EXPERIMENT

AIM

Using a simple pendulum, to plot L−T² graphs and hence find the effective length of seconds pendulum using appropriate graph.

MATERIAL REQUIRED

A spherical metallic bob with hook on top, a fine, light weighted inelastic string, stopwatch, clamp stand, split cork, Vernier calipers, scale and chalk etc.

DIAGRAM

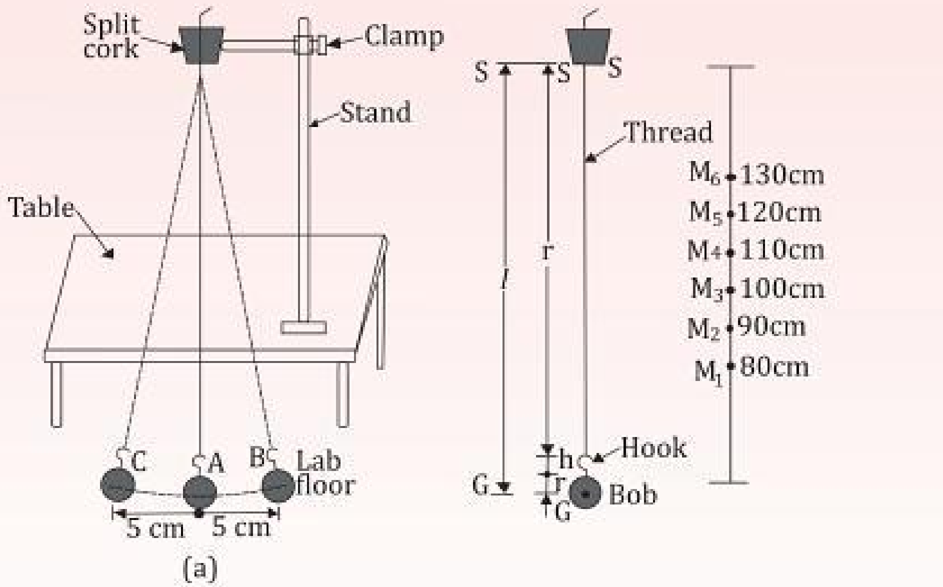


Fig. (a) Simple pendulum (b) Effective length of a simple pendulum
(c) Marks on thread $l = l' + h + r$

THEORY

A simple pendulum is a system in which a point mass (bob) is suspended from a virtually massless, inextensible string or rod. The practical definition involves a heavy brass bob with a radius (r) significantly smaller than the suspension length, connected by a thin, sturdy cotton thread to a rigid support.

The amplitude of a simple pendulum refers to the maximum displacement from its mean position to the furthest point. Oscillation is the bob's movement from one extreme to the other and back to the initial extreme, completing one full oscillation.

The frequency of a simple pendulum, measured in seconds^{-1} or Hertz (Hz), is the number of complete oscillations the bob performs in one second. The effective length of a simple pendulum is the overall length

(L) from the suspension point to the center of gravity of the metallic bob. This is mathematically expressed as,

$$L = l + r + e$$

Where, l is the length of the thread, r is the radius of the metallic bob, and e is the length of the hook.
A second's pendulum is characterized by a time period of two seconds, signifying that it precisely takes one second to move from one extreme position to another.
A simple pendulum exhibits Simple Harmonic Motion (SHM) because the acceleration of the bob is directly proportional to its displacement from the mean position at any given instant, directed towards the mean position. The time taken to complete one full oscillation is termed the time period of a simple pendulum.

PROCEDURE

1. Find the vernier constant and zero error of the given vernier calipers. Obtain the diameter of the given metallic bob and calculate its radius.
2. Using a meter scale, note the length of the hook.
3. Take the string and tie its one end firmly to the bob hook. From this point, measure the length on the string and mark a fine ink spot, such that the effective length of the pendulum sums to 80 cm. Mark such ink spots at effective length 90 cm, 100 cm, 110 cm, 120 cm, 130 cm, 140 cm and 150 cm.
4. Place the stand on a short table or stool. Adjust the position of the clamp and fix the pendulum string into the split cork tightly at mark on the string.
5. Make sure that the pendulum bob is suspended very close to the ground.
6. Wait for pendulum to come at rest. Mark the mean position on the ground under the pendulum with the help of a chalk/marker.
7. To make the point at effective length of, say, we must measure length of string from point of trying to the hook as, (length of hook + radius of bob).
8. Check the least count of the stopwatch and note if any zero error exists.
9. Gently displace the pendulum bob to the side and release it. Make sure not to displace the bob to a large distance from mean position. The pendulum starts oscillating.
10. In case the pendulum exhibits spinning, let it come to rest and repeat Step 8.
11. As the bob reaches the mean position, immediately start the stopwatch.
12. Count 20 complete oscillations of the pendulum. As soon as the 20 the oscillation ends and pendulum bob reaches the mean position, immediately stop the stopwatch.
13. Note the reading of stopwatch and correct the observation by treating with zero error, if required.
14. Repeat steps numbered 4 to 12 for effective pendulum lengths, by successive ink spots on the thread. as marked.
15. Obtain the time period of oscillations in each case by dividing the total time by the number of oscillations, i.e., 20.
16. Obtain the value of T^2 in each case.
17. Plot graph for the observations. Use $L-T^2$ graph to determine the value of L, corresponding to which $T^2 = 45$, i.e., the length of seconds pendulum.

OBSERVATIONS

Vernier caliper:

Vernier constant = _______ mm.

Zero error = ______ mm.

Pendulum bob

S. No.	Observed diameter(cm)	Corrected diameter(cm)	Radius(cm)
1.			
2.			
3.			

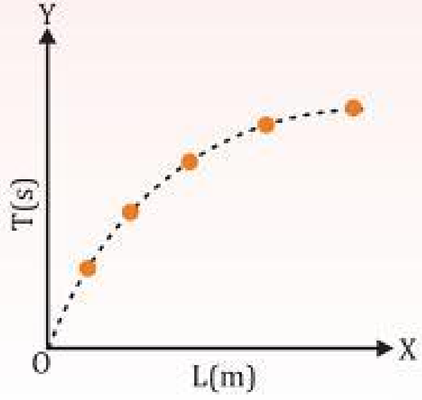
Hook length of pendulum = ________ cm.
Mean radius = ________________ s.
Stopwatch: Least count = _________ s.
Zero error = __________________ s.

S. No.	Effective pendulum length (L) (cm)	Time taken for 20 oscillations	$T = \frac{t}{20}$ s	T^2 (s^2)
1.				
2.				
3.				
4.				
5.				
6.				
7.				

CALCULATIONS

i. L versus T graph

Draw a graph L versus T with the help of readings in the above observation table. Take the length of the simple pendulum L along the X-axis and the time period along the Y-axis. As a result, you will get a curve (a part of the parabola).



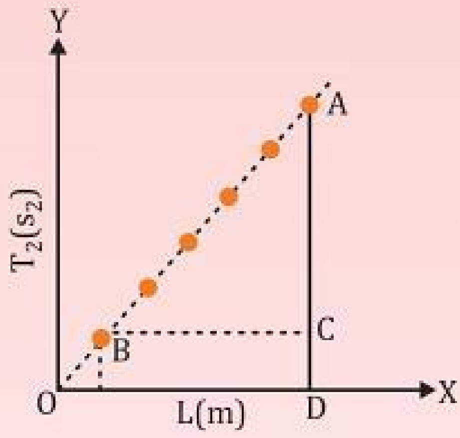
Graph of L versus T

ii. L versus T^2 graph

Draw a graph L versus T^2 with the help of readings in the observation table. Take the length of the simple pendulum L along the X-axis and the time period along the Y-axis. As a result, you will get a straight line passing through the origin.

From the L versus T^2 graph, locate the effective length of second's pendulum for $T^2 = 4s^2$

[For second pendulum, T = 2s]



Graph of L versus T_2

NOTE: The moment you will get the straight line from the L versus T^2 graph, calculate its slope, its value should be either equal to the value of g or near to g. So, when you will get the same, then don't waste your time anywhere else, continue with your next required step while performing the experiment.

RESULT

1. L−T graph is a parabola while L−T^2 graph is a straight-line graph.
2. Effective length of second's pendulum from the graph = ______ cm.
3. The measurements obtained using a vernier caliper might lack precision.
4. The laboratory fan could be activated during the experiment, causing disturbances in the air.
5. The accuracy of the stopwatch may be questionable.
6. The thread used may have the property of being stretchable.
7. The meter scale might lack precision in its measurements.
8. The stand's base may not have sufficient weight.
9. Errors may arise from delays in initiating and concluding the stopwatch.

PRECAUTIONS

1. The thread should have negligible weight and should be inelastic.
2. The clamp stand must be rigid, and the thread should be so tightly clamped that it does not slip or move during oscillations.
3. The pendulum should not swing during its oscillation.
4. Only small displacement should be given to the pendulum to make it oscillate.
5. The pendulum bob should be held very close to the ground, but not touching the ground.
6. Fans and windows of the room should be closed, to avoid any air currents disturbing the oscillations.
7. The stopwatch should be started and stopped instantly when required. Any time lag in doing so may result in unexpected results.
8. The pendulum should oscillate in a plane perpendicular to that of the split of the cork.

SOURCES OF ERROR

1. The thread is not completely weightless. So, the center of mass of the pendulum does not lie exactly at its center, but slightly above it.
2. Greater reaction time is taken by the observer to start/stopwatch results in an experimental error.
3. Some air currents are always present in the room which affect the oscillations.

VIVA VOCE

Q1. Which pendulum is independent of the change in the value of acceleration due to gravity?

Ans. A spring pendulum that works on inertia and elasticity, has no effect on its time due to the change in the value of g.

Q2. What do you think, what can be the reason of decreasing amplitude of the oscillating pendulum?

Ans. When the pendulum oscillates, then it is only the air resistance due to which a part of energy is lost in every oscillation. In the result of this, the oscillations die out slowly.

Q3. What is a ticker-tape timer?

Ans. It is a time-measuring device that can measure the time intervals of the order of $\frac{1}{5}$th or $\frac{1}{100}$ of a second.

Q4. Define the effective length of the simple pendulum.

Ans. The distance between the point of suspension of the pendulum and its center of gravity is called the effective length of simple pendulum.

Q5. What is the reason for keeping the small amplitude of oscillation?

Ans. Since, while deriving the expression for the time period of simple pendulum, we always consider. $\sin\theta = \theta$ So, it is possible only when, θ is small. So, this is the reason for keeping the small amplitude of oscillation.

Q6. What effect can be observed if the same experiment is performed on the moon?

Ans. The increase in time will be observed. As we know, the value of acceleration due to gravity on the moon is less than that on earth. Moreover, the value of on the moon is $\frac{1}{6^{th}}$ of that on earth i.e.,

$$g_m = \ g_e\sqrt{6}$$

Also, time of a simple pendulum,

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Which shows that the time is inversely proportional to the acceleration due to gravity.

Q7. Why is a massless and inextensible string usually preferred while performing the experiment?

Ans. Since it is very difficult to obtain an ideal simple pendulum or perfect experimental setup. So, to achieve this, a massless and inextensible string is preferred.

Q8. How can you define a simple pendulum?

Ans. An ideal pendulum which consists of a heavy point mass (can be a bob) tied to one end of a perfectly inextensible, weightless thread suspended from a solid support is called simple pendulum.