To Study Dissipation of Energy of a Simple Pendulum by Plotting a Graph Between Square of Amplitude and Time

Aim

To study dissipation of energy of a simple pendulum by plotting a graph between square of amplitude and time.

Apparatus

A pendulum bob, a split cork, thread, metre scale, a clamp stand, stop watch, and chalk piece.

Theory

If a body executes S.H.M., the force F acting on the body is always directly proportional to the displacement x, i.e.,

$$F \propto x$$

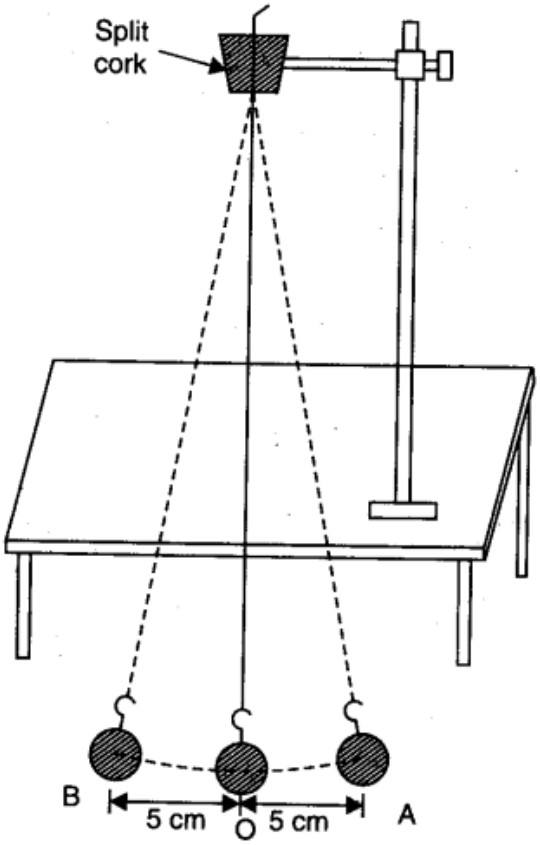
$$F = -kx$$

where k is a constant called force constant (spring constant). Negative sign represents the direction of F toward the mean position.

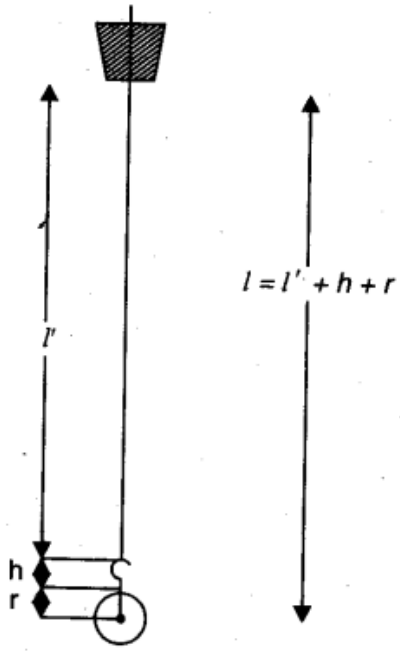
Force constant k for a pendulum $= \frac{mg}{l}$. The potential energy stored in the bob of simple pendulum for the maximum displacement A_0 at its extreme position is

$$E = \frac{1}{2} k A_0^2$$

Diagram



(a) Set-up of dissipation of energy of an oscillating simple pendulum.



(b) Effective length of the pendulum

When the bob of simple pendulum oscillates, its amplitude decreases and hence its energy also decreases. The energy dissipates due to the damping force (such as air resistance etc.) experienced by the bob of the pendulum.

The maximum energy E_0 at the maximum amplitude A_0 can be given as

$$E_0 = \frac{1}{2} k A_0^2$$

where

$$k = \frac{mg}{l}$$

Procedure

1. Determine mass m of the bob with the help of physical balance.
2. Take a cotton thread of about 150 cm long, tie the bob to one end of the thread and pass the other end of the thread through the split cork so that the effective length of the pendulum is 130 cm, (effective length of the pendulum is equal to radius of the bob + length of the hook of the bob-pendulum + length of the thread) as shown in diagram. Tight the two half cork pieces between the clamp.
3. Now put the stand on the table in such a manner so that the bob is about 1 to 2 cm above the ground.
4. Put a metre scale just below the bob so that a full scale division lies below the centre of the bob'.
5. Take the bob along the metre scale 5 cm away from the rest position (mean position) of the bob and release it. The bob starts vibrating about the mean position O and you will observe that its amplitude decreases as the time passes.
6. Take the bob to its mean position O (stop position). Find out the least count of the stopwatch.
7. Again take the bob along the metre scale 5 cm away from the rest position O and release it so that it vibrates in the same vertical plane.
8. Watch the moment of the bob, when it comes to the extreme right position, start the stopwatch and also note the position of the bob on the metre scale and record this time as zero.
9. Keep your eye on the movement of the bob continuously and observe the amplitude of the bob and record time simultaneously after every alternate oscillation, i.e., 0,2,4, 6,…….oscillations till the amplitude decays to about 1 cm.
10. Take 10 observations.
11. Record all the observations in the table.
12. Plot a graph between amplitude square, i.e., A_0^2 and time (t), taking alongX-axis and A_0^2 along F-axis.

Observations

Mass of the bob by physical balance = ... g = ... $\times 10^{-3}$ kg.

Least count of the stopwatch = ... s.

Effective length of the pendulum l = ... cm = ... m

Force constant $k = \frac{mg}{l}$ = ... N m^{-1}

(Take the value of $g = 9.8$ m s^{-2})

Table for the dissipation of energy

S. No.	Amplitude A		A^2		Time t (sec)	$E = 1/2\ kA^2$ E_0 = (Joule)	Energy dissipation $E = (E_0 - E)$ Joule
	(cm)	(m)	(cm^2)	(m^2)			
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Result

The graph plotted between square of the amplitude and time is shown below. The graph

shows the dissipation of energy of simple pendulum with time.

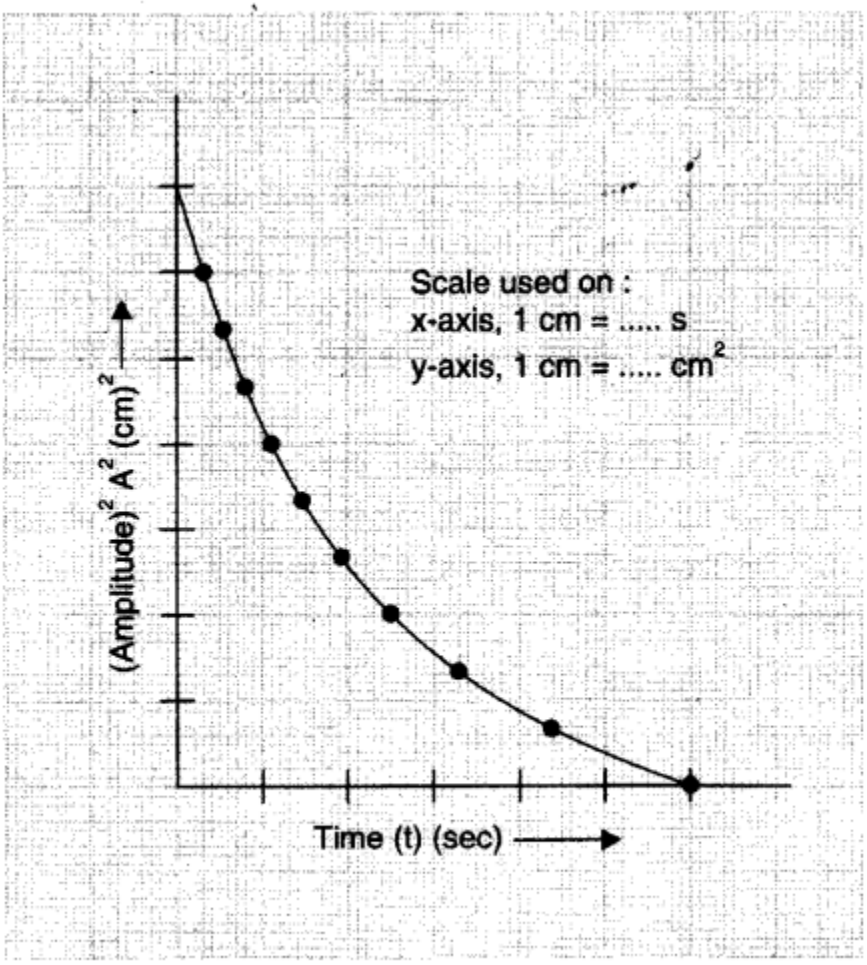


Fig. The variation of A^2 with t.

Conclusion

We know that the energy E of a simple pendulum is directly proportional to the square of the amplitude A^2 $\left(E = \frac{1}{2} k A_0^2 \right)$, and we observed that amplitude decays with passage of time and hence the energy of pendulum dissipates with time.

Precautions

1. Pendulum support should be rigid.
2. The amplitude should remain small.
3. Pendulum should be sufficiently long (about 2 metres).
4. Pulling string should be used to avoid spinning of the metallic block.

5. Paper tape should be attached to the centre of the bottom of the block.

Source of errors

1. The support may not be fully rigid.
2. Movement of metallic block may not be proper.