression in it is directly in front of the groove and about one radius of the steel ball away from the groove end. Roll a steel ball down the ramp and adjust the set screw by moving upward/downward so that the ball just clears it as it falls freely. Place the target ball on the depression in the screw. Suspend the plumb line with it.

2. Next adjust the position of the set screw so that the bullet ball will collide with the target ball at an angle. Mark the incident and target balls as 1 and 2. Ensure that the two balls are exactly at the same height from the floor at the time of collision.

3. Spread on the floor a large sheet of tracing paper on a similar sized carbon paper. The steel balls would be falling on this combination to make their imprints. In case large sheets of carbon paper or plain paper are not available tape together their pieces (A-4 size) to make a large sheet.

4. Put the carbon paper on the floor, with its inked side facing up. Place the tracing paper directly over it. Place the sheets such that the centre of one end of the paper lies just below the plumb line.

5. Without placing a target ball on the set screw, roll the ball marked 1. Mark the point on the tracing paper where the ball lands (P_0). Repeat it several times and mark the cluster P_{01}, P_{02}, P_{03}, etc. ... Find the centre of the cluster and mark it P_0.

6. Using identical steel ball (2) to act as a target ball, try a few collisions. Ensuring that the incident ball (1) is always released from the same height. Circle and label the clusters of points where the incident ball and the target ball hit the paper.

   (You can find the centre of cluster points, by drawing a quadrilateral and intersecting diagonals to find the location of mean point.)
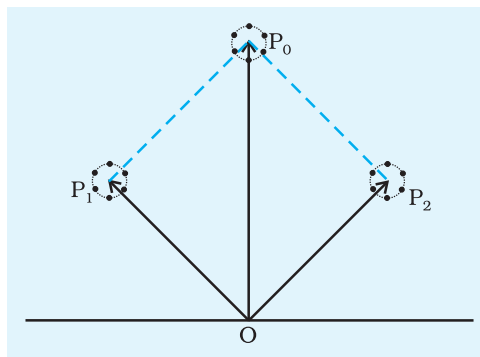
Fig. P 7.2: *To find location of mean print*

7. Mark point *'O'* on the paper where the plumb line touches the paper. Draw vectors from the point O to the mean point P_0, P_1 and P_2.

8. (a) Add the two vectors $\overrightarrow{OP_1}$ and $\overrightarrow{OP_2}$ representing the momentum of the incident ball and target ball to determine the total momentum *P* after the collision (Fig. P7.2).

    (b) Relate the total momentum *P* after the collision with the initial momentum of the incident ball represented by vector $\overrightarrow{OP_0}$ and the target ball.

RESULT

The total momentum of the two ball after collision is ... g cms⁻¹ which is almost equal to the initial momentum of the incident ball.

PRECAUTIONS

1. Adjust the set screw and ensure that the two balls are exactly at the same height from the floor at the time of collision.

2. In each trial, the incident ball should be rolled down from the same height.

SOURCES OF ERROR

Friction between the ball and surface may introduce an error.

SELF ASSESSMENT

1. For each trial, measure the angle between the two final momentum vectors. Can you make any generalisation?

2. Suppose the target ball is replaced by a glass marble of same size and we carry out the experiment using the same incident ball. In

this case, the horizontal distances, would represent velocity vectors? Do they still represent momentum vectors? How will you draw momentum vectors in this case and verify the law of conservation of momentum?

3. What happens to the momentum components corresponding to OP_1 and OP_2 in Fig. P7.2 in the direction perpendicular to OP_0?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

This experiment can also be used to verify the law of conservation of momentum quantitatively, the momentum of a ball can be calculated knowing its mass and velocity. Measure the mass of each ball with a balance. The horizontal velocity is equal to the horizontal distance travelled divided by the time taken. Note that this time is equal to the time taken by the ball to hit the floor. This time can be determined by measuring the distance (d) from the top of the set screw to the floor and using the equation $d = (gt^2)/2$. Further, note that t will be the same for all calculations.

Calculate the original momentum of the incident ball and final momenta of the incident and target balls for the case with balls of (1) equal mass and (2) unequal mass. Find the resultant of the two final momenta in each case and compare it with the initial momentum.

ALTERNATE METHOD FOR MAKING CHANNEL

Take plastic pipe having internal diameter slightly more than the diameter of the balls.

Cut the pipe lengthwise into two equal parts (two halves). Bend slightly one part of the cut pipe by gently warming it and fix it on a table top as shown in the figure below.

Make a small depression near end B of the pipe with the help of a heated thick nail/rod for resting the target ball.
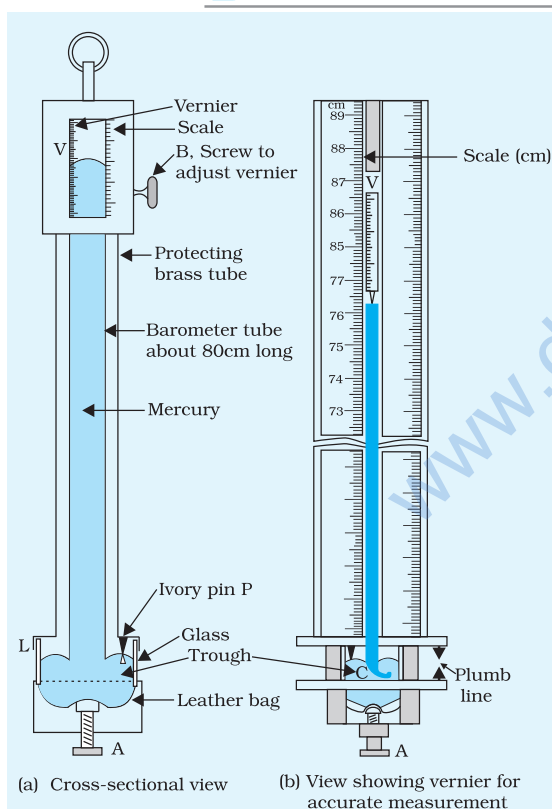
A_{IM}

To study Fortin's Barometer and use it to measure the atmospheric pressure.

A_{PPARATUS AND MATERIAL REQUIRED}

Fortin's Barometer and a thermometer.

D_{ESCRIPTION OF APPARATUS}

Fig. P 8.1: *Fortin's barometer*

Fortins's Barometer

It consists of a uniform glass tube about 80 cm long, open at one end. It is filled with mercury and turned upside down carefully in a trough of mercury C. The lower part of the trough is made of leather and the level of mercury in the trough can be adjusted by means of screw A [Fig. P 8.1 (a)]. The upper side of the trough is closed by a leather patch L in such a way that the contact is maintained between the outside air and the mercury in the trough. There is a small ivory pin P fixed with its pointed tip touching the mercury in the trough. The function of the pin P is to adjust the zero of the scale at the same level as the mercury in the trough. The glass tube is enclosed in a brass tube for protection. There are two vertical slits diametrically opposite each other so that the level of mercury in the tube can be seen [Fig. P 8.1 (b)]. A scale graduated in centimetre is engraved on the brass tube on both sides along the edges of the front slit. The scale graduation does not start from zero but from 68 cm to 85 cm, as the atmospheric pressureremains within these limits. A brass vernier scale slides along the front slit and can be adjusted using screw B.

PRINCIPLE

When a completely filled mercury tube is turned upside down in the trough C, some mercury flows out of the tube in the trough leaving a vacuum on the top.
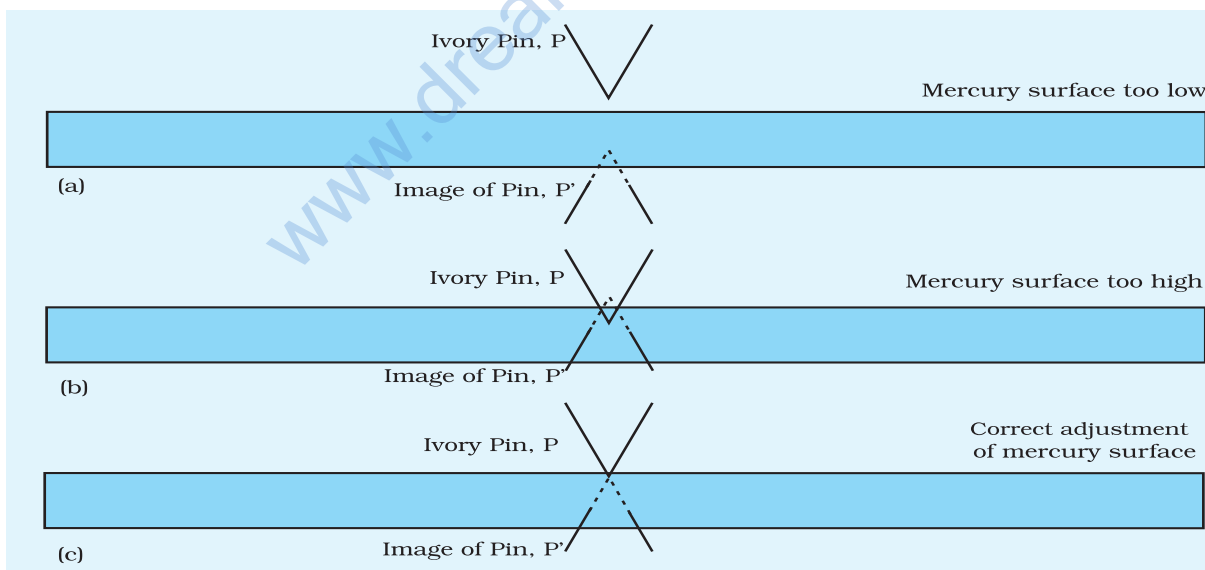
The level of mercury stabilises when the atmospheric pressure exerted on the surface of mercury in the trough equalises that due to the mercury column in the tube. The height of the mercury column in the tube is proportional to atmospheric pressure under normal conditions, Column of mercury in the glass tube stands at a height of about 76 cm at sea level.

From theoretical point of view, a barometer could be made of any liquid. Mercury is chosen for many reasons mainly it is so dense (13600 kg/m^3) that column supported by air pressure is of a managable height.

A water barometer would be more than 10 m in height.

PROCEDURE

1. Use the plumb line to hang the barometer vertically on a wall.

2. Examine the screws A, B, pin P and vernier V.

3. Determine the least count of the vernier scale.

4. Adjust the level of mercury surface in the trough of the barometer

(a)   Ivory Pin, P   Mercury surface too low   Image of Pin, P'

(b)   Ivory Pin, P   Mercury surface too high   Image of Pin, P'

(c)   Ivory Pin, P   Correct adjustment of mercury surface   Image of Pin, P'

Fig. P 8.2: *Correct adjustment of mercury surface in the reservoir*

Vernier V

R

Correct
adjustment
of Vernier Scale

Fig. P 8.3: *Eye should be at the level of
meniscus of mercury in the tube*
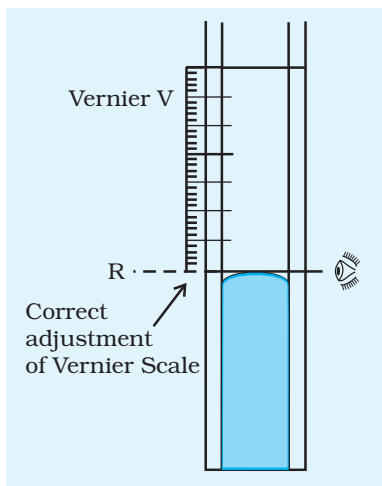
with the help of screw A and by looking at the ivory pin and
its image on the mercury surface in the trough (Fig. P 8.2).

5. Adjust the vernier using screw B such that the zero of the vernier
    touches the convex meniscus of mercury in the tube. The eye
    should be kept at the level of the meniscus (Fig. P 8.3).

6. Note the reading on the main scale and the vernier.

7. Record the room temperature using a thermometer.

8. Repeat the procedure two more times and determine the
    average atmospheric pressure.

OBSERVATIONS

(i)   Vernier constant or least count = ...

No. of divisions on the vernier = ...

No. of divisions on the main scale = ...

Least count of main scale (1 MSD) = ... cm

Least count of vernier scale

$$= \frac{1\,\text{MSD}}{\text{No. of divisions on vernier scale}} = \text{...cm}$$

(ii) Room Temperature = ... °C

Table P 8.1: Measuring height of mercury column in a barometer

S. No.	Main scale reading below zero mark of vernier scale, S (cm)	Vernier scale reading n	Height of mercury column $h = (S + n \times \text{least count})$ (cm)
1			
2			
3			

RESULT

Atmospheric pressure in the laboratory on dd/mm/yr (date) at ... am/
pm at room temperature ...°C was measured as ...cm of Hg.
Atmospheric pressure = ...N/m^2

PRECAUTIONS

1. The barometer is a fragile instrument and should be handled carefully.

2. The wall mount should be firm in a room of a laboratory and not in any passage.

3. Adequate light must fall on the ivory pin and the vernier scale.

4. Least count should be calculated with care.

5. Screw A should be moved slowly and gently.

SOURCES OF ERROR

1. There may be air bubbles in the barometer tube.

2. Ivory pin may not be fixed properly.

3. Room temperature may change, affecting the observations.

DISCUSSION

1. The barometer should be placed in such a way on the wall that screw A can easily be adjusted by viewing the ivory pin P. A suitable platform can be used to stand and see the vernier reading at eye level.

2. Why does the barometer require adjustment everytime one has to use it?

SELF ASSESSMENT

1. What effect would there be of the following:

   (a) Ivory pin not adjusted as advised?

   (b) Barometer is not vertical but tilted?

   (c) The pin P and scale S not viewed at eye level?

2. If water is used instead of mercury, what problems would you encounter?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Take barometer readings and temperature readings at different times during school hours. Study the pattern for the change in atmospheric pressure over a week.

2. Plot a graph between atmospheric pressure and humidity (as given in the newspaper) for a month. Can we relate humidity to atmospheric pressure?