UNIT III

Moving Things, People and Ideas

Experiment 32

AIM

To plot distance – time ($s - t$) graph for an object moving with a uniform speed from a given set of s and t data and to determine the speed of the object.

THEORY

A moving object changes its position with time. If the object travels a distance s in time t then its speed is

$$v = \frac{s}{t} \qquad (1)$$

When an object travels equal distances in equal intervals of time, it is said to have a uniform speed. But if the speed or its direction of motion changes with time then the object is said to be in non-uniform motion.

For a uniform motion the distance travelled by the object is directly proportional to time taken. Thus the graph of distance travelled against time is a straight line. This distance-time graph can be used to determine the speed of the object. Fig. 32.1 shows the distance–time ($s - t$)

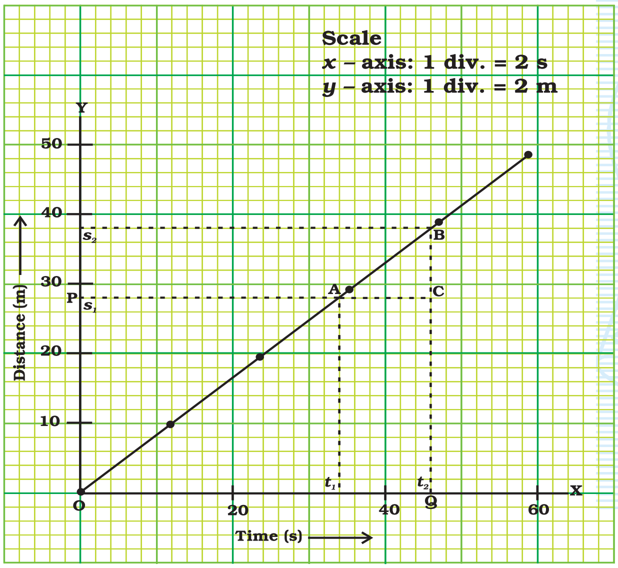


Fig. 32.1 : *Distance-time graph of an object moving with uniform speed*

graph of an object moving with uniform speed. To find the speed of the object consider a small part AB of the $s - t$ graph. The two lines PAC and BCQ drawn parallel to x-axis and y-axis respectively, meet each other at point C to form a triangle ABC. The segment AC denotes the time interval $(t_2 - t_1)$ while the segment BC corresponds to the distance $(s_2 - s_1)$. From this graph it can be seen that as the object moves from the point A to point B, it covers a distance $(s_2 - s_1)$ in time $(t_2 - t_1)$. The speed, v of the object, therefore can be represented as

$$v = \frac{s_2 - s_1}{t_2 - t_1} = \frac{BC}{AC} \qquad (2)$$

This is also the slope of $s - t$ graph. Larger the slope of the graph more is the speed of the object. The $s - t$ graph can also be used to estimate the speed of the object even at the times not given in the data. One can estimate these values at a time within the range of the given time interval at which the position of the object is not given in the given data (*interpolation*). One can similarly use the graph to obtain the values of object position and speed at a time beyond the given range of data (*extrapolation*). On the other hand, Eq. (1) can only be used to determine the speed at instants for which the distance is given in the data.

Materials Required

Graph paper

Procedure

1. Examine the given data of distance (s) of the object at different times (t). Find the difference between the highest and the lowest values of each quantity (these are the ranges of the distance and time values.) Table 1 shows the data for the distance travelled by a car (in m) and the time taken (in s) by it to cover that distance. In this table the time values range from 0 to 10 s while the distance values range between 0 and 100 m.

Table 1: The motion of a car

Sl. No.	Time, t (s)	Distance, s (m)
1.	0	0
2.	1	10
3.	2	20
4.	3	30
5.	4	40
6.	5	50
7.	6	60
8.	7	70
9.	8	80
10.	9	90
11.	10	100

2. Take a graph paper and draw two perpendicular lines OX and OY to represent x-axis and y-axis, respectively (Fig. 32.1). Measure the lengths (or count the number of divisions available) on the graph paper along the two axes. Let, for example, the graph paper you have been provided is

15 cm (or 15 cm divisions) along the x-axis and 25 cm (or 25 cm divisions) along the y-axis.)

3. Decide the quantity to be shown along the x-axis and that to be shown along the y-axis. Conventionally, time is shown along the x-axis and the distance along the y-axis.
4. On the basis of available divisions on the two axes and ranges of the given distance and time data, choose a scale to represent the distance along the y-axis and another scale to represent the time along the x-axis. For example, the scales for the motion of the car as given in Table 1, could be time 1 s = 1 cm; and distance 10 m = 2 cm. (Try to utilise the maximum part of the graph paper while choosing the scales.)
5. Mark values for the time and the distance on the respective axes according to the scale you have chosen. For the motion of the car, mark the time 1 s, 2 s, 3 s ... on the x-axis at every cm from the origin O. Similarly, mark the distance 10 m, 20 m, 30 m ... on the y-axis at every 2 cm from the origin O.
6. Now mark the points on the graph paper to represent each set of values for distance and time given in the data provided.
7. Join all the marked po ints on the graph paper. This is the plotting of $s - t$ graph of the data provided for the motion of a car. Check if this graph is a straight line. A straight line graph indicates that the car is moving with a constant speed.

Observations and Calculations

To find the speed of the car, take any two points on the straight line graph and find their corresponding values of t and s (as suggested in the theory part above). For convenience it is suggested to take the points that correspond to integral values of time and distance values. Suppose the coordinates of these two points are (t_1, s_1) and (t_2, s_2). The distance travelled by the car in time interval ($t_2 - t_1$) is ($s_2 - s_1$). Calculate the speed of the car during this time interval ($t_2 - t_1$) using Eq. (2).

Sl. No.	Value of time for the first point chosen on the graph, t_1	Value of time for the second point chosen on on the graph, t_2	Distance at time t_1, s_1	Distance at time t_2, s_2	Speed of the car, using Eq. (2)
	(s)	(s)	(m)	(m)	(m s^{-1})
1.					
2.					
3.					
4.					

In the same way determine the speed of the car for some more time intervals by choosing different sets of points on the $s - t$ graph. Tabulate the observations.

Results and Discussion

The distance-time graph for the motion of the car is a straight line graph. This indicates that the car is moving with a uniform speed. Attach the distance-time graph in your practical record book.

The average speed of the car = _____ m s^{-1}.

Precautions

- Plot graph using sharp tip pencil.
- The scales chosen for representing the distance and time quantities for the motion of the car on the two axes must be so chosen that the maximum part of the graph paper is utilised. This will help in interpreting the graph better.

Note for the Teacher

- In this write-up a specimen set of distance-time data for the motion of the car is presented. It is suggested that students must be provided with different sets of distance-time data for a moving object for plotting $s - t$ graph and to determine the speed of the uniformly moving object.
- While drawing the two axes OX and OY representing the time and distance values respectively, on the graph paper, the point O should be taken slightly away from the left bottom corner of the graph paper.
- The physical quantities and their units must be properly indicated on the axes. The scaling of the quantities may also be mentioned appropriately at the top right corner of the graph paper.

Applications

- The slope of a $s - t$ graph is a measure of speed of the moving object. There may be different $s - t$ graphs for different moving objects. Their slopes can give a comparison of their speeds. Larger the slope of the graph higher is the speed of the moving object.
- The $s - t$ graph plotted here shows the motion of the object for a given range of time interval. One can even determine the position at a time beyond the range of time interval given in the data using this graph. For this the graph should be extrapolated.

QUESTIONS

- What is the shape of the distance–time graph for an object moving with uniform speed? Name the physical quantity represented by the slope of this graph.
- What will be the $s - t$ graph for an object at rest?
- If distance-time graph plotted for an object is parallel to the time axis, what conclusion you can draw pertaining to its motion?
- Can you imagine a motion with a distance–time graph parallel to distance axis?
- In this experiment, a suggestion is made to utilise the maximum part of the graph paper. Justify the suggestion.
- State the considerations one must adhere to while choosing the scales for plotting a graph?
- What type of speed–time graph do you expect for an object moving with varying speed?

Experiment 33

AIM

To plot the velocity–time ($v - t$) graph for an object moving with uniform accelerations from a given set of $v - t$ data and to determine the acceleration of the moving object and the distance moved by the object.

THEORY

In a straight line motion, we know that when an object moves unequal distances in equal intervals of time then the object is said to be in non-uniform motion or in accelerated motion. In such a motion the velocity of the object varies with time. It has different values at different instants and at different points of the path. The acceleration of the object is a measure of change in its velocity per unit time. If an object moving with an initial (at time 0) velocity u attains the final velocity v in time t, then the acceleration a is

$$a = \frac{v - u}{t} \qquad (1)$$

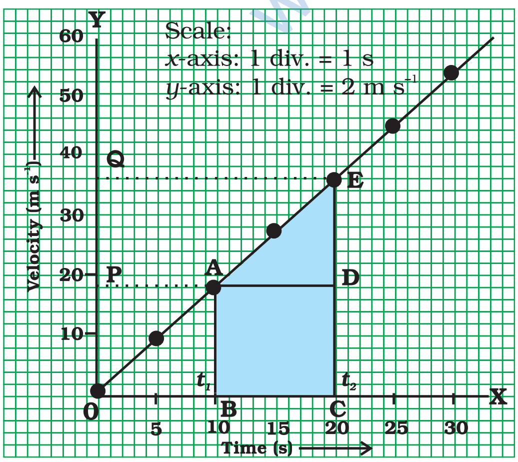


Fig. 33.1 : *Velocity-time graph for a car moving with uniform acceleration*

If the acceleration of the object remains same at all instants of time then the object is said to be in uniformly accelerated motion. Thus the velocity-time graph of a uniformly moving object will be a straight line. Fig. 33.1 shows a velocity-time graph for a car moving with uniform acceleration. The nature of the graph shows that the velocity changes by equal amounts in equal time intervals. Thus the velocity of the car is directly proportional to the time.

In the earlier activity, we have already seen that using a distance-time graph, one can determine the velocity of a uniformly moving car at any instant. One can similarly determine the acceleration of a uniformly accelerated object by plotting its velocity-time ($v - t$) graph.

To find the acceleration of the moving object consider a small part AE of the $v - t$ graph. The two lines PAD and EDC drawn parallel to x-axis and y-axis respectively, meet each other at point D to form a triangle AED. The segment AD denotes the time interval ($t_2 - t_1$) while the segment ED corresponds to a change in the velocity of the object from v_1 to v_2 or ($v_2 - v_1$). The acceleration, a of the object, therefore can be represented as

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\text{ED}}{\text{DA}} \qquad (2)$$

Thus from a given set of $v - t$ data for an object moving under a uniformly accelerated motion, the acceleration can be computed.

One can also determine the distance moved by the moving object from its velocity-time graph. The area under the velocity-time graph gives the distance moved by the object in a given time interval. Let us look at the $v - t$ graph for a uniformly accelerated car given in Fig. 33.1. The distance s travelled by the car in a time interval $t_2 - t_1$ will be given by the area ABCDE under the velocity-time graph. That is,

s = area of the rectangle ABCD + area of the triangle ADE, or

$$= \text{AB} \times \text{BC} + \frac{1}{2}(\text{ED} \times \text{AD})$$

$$s = v_1 \times (t_2 - t_1) + \frac{1}{2}[(v_2 - v_1) \times (t_2 - t_1)] \qquad (3)$$

Materials Required

Graph paper.

Procedure

1. Examine the given data of velocity (v) of the object at different times (t). Find the difference between the highest and the lowest values of each quantity (These are the ranges of the velocity and time values.) Table 1 shows the velocity of a car (in m s^{-1}) at different instants of time. In this table the time values range from 0 to 50 s while the velocity values range between 0 and 100 m s^{-1}.

Table 1: The motion of a car

Sl. No.	Time, t (s)	Velocity of the car v (m s^{-1})
1.	0	0
2.	5	10
3.	10	20
4.	15	30
5.	20	40
6.	25	50
7.	30	60
8.	35	70
9.	40	80
10.	45	90
11.	50	100

2. Take a graph paper and draw two perpendicular lines OX and OY to represent x-axis and y-axis, respectively (see Fig. 33.1). Measure the lengths (or count the number of divisions available) on the graph paper along the two axes. Let, for example, the graph paper you have been provided is 15 cm (or 15 cm divisions) along the x-axis and 25 cm (or 25 cm divisions) along the y-axis.)
3. Decide the quantity to be shown along the x-axis and that to be shown along the y-axis. Conventionally, time is shown along the x-axis and the velocity along the y-axis.
4. On the basis of available divisions on the two axes and ranges of the given velocity and time data, choose a scale to represent the velocity along the y-axis and another scale to represent the time along the x-axis. For example, the scales for the motion of the car as given in Table 1, could be time: 5 s = 1 cm; and velocity: 10 m s^{-1} = 2 cm. (Try to utilise the maximum part of the graph paper while choosing the scales.)
5. Mark values for the time and the velocity on the respective axes according to the scale you have chosen. For the motion of the car, mark the time 5 s, 10 s, 15 s ... on the x-axis at every cm from the origin O. Similarly, mark the velocity 10 m s^{-1}, 20 m s^{-1}, 30 m s^{-1} ... on the y-axis at every 2 cm from the origin O.
6. Now mark the points on the graph paper to represent each set of values for velocity and time given in the data provided.
7. Join all the marked points on the graph paper. This is the $v – t$ graph of the data provided for the motion of a car. Check if this graph is a straight line. A straight line graph indicates that the car is moving with a uniform acceleration.

Observations and Calculations

A. Determination of Acceleration of the Object

To determine the acceleration of the car, take any two points on the straight line graph and find their corresponding values of t and v (as suggested in the theory part above). For convenience it is suggested to take the points that correspond to integral values of time and velocity. Suppose the coordinates of these two points are (t_1, v_1) and (t_2, v_2). The change in the velocity of the car in this time interval ($t_2 – t_1$) is ($v_2 – v_1$). Calculate the acceleration of the car during this time interval ($t_2 - t_1$) using Eq. (2)

$$a = \frac{v_2 - v_1}{t_2 - t_1}$$

In the same way, determine the acceleration of the car for three more time intervals by choosing different sets of points on the $v - t$ straight line graph. Tabulate the observations.

B. Determination of Distance Moved by the Object

Using $v - t$ graph one can determine the distance moved by the car in a

Sl. No.	Value of time for the first point chosen on the graph, t_1	Value of time for the second point chosen on on the graph, t_2	Velocity at instant t_1, v_1	Velocity at instant t_2, v_2	Acceleration of the car, a [Using Eq. (2)]
	(s)	(s)	(m s^{-1})	(m s^{-1})	(m s^{-2})
1.					
2.					
3.					
4.					
5.					

given time interval. Choose a fixed time interval T, say 10 s. Using the method described in the theory part [Eq. (3)], calculate the distance travelled by the car in first 10 s. That is the distance travelled by the car between t = 0 s to 10 s. Next, calculate the distance travelled by the car in next 10 s (that is distance travelled by the car between t = 10 s to 20 s.) Calculate the distance travelled by the car in time T between different instants of time. Tabulate the calculations.

The distance travelled by the car in a given time interval can also be computed from the graph by counting squares covered under $v - t$ graph.

Sl. No.	Initial time, t_1	Final time, t_2	Velocity at time t_1, v_1	Velocity at time t_2, v_2	Distance travelled by the car in time interval, (t_2 - t_1) Using Eq. (3)	By counting squares
	(s)	(s)	(m s^{-1})	(m s^{-1})	(m)	(m)
1.	0	T =				
2.	T =	$2T$ =				
3.	$2T$ =	$3T$ =				
4.	$3T$ =	$4T$ =				
5.	$4T$ =	$5T$ =				
		Time at the end of the journey			Total distance	Total distance

Results and Discussion

The velocity-time graph for the motion of the car is a straight line graph sloping with the time axis. This indicates that the car is moving with a uniform acceleration. Attach the velocity-time graph in your practical record book.

The acceleration of the moving car (from the graph) = ______ m s^{-2}.

The total distance covered by the car [from the graph, but using Eq. (3)] = ______ m; and the total distance covered by the car [by counting the squares under the $v - t$ graph = ______ m.

It is observed that the distance travelled by the car in a given time intervals but at different instants are different. This shows that the car is in accelerated motion.

Precautions

- Plot graphs using a sharp tip pencil.
- The scales chosen for representing the velocity and time quantities for the motion of the car on the two axes must be so chosen that the maximum part of the graph paper is utilised. This will help in interpreting the graph better.

Note for the Teacher

- It is advised that before performing this activity all students must have completed the earlier activity titled: To plot distance–time ($s - t$) and graph for an object moving with a uniform velocity from a given set of s and t data and to determine the velocity of the object.
- In this write-up a specimen velocity-time data for the motion of the car is presented. It is suggested that students be provided with different sets of velocity-time data for a moving object for plotting $v - t$ graph and to determine the acceleration of the object under uniformly accelerated motion. The distances travelled by the object between different time intervals may also be determined.
- While drawing the two axes lines OX and OY representing the time and velocity values respectively, on the graph paper, the point O should be taken slightly away from the left bottom corner of the graph paper.
- The physical quantities and their units must be properly given on the axes. The scaling of the quantities may also be mentioned appropriately at the top right corner of the graph paper.

APPLICATIONS

- The slope of a $v - t$ graph is a measure of acceleration of the moving object. And the area under a $v - t$ graph gives the distance travelled. One can draw several $v - t$ graphs for different moving objects. Their slopes can give a comparison of their accelerations. Larger the slope of the graph higher is the acceleration of the moving object. Similarly larger the area under the $v - t$ graph, more the distance travelled.
- The $v - t$ graph plotted here shows the motion of the object for a given range of time interval. One can even determine the velocity (or acceleration) at a time beyond the range of time interval given in the data. For this, the graph should be extrapolated.

QUESTIONS

- What is the nature of the velocity–time graph for an object moving with uniform velocity? What will be the slope of this graph?
- What is the nature of the velocity–time graph for an object moving with uniform acceleration? With non-uniform acceleration?
- What will be the shape of the $v - t$ graph for an object at rest?
- What conclusion you draw if velocity-time graph plotted for an object is parallel to the time axis?
- Can you imagine a velocity–time graph parallel to velocity axis?
- Two cars run on a straight road with different uniform accelerations for 15 minutes. Thus their $v - t$ graphs have different slopes. Which car will travel more distance?
- In this experiment it is suggested to utilise the maximum part of the graph paper. Why?
- State the considerations one must adhere to while choosing the scales for plotting a graph.

Experiment 34

AIM

To study the third law of motion using two spring balances.

THEORY

The first two laws of motion tell us how an applied force changes the state of motion of an object and provide us with a method of determining the force. The third law of motion states that when one object exerts a force on another object, the second object also exerts a force back on the first. These two forces are always equal in magnitude but opposite in direction. These forces act on different objects and never on the same object. The two opposing forces are also known as action and reaction forces. Let us consider two spring balances, A and B connected together as shown in Fig. 34.1. The fixed end of balance B is attached with a rigid support, like a wall. When a force is applied through the free end of spring balance A, it is observed that both the spring balances show the same readings on their scales. It means that the force exerted by spring balance A on balance B is equal but opposite in direction to the force exerted by the balance B on

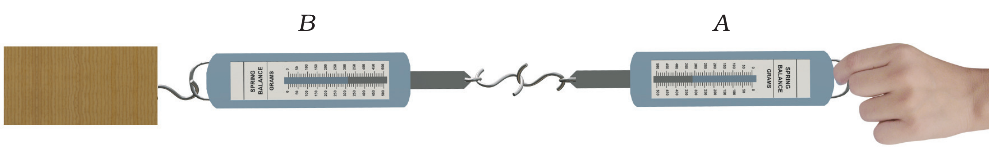


Fig. 34.1 : *Action and reaction forces are equal and opposite*

balance A. The force which spring balance A exerts on spring balance B is called the *action* and the force of balance B on balance A is called the *reaction*. This gives us an alternative statement of the third law of motion. That is to every action there is an equal and opposite reaction. However, it must be remembered that the action and reaction always act on two different objects.

MATERIALS REQUIRED

Two identical spring balances (0 – 5 N; 0 – 500 g), weight box, inextensible thread, a frictionless pulley (which can be fixed at the edge of the table), and a pan of known mass.

PROCEDURE

1. Find the range and the least count of the two spring balances.
2. Ensure that the two spring balances are identical.
3. Check whether the spring balances can measure the force? If the two spring balances have the graduation markings in terms of force units — well. If not, that is the spring balances have graduation markings in terms of mass only, then learn to convert it in force units as explained in the Note for the Teacher.
4. Hold the two spring balances vertically and ensure that their pointers are at zero mark.

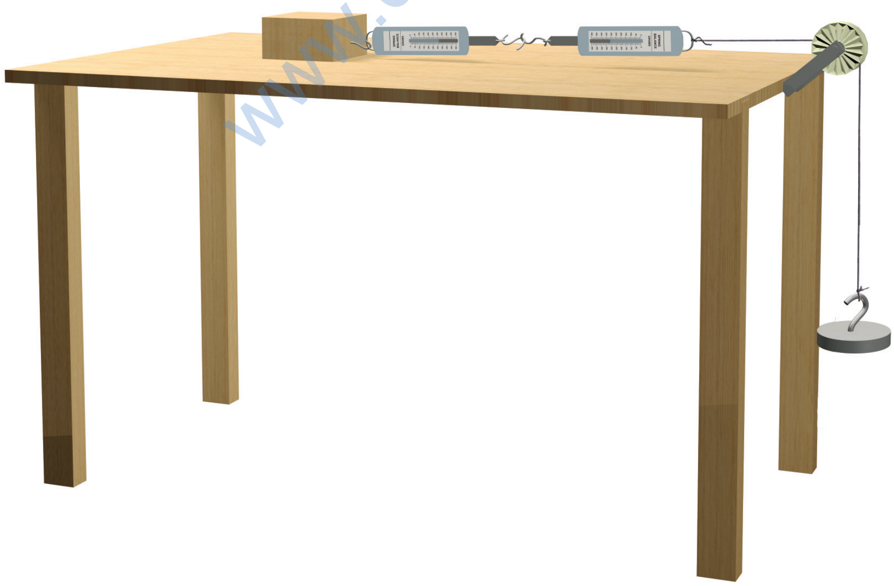


Fig. 34.2 : *The experimental set up*

5. Arrange two spring balances A and B, a pulley and a pan with the help of an inextensible thread, as shown in Fig. 34.2. The spring balance B must be attached to a rigid support. The spring balances may rest on the smooth table-top while the thread must not touch the table-top. The other end of the thread, which is attached with the pan, should also hang freely without touching the table.
6. What are the readings of the scales on the two spring balances? Are they equal? Is it approximately equal to the weight (w) of the pan (mass of the pan (m) × acceleration due to gravity (g) at your place)?
7. Identify the action and reaction forces. The force which spring balance A exerts on B is action (reading on the scale of spring balance B). The reading on the scale of balance A shows the reaction that spring balance B exerts on A.
8. Put some mass M on the hanger (say 100 g). The total mass attached to the thread is now ($M + m$). Observe the readings of both the balances.
9. Repeat step 8 for at least five more masses on the pan. Tabulate your observations.

Observations and Calculations

(i) Range of the two spring balances = ___ — ___ N or ___ — ___ g.
(ii) Least count of the spring balance = ___ — ___ N or ___ — ___ g.
(iii) Acceleration due to gravity (g) at your place = ___ m s^{-2}.
(iv) Mass of the pan (given) m = _____ g = ___ kg.
(v) Weight of the pan $w = m$ (in kg) $\times g$ = ___ N.

Sl. No.	Mass on the pan, M	Total mass attached to spring balance A $(M + m)$		Total Weight attached to the balance A $(M + m) \times g$	Reading on the scale of the spring balance A			Reading on the scale of the spring balance B			$F_A \sim F_B$
					F_A			F_B			
	(g)	(g)	(kg)	(N)	(g)	(kg)	(N)	(g)	(kg)	(N)	(N)
1.	0										
2.											
3.											
4.											
5.											

Results and Discussion

The readings on the scales of the two spring balances are same. It means the action force; exerted by the spring balance A on B is equal to the reaction force (exerted by the spring balance B on A). Thus the action and reaction forces are equal and opposite and act on different objects. This verifies the third law of motion.

In case if the readings on the scales of the two spring balances are approximately same (that is, not exactly same), discuss the reasons.

Precautions

- Before making use of the two spring balances it should be ensured that their pointers are at zero mark.
- The readings of the two spring balances should be noted only when their pointers come to rest.
- Select spring balances having uniform and evenly spaced calibration marking.
- The thread used in experiment should be inextensible lest the stretch in the string may change the force on the spring balances.

Note for the Teacher

- In order to make use of spring balances properly, it is advised that before performing this experiment students may be given proper grooming in the use of spring balance (see Experiments 3 and 4).
- The purpose of this experiment is to elucidate the third law of motion. In order to give avoid unnecessary importance to the measuring skills, it is advised that the mass of the pan may be provided.
- A spring balance is primarily meant for measuring the weight (force) of an object. However in laboratories, a spring balance is often used to measure the mass of an object. It should be remembered that the calibration of spring balance scale is done at the place of its manufacture and depends on the value of acceleration due to gravity (g) at that place. Therefore, if a spring balance is used to measure mass at any other place where the value of g is different, an error in the measurement of mass will appear. In this experiment however, if the two spring balances are identical then this error will not matter because here we use spring balances to compare the forces due to gravity.

- In this experiment we intend to study the third law of motion, which is about the action and reaction forces. It is therefore important to measure forces rather than the masses. It is therefore suggested to use the spring balances which also measure weight (force) in N. In case such spring balances are not available and students are compelled to make use of spring balances that denotes mass readings only, then suggest them to take mass readings correctly. The mass readings then can be multiplied by the value of the acceleration due to gravity (*g*) at the place where the experiment is being performed.

APPLICATIONS

Look for some examples from your daily life where you can see application of third law of motion. How do we move on the road? Identify the pair of action and reaction forces. Do they produce accelerations of equal magnitudes on the two objects involved?

QUESTIONS

- Why do we find it difficult to move on sand?
- When a horse pulls a cart, according to the third law of motion, the cart also pulls the horse in opposite direction with equal force. Why does the horse-cart system move at all then?
- A spring balance is calibrated in mass. Does it measure mass or weight?
- A spring balance is calibrated in grams at Kolkata (say). The mass of an object measured from this balance at New Delhi is 60 g. What is the accurate mass of this object? What mass of the object will be shown by this spring balance on the surface of the moon?
- In one of the experimental observations with a good spring balance, the mass of an object was found to be 495 g. However the accurate mass of this object was 500 g. How will you explain this observation? Does it go against the third law of motion?

Experiment 35

AIM

To study the variation in limiting friction with mass and the nature of surfaces in contact.

THEORY

Whenever an object is made to slide over another surface by applying a force, the force of friction (or simply friction) opposes its motion. The force of friction acts in a direction opposite to the direction of the applied force. As the force applied on the object is increased, the force of friction also increases accordingly to balance it. The net force on the body remains zero and it doesn't move. However, the force of friction can increase only up to a certain limit. Once the applied force is increased beyond this limit, an unbalanced force acts on the object and it begins to move. The maximum value of force of friction, acting between the two solid surfaces just before the object sets into motion is called *limiting force of friction* (or simply *limiting friction*).

To study the dependence of limiting friction on the mass of an object, you will need an arrangement to measure the force applied on the object and find the force that is just sufficient to make it move on the surface. One such arrangement is shown in Fig. 35.1. In this arrangement, one end of a string is fixed to the object to be moved while its other end has a pan attached to it. The string passes over a frictionless pulley such that the pan remains suspended freely in air. When a weight is kept on the pan, a force acts on the body in the horizontal direction through the string. If the weight of the pan is equal to the *limiting friction*, the object starts sliding. Thus,

Limiting friction = Force exerted through the string
= Mass of the pan and the mass of extra weights placed on it × acceleration due to gravity (*g*)

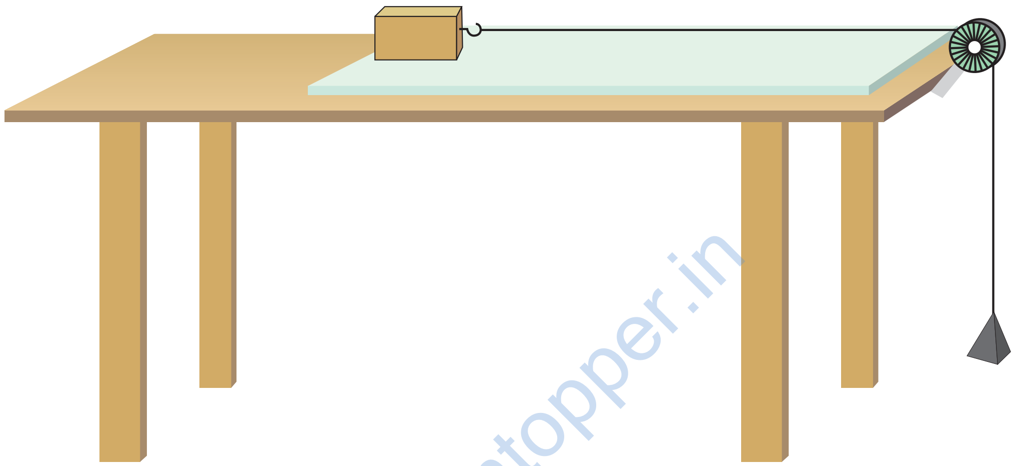


Fig. 35.1 : *Experimental set up to study variation in limiting friction with the mass of the object suspended*

MATERIALS REQUIRED

A wooden block with a hook, horizontal plane, two different plane top surfaces (such as glass top, a wood mica top or a hard board), a frictionless pulley (which can be fixed at the edge of the plane), a pan of known mass, a spirit level, weight box including forceps, spring balance, a string, and ten pieces of mass (say each of 100 g).

PROCEDURE

1. Place a clean glass sheet on the top of a table. Make the surface horizontal with the help of a spirit level. To make the glass top horizontal, pieces of paper or cardboard may be inserted below it.
2. Find the range and the least count of the spring balance.
3. Measure the mass of wooden block having hook (*M*) using a spring balance.
4. Fix the pulley at the edge of the table as shown in Fig. 35.1.
5. Tie one end of the string to the pan and other end to the hook of the block.
6. Place the wooden block on the horizontal glass top and pass the string

over the pulley as shown in Fig. 35.1. Make sure that the portion of string between the pulley and the wooden block is horizontal and does not touch the table-top anywhere. For this adjust the height of pulley so that its top is at the same level as the hook fixed to the wooden block.

7. Put a small mass (*p*), say 20 g, on the pan from the weight box. Gently tap the glass surface and observe whether it makes the block move. Increase or decrease the mass on the pan in steps till the wooden block just begins to slide on gently tapping the glass top surface. Note the mass kept on the pan.
8. Remove the mass from the pan and move the block to the same positon as before.
9. Put some mass (*q*), say 200 g, on the wooden block. Find out the mass required to be kept on the pan that is just sufficient to make the wooden block (together with the mass *q*) slide over the glass top surface. Note the mass kept on the pan.
10. Repeat the activity by putting different mass on the top of the wooden block and note the mass required (to be placed on the pan) to make it slide in each case.
11. Replace the glass top with any other surface such as wood mica, hard board and repeat the steps 6 to 10 and record your observations.

Observations and Calculations

Record the observations for two different surfaces in different tables.

(i) Range of the spring balance = ______ g

(ii) Least count of the spring balance = ______ g

(iii) Mass of the wooden block with hook, M = ______ g

(iv) Mass of the pan, m (given) = ______ g

(v) Acceleration due to gravity at your place = ______ m/s²

Table 1 : Sliding of Wooden Block on Surface 1 (Glass Top)

Sl. No.	Mass on the wooden block, q	Total mass of wooden block $= M + q$		Mass on pan, required to make the wooden block slide on glass top, p	Total mass of the pan $= m + p$		Limiting friction = Weight of the pan $= (m + p)g$
	(g)	(g)	(kg)	(g)	(g)	(kg)	(kg m/s^2) or (N)
1.	0						
2.							
3.							

Table 2 : Sliding of Wooden Block on Surface 2 (Wood Mica Top)

Sl. No.	Mass on the wooden block, q	Total mass of wooden block = $M + q$		Mass on pan required to make the wooden bloc slide on wood mica top, p	Total mass of the pan = $m + p$		Limiting friction = Weight of the pan = $(m + p)g$
	(g)	(g)	(kg)	(g)	(g)	(kg)	(kg m/s^2) or (N)
1.							
2.							
3.							

Results and Discussion

- The limiting friction increases with the increase in weight of the object sliding on a given surface.
- The value of limiting friction changes with the change in the nature of surfaces in contact. Friction between _______ and _______ surfaces is more than friction between ________ and ________ surfaces.

Precautions

- Since the friction at the pulley affects the value of limiting friction, the pulley should be as smooth as possible.
- The string should be inextensible.
- The portion of the string between the pulley and wooden block must be horizontal.
- The surface of plane (glass, wood mica, hard board etc.) and the wooden block in contact must be clean and dry.
- The pan should be attached with the string in such a manner that it remains horizontal when it is suspended freely with no mass on it.
- Whenever a mass is added to the pan, tapping on horizontal plane surface (glass, wood mica, hard board etc.) should be done very gently to check whether the block just moves or not.
- Forceps should be used while handling the weights. Ensure that mass does not slip down as the pan moves.

Note for the Teacher

- Give practice to the student for the use of spring balance (Experiments 3 and 4).
- The purpose of this experiment is to understand the phenomenon of limiting friction. It is advised that the mass of the pan (m) and that of the wooden block (M) may be provided.
- The portion of string that lies between the pulley and wooden block should remain horizontal. For this the position of pulley fixed on one end of a table may have to be adjusted (in accordance to the thickness of plane surfaces and the position of the sliding wooden block).
- It is important to make a judicious choice of the size of the block and set of mass for this experiment. If the block is too light, the force of limiting friction may be even less than the weight of the empty pan and in this situation the observations cannot be taken with the block alone. Similarly, the maximum mass of the block, which can be varied by putting a given set of mass on it, should not be so large that a large mass is required to be kept on the pan to make the wooden block slide.

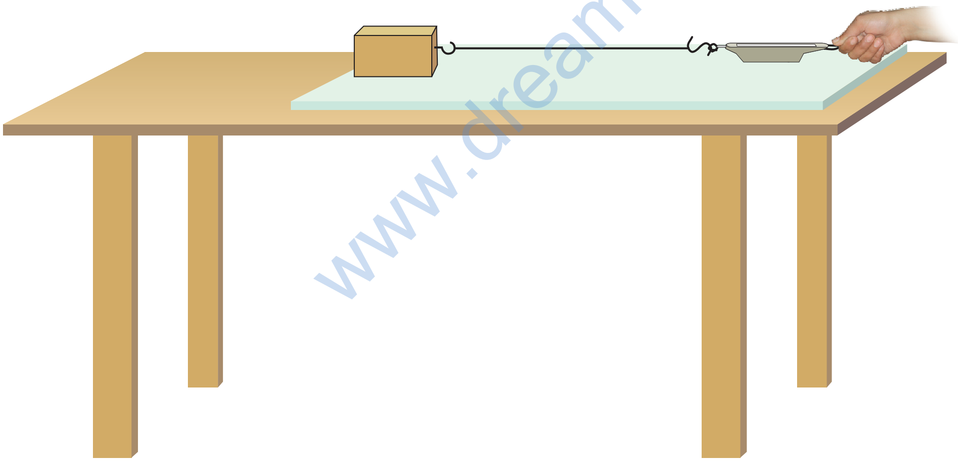


Fig. 35.2 : *An alternate arrangement (improvised) to study the limiting friction*

- In case a pulley is not available or cannot be positioned properly, a spring balance may be used to measure the force required to make the block move. Tie one end of the string with the wooden block and its other end with the hook of the spring balance. The length of the string should be such that the spring balance could be held at one end of the table while the wooden block is kept near the other end of the horizontal plane surface (Fig. 35.2). Here too, the string should be kept horizontal while the force is applied on the block. Now apply a small force on the wooden block by pulling the spring balance. Gradually increase the force till the block begins to slide on the horizontal surface. Note that the spring balance shows a larger value of force just before the wooden block begins to slide. This maximum reading of the spring balance gives the value of limiting friction. If the given spring balance is calibrated in newtons, the force can be measured directly. However, if it is calibrated in kilograms, then the measured value has to be multiplied with the acceleration due to the gravity.

Questions

- Why is use of a frictionless pulley advised?
- In this experiment, what will happen if the weight of the empty pan is more than the limiting friction between the surface and the wooden block you are using?
- In which direction the force of friction acts on the block?
- Why is the thread used to move the block kept horizontal to the surface and the wooden block you are using?
- How is limiting friction between two surfaces in contact affected when grease or oil is put between them?
- A 100 g block slides when tension in the string is x N. What will be the tension in the string when an identical block is placed at top of the first block?
- The two blocks mentioned in above question are connected and placed on the same surface. What would be the tension in the string now?
- How can you use the concept of limiting friction to measure a force?
- In the above experiment as the block slides over the surface a sound is heard. Can you explain the reason for the sound produced?

Experiment 36

Aim

To verify Archimedes' principle.

Theory

Archimedes' principle, also called law of buoyancy, states that any object that is completely or partly immersed (or submerged) in a fluid at rest is acted on by an upward (or buoyant) force. The magnitude of this force is equal to the weight of the fluid displaced by the object. The volume of the fluid displaced is equal to the volume of the portion of the object submerged. Here in this experiment we shall make an attempt to verify this principle by submerging a solid object in water.

Materials Required

An overflow-can, a wooden block, a measuring cylinder (100 mL and preferably with a least count of 1 mL), a spring balance, a solid object (a stone or a metallic block of size that can be easily lowered in the overflow-can), laboratory stand, and a piece of silk thread.

Procedure

1. Find the range and least count of the spring balance and the measuring cylinder. In case the spring balance is calibrated in newton (N), note its range and the least count in N.

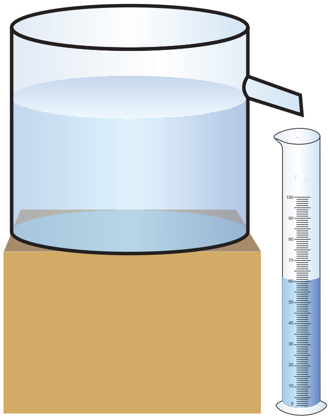


Fig. 36.1(a) : *The overflow-can and measuring cylinder assembly*

2. Place an overflow-can on a wooden block and fill it with tap-water until the water begins to flow from its spout. Wait till the last drop of excess water flows out. This is to ensure that the level of water in the can is up to its brim.
3. Place an empty measuring cylinder under the spout of the overflow-can to collect water [Fig. 36.1(a)].
4. Tie the given solid with a thread and suspend it from the hook of spring balance. Clamp the spring balance with a laboratory stand such that the solid is suspended freely in air as shown in Fig. 36.1(b). Note the reading of the spring balance.
5. Lower the solid into the water in the overflow-can such that a part of it, say less than half of it gets immersed in water. Let the water displaced by the solid in the overflow-can flows out form its spout and gets collected in the measuring cylinder placed below (as shown

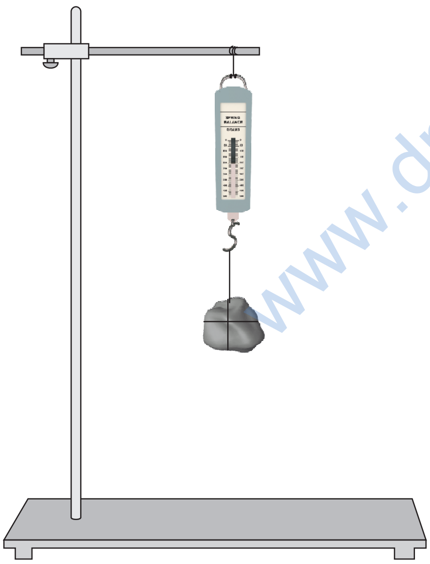


Fig. 36.1(b) : *Measuring the weight of the object in the air*

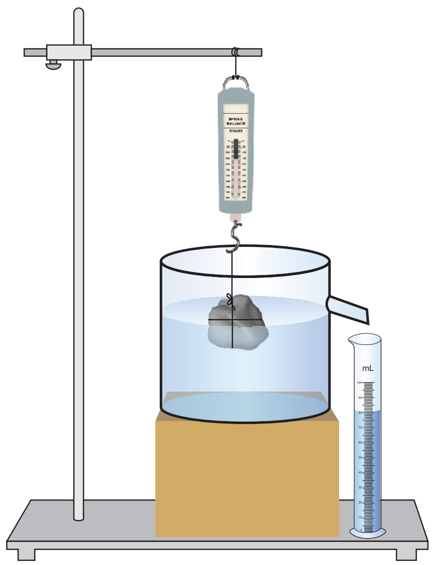


Fig. 36.1(c) : *Measuring the weight of the object when it is immersed in water*

in Fig. 36.1(c). Wait till the water stops dripping out from the overflow-can. Note the volume of the water collected in the measuring cylinder.

6. Note the reading of spring balance while the solid is partly immersed in water and the dripping of water has stopped. This corresponds to the weight of the solid when it is partly immersed in water.
7. Lower the solid further into the water (but do not let it immerse completely) in the overflow-can. Let the displaced water be collected in the measuring cylinder as before and note the new volume of water. Note the reading of the spring balance as you did before in step 6.
8. Next, lower the solid further into the water till it gets completely immersed in it. Again note the volume of water collected in the measuring cylinder and the reading of the spring balance.
9. As a courtesy to your fellow students, clean the table as some water might have been spilled on the table while performing this experiment.

Observations and Calculations

(i) Range of the spring balance = _____ g = _____ N
(ii) Least count of the spring balance = ______ g = ______ N
(iii) Range of the measuring cylinder = ______ mL
(iv) Least count of the measuring cylinder = ______ mL
(v) Weight of solid in air, W_0 = ______ N
[or W_0 = mass of solid in air, m_0 (in kg) × acceleration due to gravity g (in m/s^2)]
(vi) Density of water, ρ (given) = ______ g/mL
(vii) Acceleration due to gravity (g) at your place = ______ m/s^2.

Sl. No.	Reading of the spring balance when succesively greater volume of the solid is immersed in water W_1 (or m_1g)	Corresponding loss in weight of the solid, $W = W_0 - W_1$ (or $W = m_0g - m_1g$)	Volume of water collected in the measuring cylinder, V	Weight of water collected in the measuring cylinder (buoyant force), $W_w = V_{Tap} \times \rho \times g$	Difference in apparent loss in weight and the weight of displaced water $W \sim W_w$
	(N)	(N)	(mL)	(N)	(N)
1.					
2.					
3.					
4.					

Results and Discussion

The difference between the apparent loss in weight of the solid when immersed in water and the weight of water displaced is negligibly small (_____ N). In each case the observed value of the apparent loss in the weight of solid immersed in water is nearly equal to the weight of displaced water. This verifies Archimedes' principle.

Precautions and Sources of Error

- The graduation marks on the measuring cylinder and on spring balance should be evenly spaced.
- The impurities present in the water may alter its density.
- The solid used should be non-porous otherwise it will absorb some water. Absorption of water by the solid may affect the change in its weight and the volume of water displaced by it.
- The density of solid should be larger than that of water so that it sinks in water.
- The measuring cylinder must be kept on a horizontal surface and the line of sight should be at the same level as that of the lower meniscus of water while recording the volume of displaced water.
- Before reading the liquid meniscus in the measuring cylinder, it must be ensured that there is no air bubble inside the liquid.
- The readings of the spring balance should be taken only after its pointer comes to rest. If the spring balance has some zero error then it must be noted before taking measurements and the same should be taken into account while using the spring balance.
- The thread used in this experiment may also absorb some water.

Note for the Teacher

- Experiment 37 "*To establish the relation between the loss in weight of a solid when fully immersed in (i) tap water; (ii) strongly salty water, with the weight of water displaced by it by taking at least two different solids*" and this experiment have some-what similar objectives and procedure. It is therefore advised that students may be asked to perform only one of these two experiments.
- In case, an overflow-can is not available, a large size-beaker with a spout may also be used.

QUESTIONS

- Why does the pointer of a spring balance move up when the stone suspended from it is immersed in water?
- State the factors on which buoyant force acting on an object immersed in a fluid depend.
- What will be the effect on the apparent loss in weight of a stone if it is immersed in salty water instead of tap-water?
- State two precautions that should be observed while making use of an overflow-can.
- An object suspended from a spring balance is gradually lowered in an overflow-can. What will be the change in the apparent loss in the observed weight as the object is immersed in water?
- What is a fluid? Is it different from a liquid or from a gas or from a solid?

Experiment 37

AIM

To establish the relation between the loss in weight of a solid when fully immersed in (i) tap water; (ii) strongly salty water, with the weight of water displaced by it by taking at least two different solids.

THEORY

When a solid object is immersed in water, there is a loss in its weight. This loss is equal to the weight of the water displaced. In this experiment we shall appreciate this relationship by immersing two different solid objects in tap-water and in strongly salty water.

MATERIALS REQUIRED

An overflow-can, a wooden block, a measuring cylinder (100 mL and preferably with a least count of 1 mL), a spring balance, two small different solid non-porous objects, laboratory stand, tap-water and strongly salted water of known densities, and a piece of silk thread.

PROCEDURE

1. Find the range and the least count of the spring balance and measuring cylinder.
2. Hold the spring balance vertically and ensure that its pointer is at zero mark.

3. Check whether the spring balance can measure the weight? If it has the graduation markings in terms of force units, that is N — well. If not, that is the spring balances have graduation markings in terms of mass only, then convert it in weight by multiplying the mass with the acceleration due to gravity at your place.
4. Place an overflow-can on a wooden block and fill it with tap-water until the water begins to flow from its spout. Wait till the last drop of excess water flows out. This is to ensure that the level of water in the overflow-can is up to its brim.
5. Tie one of the two given solid objects with a thread and suspend it from the hook of spring balance. Clamp the spring balance in a laboratory stand such that the solid is suspended freely in air. Measure its mass (m_{1a}) or its weight (w_{1a}) in air [Fig. 37.1(b)].
6. Place an empty measuring cylinder under the spout of the overflow-can to collect water [Fig. 37.1(a)].

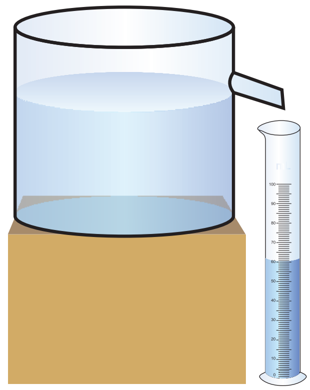


Fig. 37.1(a) : *The overflow can and measuring cylinder assembly*

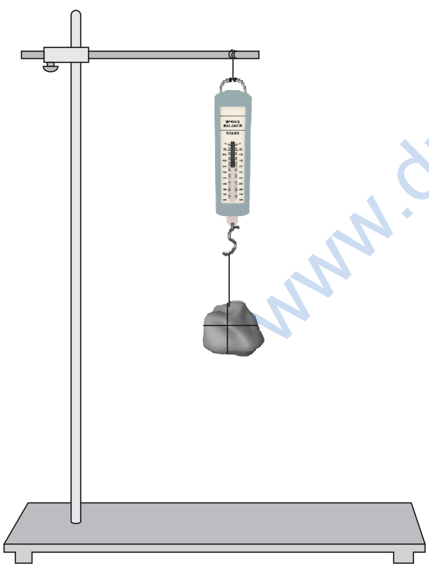


Fig. 37.1(b) : *Measuring the weight of the object in the air*

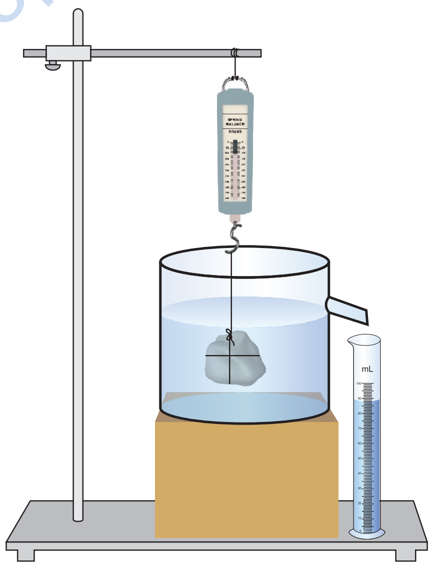


Fig. 37.1(c) : *Measuring the weight of the object when it is immersed in water*

7. Bring the laboratory stand (clamped with the spring balance and the solid object) over the tap-water filled overflow-can. Immerse the solid fully into the tap-water in overflow-can, as shown in Fig. 37.1(c).

8. Collect the water displaced by the solid in the overflow-can that flows out from its spout in measuring cylinder. Wait till the water stops dripping out from the overflow-can. Note the Volume V_{Tap} of water collected in the measuring cylinder.
9. Note the reading of spring balance to get the mass (m_{1Tap}) or the weight (w_{1Tap}) of the solid in tap-water. Record your observations.
10. Repeat step 3 onwards for second solid object.
11. Repeat the whole procedure for strongly salted water in place of tap-water. Do you observe difference in your readings?

Observations and Calculations

(i) Range of the spring balance = __ — __ N or __ — __ g

(ii) Least count of the spring balance = __ N or ___ g

(iii) Acceleration due to gravity (g) at your place = ____ m s^{-2}

(iv) Other Values:

Sl. No.	First/ Second	Solid object: Mass in air, m_a		Solid object: Weight in air $w_a = m_a \times g$	Density of: Tap water, ρ_{Tap}		Density of: Strongly salty water, ρ_{SSW}	
		(g)	(kg)	(N)	g/mL	kg/m^3	g/mL	kg/m^3
1.	First							
2.	Second							

A. For tap-water

Sl. No.	Solid Object	Reading of the spring balance when the solid object is fully immersed in tap water			Loss in weight of the solid when fully immersed in tap water, W_{STap}	Volume of tap water collected in measuring cylinder, V_{Tap}		Weight of tap water collected in measuring cylinder, $W_{WTap} = V_{Tap} \times \rho_{Tap} \times g$	Difference in loss inweight of solid and weight of displaced tap water $W_{STap} \sim W_{WTap}$
	First/ Second	Mass		Weight W_{Tap}					
		(g)	(kg)	(N)	(N)	(mL)	(m^3)	(N)	(N)
1.	First								
2.	Second								

B. For strongly salty water

Sl. No.	Solid Object	Reading of the spring balance when the solid object is fully immersed in strongly salty water			Loss in weight of the solid when fully immersed in strongly salty water W_{sssw}	Volume of strongly salty water collected in measuring cylinder, V_{ssw}		Weight of strongly salty tap water collected in measuring cylinder, $W_{wssw} = V_{ssw} \times \rho_{ssw} \times g$	Difference in weight of loss of solid and weight of displaced strongly salty water $W_{sssw} \sim W_{wssw}$
	First/ Second	Mass		Weight W_{ssw}					
		(g)	(kg)	(N)	(N)	(mL)	(m^3)	(N)	(N)
1.	First								
2.	Second								

Results and Discussion

The loss in weight of both the solids used in this experiment when fully immersed in tap and strongly salty water are equal (or approximately equal) to the weight of water displaced by them, respectively.

For a given solid, the weight of water displaced by it when immersed fully in strongly salty water is more than the weight of the water displaced when fully immersed in tap-water. Thus larger the density of liquid in which the solid is immersed, larger the weight of liquid displaced or larger the upward (or buoyant) force.

Precautions and Sources of Error

- Before making use of the spring balance it should be ensured that its pointer is at zero mark.
- Ensure that the spring balance hangs vertically with the laboratory stand.
- The solid objects used should be non-porous otherwise they will absorb some water. This may affect the apparent change in its weight and the volume of water displaced by it.
- The density of solid should be larger than that of liquid so that it sinks in it.
- The measuring cylinder must be kept on a horizontal surface and the line-of sight should be at the same level as that of the lower meniscus of water while recording the volume of displaced water.
- Before reading the water meniscus in the measuring cylinder, it must be ensured that there is no air bubble inside the water.
- The readings of the spring balance should be taken only after its pointer comes to rest. If the spring balance has zero error then it must be noted before taking measurements and the same should be taken into account while using the spring balance.

- The graduations mark on the two spring balances may not be evenly spaced.
- The impurities present in the water may alter its density.
- The thread used in experiment may also absorb water to introduce some error.

Note for the Teacher

- The earlier experiment: "*To verify Archimedes' principle*" and this experiment have some-what similar objectives and procedure. It is therefore advised that students may be asked to perform only one of these two experiments.
- In case an overflow-can is not available, a large size beaker with a spout may also be used.
- Students may be provided tap water and strongly salty water separately. The density of salty water may also be provided. In case if the density of salty water is not provided then students can be asked to prepare strongly salty water by dissolving a known quantity of salt in known volume of tap water (to calculate the density of strongly salty water).
- Thread used for tying the solid objects may absorb some water to cause error. It is therefore suggested that cotton thread be not used instead a silk thread may be used.
- If the density of any solid object is less than the density of water then a sinker can be used to perform the experiment.

Applications

This method can be used to determine the density of any liquid.

Questions

- Why is it easier to swim in sea-water rather than a swimming pool or river water?
- In which liquid—glycerin or kerosene—the loss in the weight of a solid object when fully immersed in it will be more?
- How can you perform this experiment for a solid whose density is lesser than that of the liquid used?
- What are the limitations of this experiment?
- Using this method, how would you find the density of a liquid?
- How will you select solid to perform this experiment using glycerin instead of water?

Experiment 38

AIM

To plot temperature–time graph for a hot object as it cools.

THEORY

A hot object loses heat to its surroundings in the form of heat radiation. The rate of loss of heat depends on the difference in temperature between the object and its surroundings.

MATERIALS REQUIRED

A calorimeter (500 mL) with a stirrer, a lid for the calorimeter with two holes in it, a thermometer (–10 °C — 110 °C), a stop-watch or stop-clock, spirit lamp or gas burner, tripod stand with wire gauze, a laboratory stand, water and a piece of thread.

PROCEDURE

1. Find the range and least count of the thermometer.
2. Hold the thermometer vertically in air and note the room temperature.
3. Take about 300 mL of water in the calorimeter with a stirrer and cover it with two-holed lid. Fix a thermometer through a hole in the lid (Fig. 38.1). Make sure that the bulb of thermometer is immersed in the water.

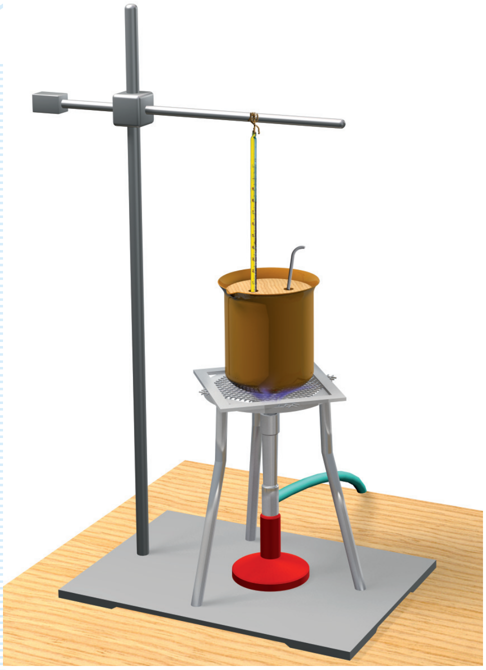


Fig. 38.1 : Heating of water in a calorimeter

4. Place the calorimeter over the wire gauze on the tripod stand and heat it with a spirit lamp or a gas burner.
5. Heat the water till it attains a temperaure nearly 40 °C above the room temperature (temperature of the surroundings). Stop heating the water.
6. Switch on the stop-watch or stop-clock. Note the reading of the thermometer after fixed intervals of time. One can read the thermometer initially after every one minute and after every two minutes once the temperature of water falls down to nearly 10 °C above the room temperature. In order to maintain uniform temperature of the water in the calorimeter, keep it stirring gently with the stirrer.
7. Continue to note the temperature of water till it attains a temperature about 5 °C above that of the surroundings (room temperature).

Observations and Calculations

Room temperature (temperature of surroundings), θ_1 = ___ °C = ___ K.

Sl. No.	Time, t	Temperature of water	Temperature difference, θ
	(minute)	θ_2 1(°C)	$= \theta_2 - \theta_1$ (°C)
1.			
2.			
3.			
..			
..			
..			
9.			
10.			

Graph

Study the range of variation in the values of temperature difference θ and that of time t. Choose appropriate scales for the temperature and time to plot a graph between them. Draw x and y-axis on the graph paper. Take θ along the y-axis and time t along the x-axis. Plot the points on the graph for each value of temperature difference θ and the corresponding value of time t. Join all the points with as smooth (without pointed edges) a curve as possible. It is likely that a smooth curve may not be obtained by joining all points on the graph. However, a smooth curve can be drawn by joining as many points as possible. Do not bother even if some points are left out on either side of the curve drawn (Fig. 38.2).

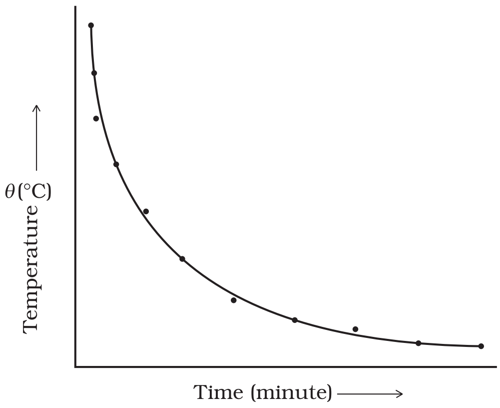


Fig. 38.2 : *Curve showing cooling of hot water with time*

Results and Discussion

Study the curve obtained on plotting the graph. From the graph infer as to how the cooling of hot water depends on the difference of its temperature with that of the surroundings. Remember that a curve nearly parallel (or close to it) to the y-axis shows that cooling is quick (that is, rate of cooling is high). While the curve nearly parallel (or close to it) to the x-axis shows that cooling is slow (that is the rate of cooling is slow).

Precautions

- The initial temperature of hot water in calorimeter should be about 40 °C above the temperature of surroundings (the room temperature).
- The water in the calorimeter should be gently stirred all the times during the experiment.
- The calorimeter should be covered properly to avoid (or to minimise) loss of heat by water due to convection or evaporation.
- The scale for drawing the graph should be chosen such that all the observed values could be accommodated easily. The curve drawn should not only be continuous and smooth but care should also be taken to ensure that it passes through maximum number of points in such a manner that nearly equal number of remaining points lie on either side of it. In some cases the smooth curve may be such that nearly all points lie outside it.

NOTE FOR THE TEACHER

- Blackening of calorimeter from outside will reduce the cooling of hot water by conduction. Therefore, use of blackened calorimeter should be preferred.
- In case a calorimeter is not available, then a beaker with its outer surface painted black may be used instead of a calorimeter.
- Experiments 32 and 33 provide a good practice in plotting graphs. It is therefore advised that students must first perform either of these two experiments.

QUESTIONS

- Why does the temperature fall rapidly when we start reading the temperature of given hot water in this experiment?
- Why is the calorimeter covered with a lid while performing the experiment?
- Why do we prefer to keep the calorimeter on an insulating surface while performing the experiment?
- Why does the temperature fall slowly when the temperature of hot water in the calorimeter approaches the room temperature?
- Why do we prefer to use a calorimeter whose outer surface is blackened?
- For a given hot liquid, the θ - t graph is parallel to time axis. What inference do you draw from such a graph? (*Caution: This situation may not be real one.*)
- What would you infer from a temperature - time graph that is parallel to temperature axis?
- In this experiment you might have observed that initially the temperature of hot water falls rapidly. But as the temperature of water comes close to the temperature of surroundings, the fall of temperature becomes rather slow. How?

Experiment 39

AIM

To study the effect of amplitude on the time period of a simple pendulum.

THEORY

A simple pendulum consists of a small object of heavy mass, called the pendulum bob, suspended by a light inextensible thread from a fixed and rigid support [Fig. 39.1(a)]. When the bob P is released after taking its free end P slightly to one side (say to point R), it begins to oscillate about its mean position O [Fig. 39.1(b)]. The time taken by the pendulum to complete one oscillation is called its time period. The maximum departure of the pendulum from its mean position (or half the length of the swing) is called its amplitude. Does the time period of a simple pendulum depend on its amplitude? In this experiment we shall attempt to explore it.

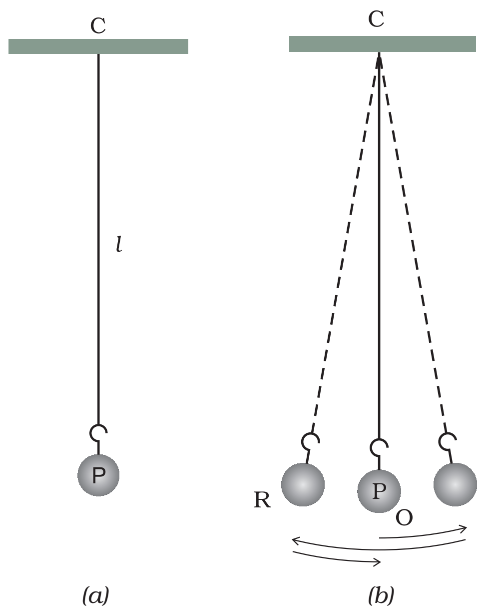


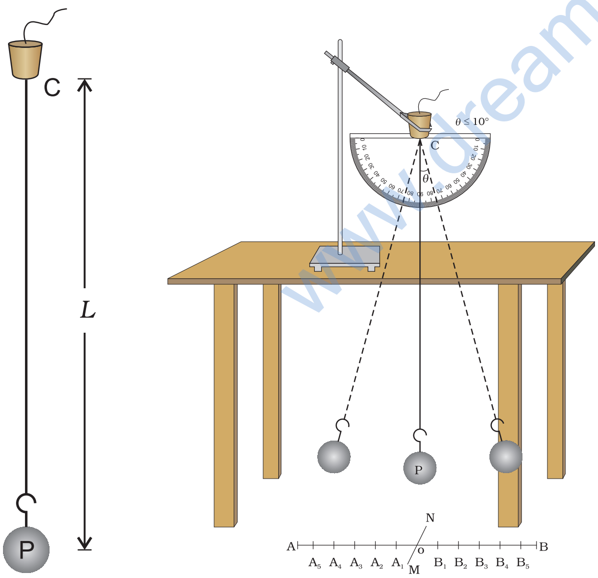
Fig. 39.1 : *(a) A simple pendulum; and (b) Different positions of the bob of an oscillating simple pendulum and a complete oscillation*

Materials Required

A heavy iron stand, a cork (split along length through middle), an inexstensible thread of about 1.5 m length, a metallic spherical bob of known radius, a stop-watch (or a stop clock), a large size protractor, and a meter scale.

Procedure

1. Find the least count of the given stop-watch or stop clock.
2. Tie one end of an inextensible thread of nearly 1.5 m length with a pendulum bob and pass the other end of thread through the split cork as shown in Fig. 39.2(a).
3. Clamp the cork firmly to a heavy iron stand and place it on a horizontal table. The pendulum must over-hang the table.
4. Fix a large size protractor just below the split cork such that its 0° - 180° line is horizontal so that the pendulum, hanging vertically, coincides with the 90° line of the protractor. Also ensure that the centre of the protractor lies just below the point C of suspension of the pendulum in its rest position [Fig. 39.2(b)].



(a) (b)

Fig. 39.2 : *(a) A simple pendulum fixed in a split cork; and (b) Experimental set up for studying the variation in the time period of pendulum with a change in its amplitude*

5. Adjust the effective length of the pendulum, *L*, to any desired length (say 1 m). The effective length of pendulum is measured from the point of suspension (the lowest point on the split cork from which the bob suspends freely) to the centre of mass of the pendulum bob (which in the case of a spherical object is at its geometric centre), that is, length CP in Fig. 39.2(a). The length of the pendulum can be increased (or decreased) by pulling down (or up) the thread through the split cork after slightly loosening the grip of the clamp. Note the length of the simple pendulum.
6. Draw two lines on the surface, one parallel to the edge of table (AB) and other perpendicular to it (MN) such that the two intersect at the point O [Fig. 39.2(b)].
7. Adjust the position of the laboratory stand and the height of the clamp

such that the point of intersection, O, of lines AB and MN lies exactly below and very close to the centre of bob in its rest position.

8. Divide line AB through equal divisions of 4 cm each (say) on both sides of the point O.
9. Gently hold the pendulum bob P just above the point O. Keeping the thread stretched, displace the bob to the first division point OA_1(or OB_1) on line AB in either side of mean position (O). Also check the angular displacement of the bob on the protractor attached at the top of pendulum C, with the clamp. Release the bob so that it begins to oscillate about its mean position. What is the amplitude of the oscillating pendulum? It is the maximum departure (point A_1 or B_1) of the pendulum from its mean position (point P or O). Thus the amplitude of the simple pendulum is OA_1 (or OB_1). Measure the amplitude and angular displacement and record them in observation table.
10. Observe the time taken for appreciable number of oscillations n (say, 10 oscillations) with the help of a stop-watch or stop-clock. Record the time taken for n oscillations in the observation table.
11. Bring the pendulum at rest in its mean position. Displace the pendulum bob to the twice of the distance displaced earlier. Record the amplitude and angular displacement of the pendulum. Repeat step 10 for recording the time taken for n number of oscillations.
12. Repeat step 11 for more values of amplitude (and angular displacements) and record the time taken for n number of oscillations in each case.
13. Calculate the time period of the simple pendulum in each case.

Observations and Calculations

(i) Least count of the stop-watch or stop-clock = ___ s
(ii) Diameter of the pendulum bob, d = ___ cm
(iii) Radius of the pendulum bob, $r = d/2$ = ___ cm
(iv) (Length of the thread + length of hook (if any), l = ___ cm
(v) Effective length of the simple pendulum, L (= $l + r$) = ___ cm
= ___ m.

Sl. No.	Amplitude of the pendulum	Angular displacement	Number of oscillations	Time taken in n oscillations,	Time period $T = t/n$
	a	θ	n	t	
	(cm)	(°)		(s)	(s)
1.	4				
2.	8				
3.	12				
4.	16				
5.	20				
6.	25				

Graph

Plot a graph between the amplitude of the pendulum, *a*, and time period, *T* for a fixed effective length of the pendulum, *L*. Take *a* along *y*-axis and *T* along *x*-axis. Smoothly join all the points. Attach the graph with observations.

Results and Discussion

From the observation table and graph we may infer about the relation between the amplitude of simple pendulum and its time period.

You may discover that for smaller amplitudes (corresponding to angular displacements, $\theta \leq 10°$), the time period is independent of amplitude. But for larger amplitudes (or for larger angular displacements) the time period of the pendulum changes with amplitude.

(Why is the time period independent of amplitude for smaller amplitudes and not for larger amplitudes? You will study this in higher classes.)

Precautions

- Effective length and mass of the bob of simple pendulum must be kept same for all measurements.
- Thread used must be light, strong and inextensible. An extension in the thread will increase the effective length of the pendulum. There should be no kink or twist in the thread.
- The pendulum support should be rigid. For this take a laboratory stand with heavy base.
- The split cork should be clamped keeping its lower face horizontal.
- During oscillations the pendulum should not touch the edge of the table or the surface below.
- The bob must be released from its displaced position very gently and without a push otherwise it may not move along the straight line AB. In case you notice that the oscillations are elliptical or the bob is spinning or the bob is jumping up and down, stop the pendulum and displace it again.
- At the place of experiment, no air disturbance should be present. Even all the fans must be switched off while recording the observations.
- Counting of oscillations should begin when the bob of the oscillating pendulum passes its mean position.

Note for the Teacher

- To simplify the experiment, the values of diameter or radius of the pendulum bob and length of hook may be provided to students.
- If it is found that the experiment is taking too much time, then the measurements of angular displacements may be skipped.
- Practically the amplitude may decrease in each swing of the pendulum with time. Thus the pendulum will not keep on oscillating for a long time. Therefore counting of the number of oscillations for measuring the time taken should be stopped before the amplitude of oscillation becomes too small. It is therefore advised that number of oscillation (n) for which time is noted should be small (say n = 10).
- A large size protractor can be improvised on a cardboard.

Questions

- Discuss how does the time period of a pendulum of fixed length vary with a change in the amplitude of oscillation?
- Observe a simple pendulum swinging with some appreciable amplitude. Does its amplitude remain constant? Discuss your findings after 10 oscillations?
- Two students perform this experiment in two different conditions, namely (i) in the school laboratory, and (ii) in vacuum, respectively. Which of the students is more likely to get better result? Discuss it.
- What makes a simple pendulum oscillate when it is displaced and then released from its mean position?
- What are the factors, which are responsible for the dying out of oscillations of a simple pendulum?
- What will happen if bob of pendulum touches the edge of the table?
- While determining the time period of a pendulum why do we prefer to measure time for about ten oscillations?
- Observe Fig. 39.2(b). Locate the positions where the speed of bob is minimum and maximum. Also discuss the kinetic and potential energies of the pendulum at these points.
- Can you imagine a situation in which the time period of a simple pendulam becomes infinite?

Experiment 40

AIM

To study the variation in time period of a simple pendulum with its length.

THEORY

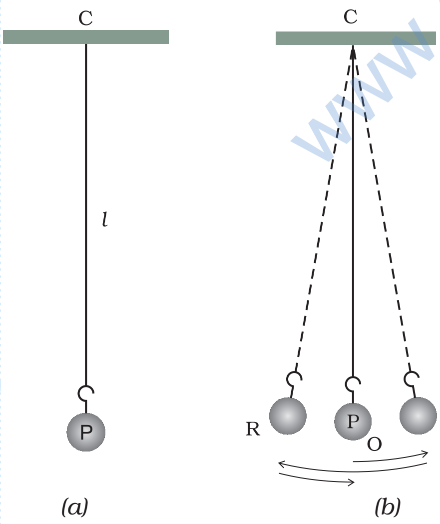


Fig. 40.1 : *(a) A simple pendulum; and (b) Different positions of the bob of an oscillating simple pendulum and a complete oscillation*

A simple pendulum consists of a small object of heavy mass, called the pendulum bob, suspended by a light thread from a fixed and rigid support [Fig. 40.1(a)]. When the bob CP is released after taking its free end P slightly to one side (say to point R), it begins to oscillate about its mean position O [Fig. 40.1(b)]. The time taken by the pendulum to complete one oscillation is called its time period. The time period of a simple pendulum depends on the length of the simple pendulum. In this experiment we shall attempt to establish a relationship between the length of the simple pendulum and its time period.

Materials Required

A heavy iron stand, a cork (split along length through middle), an inexstensible thread of about 1.5 m length, a metallic pendulum bob of known radius, a stop-watch (or a stop clock), a large size protractor, and a meter scale.

Procedure

1. Find the least count of the given stop-watch (or stop clock).
2. Tie one end of an inextensible thread of nearly 1.5 m length with a pendulum bob and pass the other end of thread through the split cork as shown in Fig. 40.2(a).
3. Clamp the cork firmly to a heavy iron stand and place it on a horizontal table. The pendulum must over-hang the table.
4. Adjust the effective length of the pendulum, *L*, to any desired length (say 1 m). The effective length of pendulum is measured from the point of suspension (the lowest point on the split cork from which the bob suspends freely) to the centre of mass of the pendulum bob (which in the case of a spherical object is at its geometric centre), that is, length CP in Fig. 40.2(a). The length of the pendulum can be increased (or decreased) by pulling down (or up) the thread through the split cork after slightly loosening the grip of the clamp. Note the length of the simple pendulum.
5. Draw two lines on the surface, one parallel to the edge of table (AB) and other perpendicular to it (MN) such that the two intersect at the point O [Fig. 40.2(b)].
6. Adjust the position of the laboratory stand and the height of the clamp such that the point of intersection, O, of lines AB and MN lies exactly below and very close to the centre of bob in its rest or position.
7. Gently hold the pendulum bob P just above the point O. Keeping the thread stretched, displace the bob to either side, say to point X or point Y, along the line AB (the displacement of the bob should be around 10 cm from its mean position so that the angular

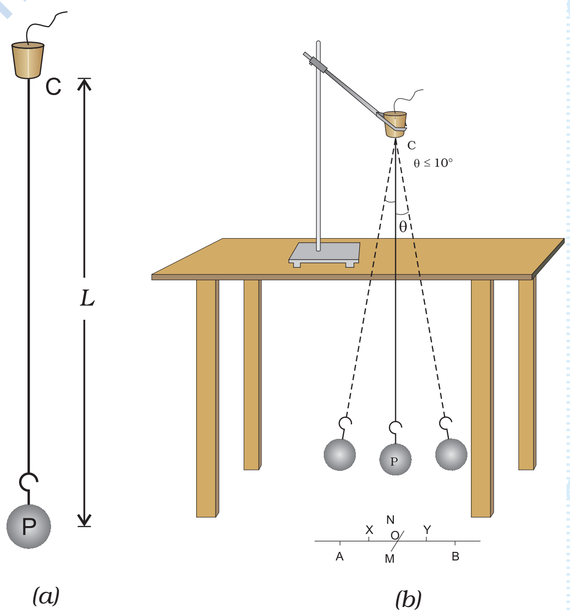


Fig. 40.2 : *(a) A simple pendulum fixed in a split cork; and (b) Experimental set up for studying the variation in the time period of pendulum with a change in its length*

displacement does not exceed 10°). Release the bob so that it begins to oscillate about its mean position. Also check the angular displacement of the bob on the protractor attached at the top of pendulum C, with the clamp.

8. Observe the time taken for appreciable number of oscillations n (say, 10 oscillations) with the help of a stop-watch or stop clock. Record the time taken for n oscillations in the observation table.
9. Bring the pendulum at rest in its mean position. Repeat steps 7 and 8 for the same length (L) of the pendulum and record the time taken.
10. Repeat the activity for different values of pendulum length in either ascending or descending order. Record the observations in observation table.

Observations and Calculations

(i)	Least count of the stop-watch or stop clock	=	___ s
(ii)	Diameter of the pendulum bob, d	=	___ cm
(iii)	Radius of the pendulum bob, $r = d/2$	=	___ cm
(iv)	Number of oscillations, n	=	___
	(Length of the thread + length of hook, if any) l	=	___ cm
(v)	Effective length of the simple pendulum, L (= $l + r$)	=	___ cm
		=	___ m.

Sl. No.	Effective length of the pendulum L = Length of thread + length of hook (if any) + radius of pendulum bob, r		Time taken for n oscillations t	Time period $T = t/n$	Mean time period, T	T^2
	(cm)	(m)	(s)	(s)	(s)	(s^2)
1.						
2.						
3.						
4.						
5.						
6.						

Graph

Plot a graph between the effective length of pendulum, L, and square of mean time period, T^2, taking L along x-axis and T^2 along y-axis. Draw a line to join all the points marked by you with a straight line such that maximum number of points lies on it (Fig. 40.3). Some points may not lie on the straight line graph and may be on either side of it. Extend the straight line backwards to check whether the observed graph passes through the origin.

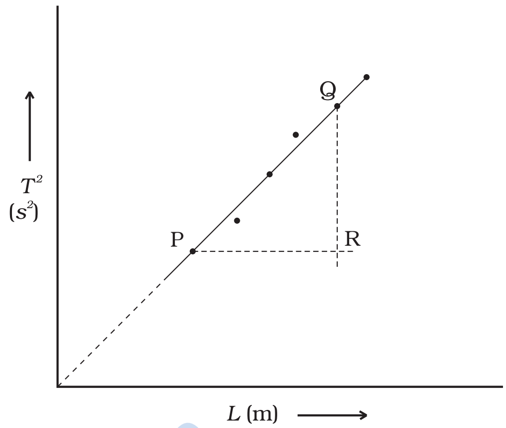


***Fig. 40.3 :** Graph between L and T^2*

Results and Discussion 

The graph between the length of pendulum and square of its time period is a straight line. This means that the time period of a simple pendulum is proportional to the square root of the length of the pendulum.

Precautions 

- Thread used must be thin, light, strong and inextensible. An extension in the thread will increase the effective length of the pendulum. There should be no kink or twist in the thread.
- The pendulum support (laboratory stand) should be rigid.
- The split cork should be clamped keeping its lower face horizontal.
- During oscillations the pendulum should not touch the edge of the table or the surface.
- The displacement of pendulum bob from its mean position must be small.
- The bob must be released from its displaced position very gently and without a push otherwise it may not move along the straight line AB. In case you notice that the oscillations are elliptical or the bob is spinning or jumping up and down, stop the pendulum and displace it again.
- At the place of experiment, no air disturbance should present. Even all the fans must be switched off while recording the observations.
- Counting of oscillations should begin when the bob of the oscillating pendulum passes its mean position.

NOTE FOR THE TEACHER

- To simplify the experiment, values of diameter or radius of the pendulum bob and length of hook may be provided to students.
- Practically the amplitude may decrease in each swing of the pendulum with time. Thus the pendulum will not keep on oscillating for a long time. Therefore counting of the number of oscillations for measuring the time taken should be stopped before the amplitude of oscillation becomes too small. It is therefore advised that number of oscillation (n) for which time is noted should be small (say n = 10).

QUESTIONS

- Define mean position of a simple pendulum.
- The amplitude of an oscillating pendulum keeps on decreasing with time. Suggest the factors responsible for it.
- When you displace a pendulum form its mean position and then release, it executes to-and-fro motion. Why does it happen? Discuss it with your friends and teacher.
- Which pendulum will oscillate for a longer period of time – the one which is oscillating in air or the one which is oscillating in vacuum?
- What will happen if bob of pendulum touches the edge of the table?
- Why should the amplitude be small for simple pendulum experiment?
- While determining the time period of a pendulum, why do we prefer to measure time for about ten oscillations?
- Observe Fig. 40.2(b). Decide the positions where the speed of bob is minimum and maximum. Also discuss the kinetic and potential energies of the pendulum at these points?
- Would the measurements of time period of pendulum be most accurate with a long or short thread?
- What will be the shape of the graph plotted between the total length, (L) and time period (T) of a pendulum?
- Can you imagine a situation in which the time period of a simple pendulum becomes infinite?

Experiment 41

AIM

To study the effect of mass on the time period of a simple pendulum.

THEORY

A simple pendulum consists of a small object of heavy mass, called the pendulum bob, suspended by a light thread from a fixed and rigid support [Fig. 41.1(a)]. When the bob CP is released after taking its free end P slightly to one side (say to point R), it begins to oscillate about its mean position O [Fig. 41.1(b)]. The time taken by the pendulum to complete one oscillation is called its time period. The force responsible for maintaning the oscillations in the simple pendulum is the restoring force which involve mass of the bob. In this experiment we shall study the effect of mass of the pendulum bob on its time period.

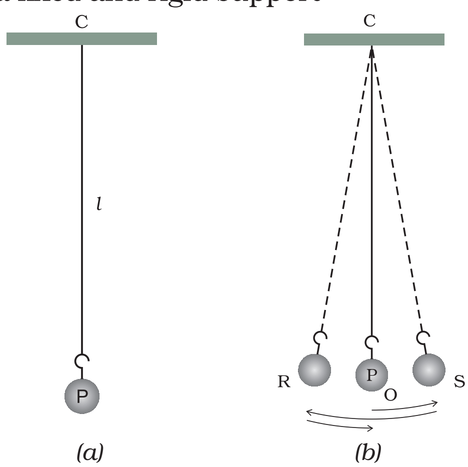


Fig. 41.1 : *(a) A simple pendulum; and (b) Different positions of the bob of an oscillating simple pendulum and a complete oscillation*

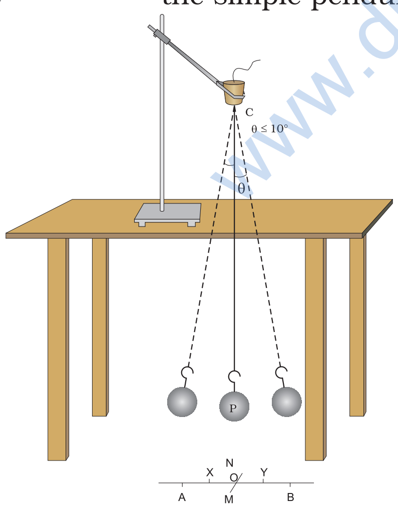
Materials Required

A heavy iron stand, a cork (split along length through middle), an inextensible thread of about 1.5 m length, three different metallic spherical bobs of known masses and diameters. a stop-watch or a stop clock, a large size protractor, and a meter scale.

Procedure

1. Find the least count of the given stop-watch or stop-clock.
2. Tie one end of an inextensible thread of nearly 1.5 m with the metallic bob of first pendulum having mass m_1 and diameter d_1 and pass the other end of thread through the split cork as shown in Fig. 41.2(a).
3. Clamp the cork firmly to a heavy iron stand and place it on a horizontal table. The pendulum must be over-hanging.
4. Adjust the effective length of the pendulum, L, to any desired length (say 1 m). The effective length of pendulum is measured from the point of suspension (the lowest point on the split cork from which the bob suspends freely) to the centre of mass of the pendulum bob (which in the case of a spherical object is at its geometric centre), that is, length CP in Fig. 41.2(a). The length of the pendulum can be increased (or decreased) by pulling down (or up) the thread through the split cork after slightly loosening the grip of the clamp. Keep the length of the simple pendulum fixed through out.
5. Draw two lines on the surface, one parallel to the edge of table (AB) and other perpendicular to it (MN) such that the two intersect at the point O [Fig. 41.2(b)].
6. Adjust the position of the laboratory stand and the height of the clamp such that the point of intersection, O, of lines AB and MN lies exactly below and very close to the centre of bob in its rest or mean position.
7. Gently hold the pendulum bob P just above the point O. Keeping the thread stretched, displace the bob to either side, say to point X or point Y, along the line AB (the displacement of the bob should be around 10 cm from its mean position so that the angular displacement does not exceed 10°). Release the bob so that begins to oscillate about its mean position. Also check the angular displacement of the bob on the protector attached at the top of pendulum C, with the clamp.

(a)



(b)

Fig. 41.2 : *(a) A simple pendulum fixed in a split cork; and (b) Experimental set-up for studying the variation in the time period of pendulum with a change in its mass*

8. Observe the time taken for appreciable number of oscillations n (say, 10 oscillations) with the help of a stop-watch (or stop-clock). Record the time taken for n oscillations in the observation table.
9. Bring the pendulum at rest in its mean position. Repeat step 8 again for the same metallic pendulum bob. Record the total time taken in n oscillations.
10. Replace the metallic pendulum bob of the pendulum with the second bob of known mass (m_2) and diameter (d_2). Using the method given in step 4, adjust the total length of the simple pendulum same, that is L. Repeat steps 8 and 9 to again record the total time taken in completeing n oscillations.
11. Repeat step 10 for the third given metallic bob.

Observations and Calculations

(i) Least count of the stop-watch or stop-clock = ___ s

(ii) Specifications of the three given metallic bobs.

Bob	Mass m (g)	Diameter d (cm)	Radius r (cm)	length of the hook attached, h (cm)
First	m_1 =	d_1 =	r_1 =	h_1 =
Second	m_2 =	d_2 =	r_2 =	h_2 =
Third	m_3 =	d_3 =	r_3 =	h_3 =

(iii) Total length of the simple pendulum, L = length of thread + r + h = ___ cm = ___ m

(iv) Number of oscillations, n = ___ .

Sl. No.	Mass of the bob, m	Length of the thread, l	Total length of the pendulum, $= l + r + h$	Time taken n oscillations, t	Time period $T = t/n$	Mean time period
	(g)	(cm)	(cm)	(s)	(s)	(s)
1.	m_1	—	L	—	—	—
2.			L	—	—	
3.	m_2	—	L	—	—	—
4.			L	—	—	
5.	m_3	—	L	—	—	—
6.			L	—	—	

Results and Discussion

From the observations, infer the effect of the mass of the simple pendulum on its time period. You are likely to see that the time period of a simple pendulum does not depend on its mass. (You will be studying about this independence in detail in higher classes.)

Precautions

- Total length of the simple pendulum must be kept same throughout the experiment.
- Thread used must be strong and inextensible. An extension (which may depend on the mass of the bob) in the thread will increase the effective length of the pendulum. There should be no kink or twist in the thread.
- The pendulum support (laboratory stand) should be rigid.
- The split cork should be clamped keeping its lower face horizontal.
- During oscillations the pendulum should not touch the edge of the table or the surface below.
- The displacement of pendulum bob from its mean position must be small.
- The bob must be released from its displaced position very gently and without a push otherwise it may not move along the straight line AB. In case you notice that the oscillations are elliptical or the bob is spinning, stop the pendulum and displace it again.
- At the place of experiment, no air disturbance should be there. So switch off all fans while taking the observations.
- Counting of oscillations should begin when the bob of the pendulum passes its mean position while it is oscillating.

Note for the Teacher

- In order to avoid unnecessary emphasis on measuring skills, the value of diameters or radii of the pendulum bobs, their masses, and their lengths of hooks may be provided to students. It is not necessary that the metallic bobs are made up same material. These can be different.
- Practically the amplitude may decrease in each swing of the pendulum with time. Thus the pendulum will not keep on oscillating for a long time. Therefore counting of the number of oscillations for measuring the time taken should be stopped before the amplitude of oscillation becomes too small. It is therefore advised that number of oscillation (n) for which time is noted should be small (say $n = 10$).

- The masses of the metallic bobs must not be very large. Otherwise the thread may break. Moreover, the amplitude of the swinging pendulum may die out quickly (friction at the point of suspension of the pendulum!).
- To ensure a constant length is pretty difficult. A small bowl may be used as pendulum bob whose mass may be altered by filling it with different materials.

QUESTIONS

- Does the time period of a simple pendulum depend on the mass of the pendulum bob?
- Does the time period of a simple pendulum depend on the size of the bob? Does it depend on the shape of the bob?
- You are provided with two simple pendulums of same length but of different masses. The two pendulums are displaced by the same amount and then released to oscillate freely about their mean positions. If the air resistance is same for both the simple pendulums, compare their time periods of oscillation?

Experiment 42

AIM

To determine the speed of a transverse pulse propagated through a stretched string.

THEORY

A pulse is a small disturbance in a medium that usually lasts for a short time. The motion of a pulse can be observed on a long stretched string or in a stretched slinky. A pulse can be classified by the direction in which it disturbs the medium. A transverse pulse is a disturbance that moves the medium at the right angles to the direction in which the pulse travels. If the disturbance is in the direction of motion of the pulse then the pulse is longitudinal.

The motion of a transverse pulse can be observed on a long stretched string that is fixed at one end. A hump created at one end of the string by giving it a jerk, is an example of a transverse pulse. A sudden pulse created at the end, held in hand moves, to the other end along the string where it dies out. However, if the string is fixed at both the ends the pulse may reflect back and forth a few times before it dies out [Fig. 42.1(a-g)]. The speed of a pulse along the string can be determined by measuring the time taken T by it to travel through a known length of the string l. The length of the string divided by the time gives the speed of the pulse in the string. That is,

$$v = \frac{l}{T}.$$

MATERIALS REQUIRED

A 10 m long tightly knitted cotton string or rope of about 0.5 cm diameter, a stop-watch or a stop clock, and a meter scale.

PROCEDURE

1. Find the least count of the stop-watch or the stop-clock.
2. Fix one end of the tightly knit cotton string (the type of the one used in skipping) or rope by tying its one end to a door handle or to a window grill or to a hook on a wall. Stretch a known length of the string (say l_1) while holding the other end firmly with your hands. The other end of the string can also be tied to another door handle, or a hook. The string might sag in the middle due to its weight. However, a little sagging do not affect your observations.
3. Give a small transverse horizontal jerk to the string at one end to create a pulse. Let the pulse travel along the string. It may require some practice to create a single pulse that moves smoothly along the string.

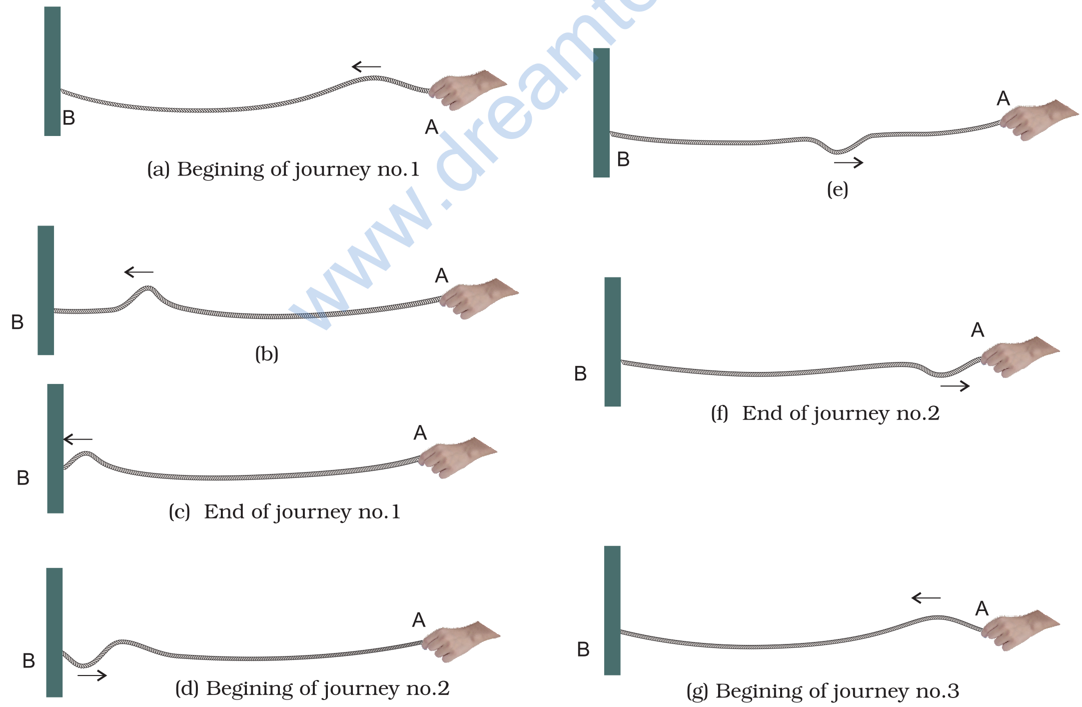


Fig. 42.1(a-g) : *A pulse moves back and forth along a string fixed at both ends before it dies out*

4. Observe the pulse as it moves along the string and note what happens when the pulse reaches at the other end of the string. Does it get reflected back? Does the same phenomena occur when it reaches the end where the pulse originated?
5. Holding one end of the stretched string give it a jerk to create a pulse. Ask one of your friends to switch on the stop-watch or clock as soon as you give a jerk to the stretched string. Measure the time taken by the pulse to make n number of journeys along the entire length of the string between its two ends [Figs. 42.1(a-g)]. This could be possible if the pulse moves back and forth along the string a few times before it dies out. The starting and closing of the stop-watch or stop-clock must be simultaneous with the creation of the pulse and its arrival at the end up to which the measurement are to be taken. Care should also be taken in counting the number of times the pulse travels through the entire length of the string.
6. Repeat the experiment with different lengths of the same string (say l_2 and l_3) by changing the distance between the two ends to which it is tied. Note the time taken by a pulse for making n journeys through different lengths of the string.

Observations and Calculations

(i) Least count of the stop-watch or stop-clock = _____ s

Sl. No.	Length of the string between two ends l (m)	Time taken by the pulse in making n journeys, t (s)	Time taken by the pulse in making one journey, T $(= t/n)$ (s)	Speed of the pulse in string $v = l/T$ (m/s)
1.	l_1 =			v_1 =
2.	l_2 =			v_2 =
3.	l_3 =			v_3 =

Results and Discussion

The speed of pulse in the string at different lengths are given in table above. In this experiment you probably find different values of speeds of the transverse pulse for different values of lengths of the string. Discuss and state the factors which affect the speed of the pulse with your friends and teacher.

PRECAUTIONS

- The string should not be too tight (large tension) when it is tied at the two ends otherwise the velocity of pulse may be high to observe and to measure time of its travel. Some sagging due to the weight of the string is helpful in creating the pulse and observing its motion.
- The string should not be placed on a rigid surface (in contact with) as in such a situation the pulse would die out quickly making observations difficult.
- It must be ensured that no part of the stretched string, except the two ends, touches any surface. Why?
- The string should not have any knots or kinks at any point along its length.
- The counting of pulse journeys must start from zero (and not from one). That is, the creation of pulse and pressing of the knob of stop-watch must be simultaneous.
- The efforts should be made to keep the amplitude of pulse appreciably high so that it can get reflected sufficient number of times from the fixed ends of the string.

NOTE FOR THE TEACHER

- This experiment requires a good amount of practice and therefore should be performed in a group of two or three students.
- Strings or ropes made of jute or plastic or some other material may also be tried instead of cotton.
- This experiment should preferably be performed in a hall or in a gallery.
- In this experiment, the speed of pulse changes for different string lengths. It is suggested that students may try to repeat the observations for the same length of string say l_1. They will probably find different values of speed the pulse. Encourage the students to find the reasoning.
- It is advised that this experiment be performed at a place where external effects such as air are minimal. Switch off the fan while performing this experiment.
- The speed of a pulse (or a wave) in a string is found to be proportional to the square root of tension in the string and inversely proportional to the square root of mass per unit length of the string. In order to keep the time measurements recordable, it is suggested to make a judicious choice of the string and of stretching it.

QUESTIONS

- What is the difference between a pulse and a wave?
- State the nature of pulse generated in a stretched string. Is it transverse or longitudinal? Can a longitudinal pulse be generated in a string or a thread (an amateur's telephone!)?
- Why we prefer a longer string to perform the above experiment?
- In this experiment, you must have noticed that while expressing the result for the speed of a pulse in a string, it is not suggested to take the average value of speeds determined with different lengths of the string. Why?

Experiment 43

AIM

To determine the speed of a longitudinal pulse propagated through a stretched slinky.

THEORY

A pulse is a small disturbance in a medium that usually lasts for a short time. The motion of a pulse can be observed on a long stretched string or in a stretched slinky. A pulse can be classified by the direction in which it disturbs the medium. A longitudinal pulse is a disturbance that causes the particles of the medium oscillate parallel to the direction of motion of the pulse. If the disturbance moves the particles of the medium at the right angles to the direction of motion of the pulse then the pulse is transverse.

A longitudinal pulse can be created in a metallic slinky if the slinky is stretched out in a horizontal direction and the first few coils of the slinky are compressed and then released horizontally. In such a case, each individual coil of the medium (slinky) is set into vibrational motion in directions parallel to the direction of motion of the pulse. A traveling longitudinal pulse in a slinky is composed of *compression*, where the parts of the medium (coils of the Slinky) are closer together

Fig. 43.1 : *A longitudinal pulse in a metallic slinky*

than normal, or *rarefaction*, where the parts of the medium are farther apart than normal. The compression or rarefaction (pulse) travel along the length of the slinky. If the two ends of the stretched slinky are rigidly fixed, the pulse may reflect back and forth a few times before it dies out. The speed of the pulse in the metallic slinky can be determined by measuring the time taken (T) by the pulse to travel through a '*known length*' (l) of the stretched slinky. The speed of the pulse v is

$$v = \frac{l}{T}$$

Materials Required

A long metal slinky, an inextensible thread, a meter scale (or a measuring tape), and a stop-watch or a stop-clock.

Procedure

1. Find the least count of the given stop-watch (or the slop clock).
2. Fix one end of the metal slinky to a rigid support such as a door handle, or a window grill or a hook on a wall.
3. Firmly hold the other end of the slinky and stretch it to a known length l_1 (Fig. 43.2). Stretch the slinky until its coils are nearly 1 cm apart. The slinky might sag in the middle due to its weight. However, a little sagging may not effect the observations. Here the known length of the slinky means the length of the stretched-sagged slinky

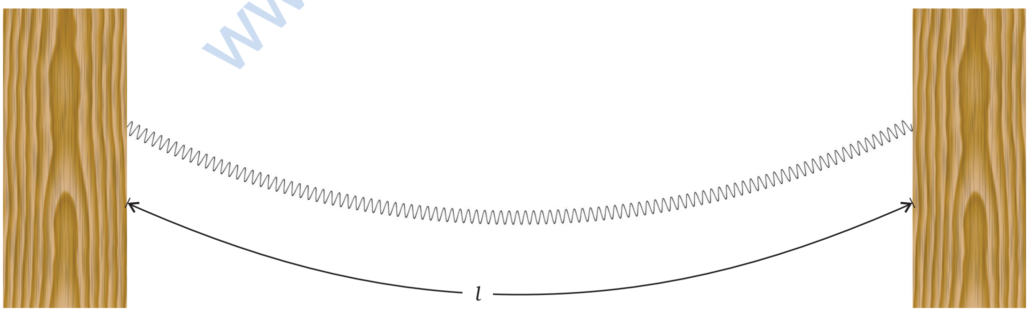


Fig. 43.2 : *A stretched slinky of known length l*

as shown in Fig. 43.2. For measuring this length use a measuring tape along the sagged path of the stretched spring. You can alternatively use a thread and meter scale to measure the length l of the stretched slinky.

4. What do you observe? The slinky is vibrating! Allow the slinky to come to rest and stable position. For this the purpose ask your friend to gently hold the stretched slinky somewhere in between for some time. This will help the slinky to come to rest quickly.
5. At the end where you are holding the slinky, gather a few slinky coils towards you. Quickly release them. Observe the direction in which the pulse move and the direction in which the coils of the stretched

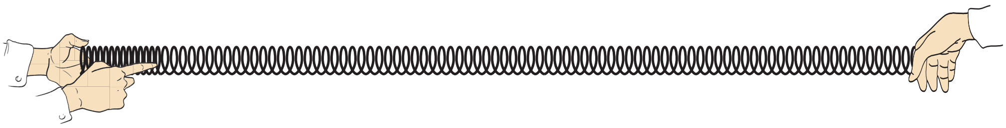


Fig. 43.3 : *Formation of a longitudinal pulse in a slinky*

slinky (the medium) move. Are the two motions in the same direction? Is the pulse a transverse or longitudinal?
6. In this case the slinky coils do not move at right angles to the direction of the disturbance. The coils rather bunch up in an area and the bunch appears to move forward in the slinky. The slinky coils move back and forth. Thus the pulse created is longitudinal (Fig. 43.3).

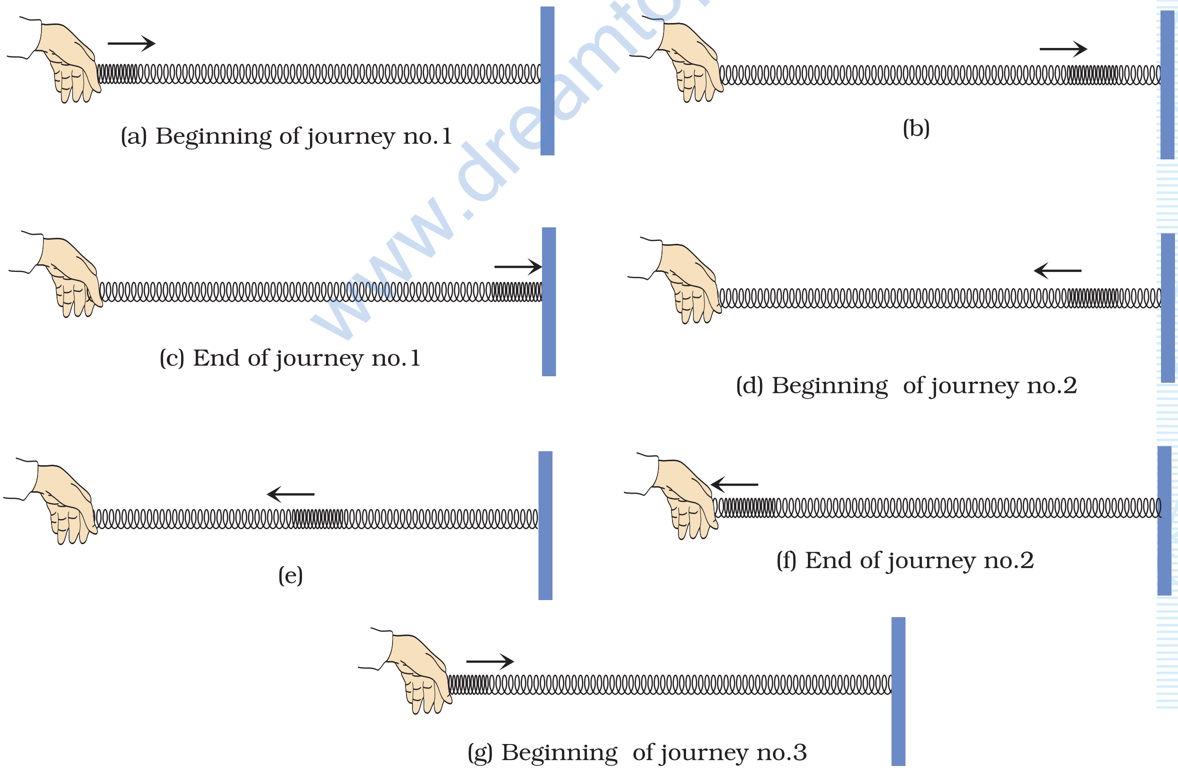


Fig. 43.4 (a-g) : *A longitudinal pulse moves back and forth along a slinky fixed at both ends before it dies out*

7. Again bring the slinky to rest as done in step 4.
8. Holding one end of the stretched slinky gather a few slinky coils towards you and quickly release them. Ask one of your friends to be ready to switch on the stop watch simultaneously as you release the coils. Measure the time taken by the pulse to make n number of journeys along the entire slinky between its two ends as shown in Fig. 43.4(a–g). This could be possible if the created pulse moves back and forth in the slinky a few times before it dies out. The starting and closing of the stop watch or clock must be simultaneous with the creation and its arrival at the end up to which the measurements are to be taken (after n number of journeys). Care should also be taken in counting the number of times the pulse travels through the entire length l_1 of the stretched slinky.

   In fact your fingers holding one end of the stretched slinky can also very well feel the pulse reflections reaching after completing two, four, six, eight, ... journeys in the slinky. Every time the pulse reaches your fingers exerts a pressure on your fingers.
9. Repeat the experiment with different lengths of the same slinky, say l_2 and l_3. For this you may change the position of your hand holding one end of the slinky (or changing your position) while keeping the other end fixed at the same place. Record your observations in the table.

Observations and Calculations

Least count of the stop watch or clock = _______ s.

Sl. No.	Length of the stretched slinky between two ends, l	Time taken by the pulse making n journeys, t	Time taken by the puse in making 1 journey, $T = t/n$	Speed of the pulse in the slinky, v $v = l/T$
	(m)	(s)	(s)	(m s^{-1})
1.	l_1 =			v_1 =
2.	l_2 =			v_2 =
3.	l_3 =			v_3 =

Results and Discussion

The speed of the longitudinal pulse in the stretched slinky at different lengths are given in the table above.

In this experiment you probably find different values of speed of a longitudinal pulse for different values of known lengths of the stretched slinky. Discuss and state the factors which affect the speed of the pulse with your friends and teacher.

PRECAUTIONS

- Do not over-stretch the slinky while performing this experiment. Over-stretching of the slinky will destroy its spring nature.
- It must be ensured that no part of the stretched slinky touches surface. Why? Any contact of coils of the stretched slinky with any surface leads to the absorption of pulse energy in the medium in contact and you may not be able to observe appreciable number of pulse journeys in the slinky.
- While creating the longitudinal pulse in the slinky, the release of compressed slinky coils must be gentle and quick. No force must be applied on the slinky while releasing the gathered coils.
- The slinky should not have any knot or any kink at any point along its length. The slinky coils must also not be entangled.
- At the time of creation of the pulse the counting must start from zero and the stop watch should be started at the same time.
- The efforts should be made to keep the amplitude of the pulse appreciably large so that it can get reflected sufficient number of time at the fixed ends of the slinky. By trial one can find the amplitude that produces best result.

NOTE FOR THE TEACHER

- This experiment requires a good amount of practice and therefore should be performed in a group of two or three students.
- In this experiment, a metallic slinky is suggested to use. However this experiment may also be performed with a plastic slinky. But you may not be able to observe (or feel) the persistence of the pulse in the slinky for appreciable time.
- It is advised that this experiment be performed at a place where external effects such as air, are minimal. (Switch off the fan while performing the experiment.)
- The speed of a longitudinal pulse in the stretched slinky is sufficiently high to measure the time taken by the pulse in a single journey. It is therefore advised to take the number of journeys for the measurement of time as large as possible.

- If the set-up of this experiment has a larger amount of sagging in the slinky, the slinky may be provided a few supports with the help of light threads as shown in Fig. 43.5.

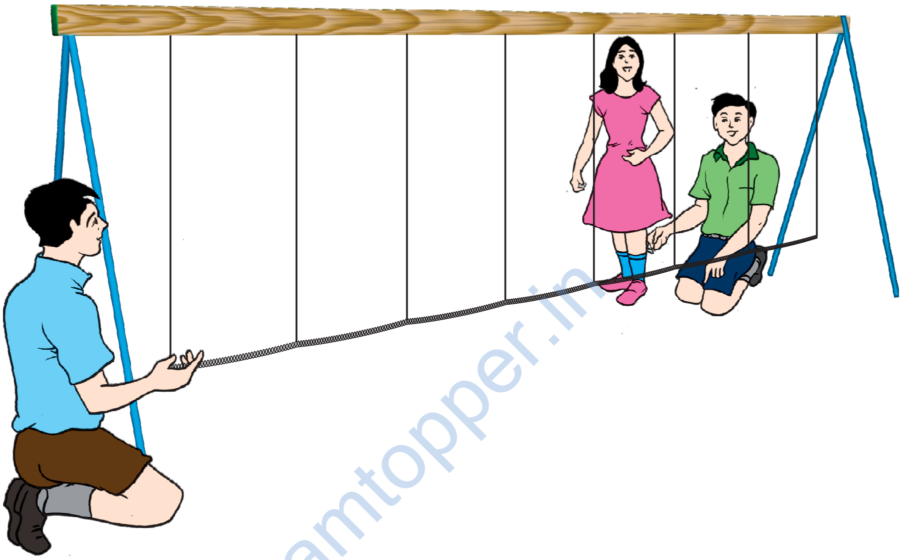


Fig. 43.5 : *A large slinky is supported with several elastic threads*

QUESTIONS

- In this experiment you are suggested to find the least count of the stop-watch or the stop-clock. At the same time you are also using a meter scale or a measuring tape. But you are not suggested to find the least count of this length measuring equipment. Why?
- Why the release of gathered slinky coils be quick at the time of creation of a longitudinal pulse in the slinky?
- How a longitudinal pulse travels in a slinky?
- Why should you take a long slinky in this experiment?
- What will happen if the middle portion of the stretched slinky touches a surface while a longitudinal pulse is traveling through it?
- While creating a longitudinal pulse in the slinky instead of quickly and gently releasing the gathered coils, a student happens to move his hand, holding one end of the slinky, sideways. What kind of pulse will be created in the slinky? Explain your answer.

- In this experiment you probably find different values of speed of a longitudinal pulse for different values of lengths of the stretched slinky. Why?
- Why do we measure time for larger number of pulse journeys in the stretched slinky in this experiment?

Experiment 44

AIM

To study the reflection of sound.

THEORY

Sound is reflected following the same laws as followed by light rays. That is, the reflected ray lies in the same plane of incidence (in which the incident ray and normal to the reflecting surface at the point of incidence lies), and the angle of reflection (∠*r*) is equal to the angle of incidence (∠*i*).

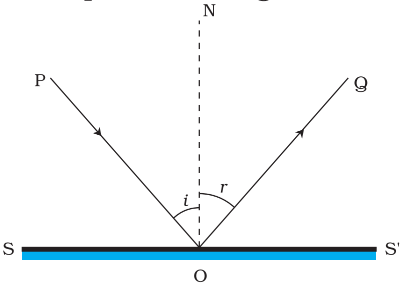


Fig. 44.1 : *Reflection of sound*

MATERIALS REQUIRED

Two identical plastic pipes of length approximately 1 m and of diameter approximately 10 cm or less, a protractor (preferably of big size), a meter scale, and a source of low-amplitude sound such as a table-clock.

PROCEDURE

1. In this experiment, you are required to hear very low-amplitude sound waves, it is therefore important to have a peaceful atmosphere. To hear such sounds clearly, it is further advised to put the fan off.
2. Using a chalk piece or a pencil, draw a line ON on the table (as shown in Fig. 44.2) normal to the wall surface.
3. Now draw a line OC making an $\angle i_1$ (say 30°) with the line ON.
4. Put one of the two plastic pipes (say PQ) along this line OC such that the end P of the plastic pipe is very close to point O on the wall. Now the axis of pipe PQ lies over the line OC (Fig. 44.2).
5. Now put the second plastic pipe RS on the table, keeping its end R towards the wall on the other side of the normal ON. Mark the position of end R on the table.
6. Keep the table-clock close to the open end Q of pipe PQ.
7. Bring your ear close to the end S of pipe RS. Try to hear the sound of the table-clock through this pipe. Do you hear any sound? Keeping the position of the end R, adjust the position of pipe RS on the table to hear the sound of the table-clock. Mark the position of end S of the pipe RS where you hear the maximum sound.

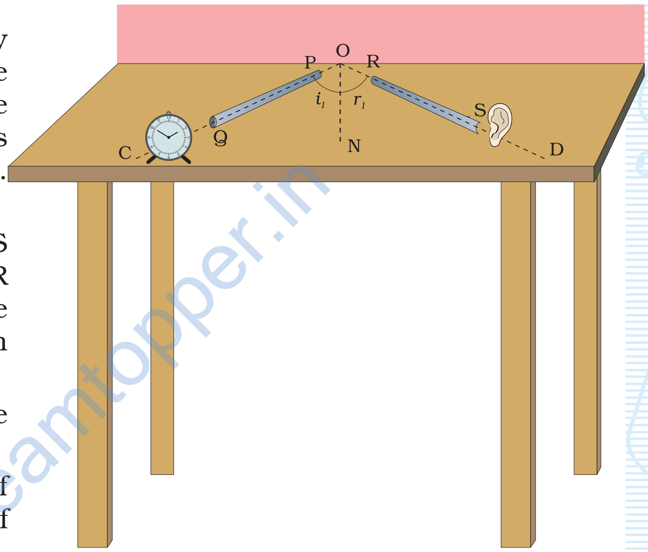


Fig. 44.2 : *The experimental set-up*

8. Draw a line OD joining the point O on the wall, the point representing the position of end R, and the point representing the position of end S.
9. Measure $\angle$NOD. This is the angle of reflection (say $\angle r_1$) for angle of incidence $\angle i_1$. Record observations.
10. Keeping the position of the end R fixed, lift the end S of pipe RS vertically to a small height. Are you able to hear the sound of the table-clock through the pipe RS? If yes, lift end S pipe vertically to some more height. Do you still hear any sound? You will observe that on raising the height of end S, the sound of the table-clock either weakens or completely diminishes.
11. Repeat step 2 onwards for three different values of angle of incidence $\angle i$ and find the corresponding values of angle of reflection $\angle r$.

12. You might have drawn several lines on the table. As courtesy to the students coming to perform this experiment next, it is advised to remove all the lines drawn on the table.

Observations and Calculations

Sl. No.	Angle of incidence, $\angle i$ (°)	Angle of reflection, $\angle r$ (°)	$\angle i \sim \angle r$ (°)
1.			
2.			
3.			
4.			

Results and Discussion

1. The angle of reflection is equal to angle of incidence in all cases.
2. When the pipe through which the sound is heard, is lifted vertically the sound of the table-clock is either weakened or diminishes completely. It shows that the reflected ray lies in the same plane of incidence.

   These observations verify that the sound reflects at the surface of a solid and follows the same laws of reflection as in case of light. In case if your observations are different from what are expected, discuss the reasons.

Precautions

- It is obvious that to hear a clear reflected sound, the incident sound must be clear and smooth.
- When sound falls on any surface, it is not only reflected but a part of it is also absorbed by the surface of the wall. Hence the sound that you hear through the pipe depends on the nature of the wall. For a smooth reflecting wall, the reflection will be more. It is thus important to have a smooth reflecting surface.
- If we take a larger-amplitude sound source, then you may hear the sound of the source directly (that is the waves coming reaching directly to your ear and not after traveling through pipe QP, reflection from the wall, and through the pipe RS). It is therefore important to have low-amplitude sound source. And for the reasons mentioned here, it is advised to close your other ear while taking observations.
- In this experiment it is assumed that the table-clock produces a ray of sound that is incident on the wall along the path QPO and reflected

along the path ORSD (Fig. P44.2). That is, the sound source is directional. In reality it is not so. Because of unwanted sound, it is advised to take the pipes of larger length and smaller diameter.

- Measurements of angles should be done taking the axis of the pipes as incident and reflected rays. Take utmost care and precaution in placing the two pipes and in drawing the lines OC and OD.
- Since you are dealing with relatively larger dimensions, it is suggested to use a bigger protractor to measure angles

NOTE FOR THE TEACHER

- In this experiment, two identical plastic pipes are recommended to use. In case plastic pipes are not available, pipes can be prepared using chart papers or news papers.
- In order to absorb all unwanted sound rays (as explained in point 4 in the Precautions and Sources of Errors), the inner surfaces of the two pipes may be painted black and kept rough. In case of plastic pipes, a layer of news papers may be inserted into these pipes. A rough paper is a good absorber of sound. This way the sound reaching to the ear of an observer will become clear and distinct.
- In place of a table-clock, a mobile phone may also be used in its vibratory mode. Some other sources of low-amplitude sound may also be explored and used.
- A cardboard (or a wooden partition) along the normal ON may help to avoid direct sound from the source.

QUESTIONS

- While performing this experiment why do we prefer to use pipes of larger length but of smaller diameter?
- How the experiment of reflection of sound is different from the experiment on laws of reflection of light?
- Which sheet will you choose as sound reflecting surface for this experiment: (a) a smooth wooden board, or (b) a thermo-cole sheet. Why?
- Suppose the whole experimental set up of this experiment is submerged in water. What changes do you expect in observations?
- Why do we require a low-amplitude sound source in this experiment?
- What alterations can be made in the pipes to make the reflected sound more distinct and clear?