Experiment 3

Study of Small Oscillations using a Bar Pendulum

Apparatus:

A bar pendulum with holes for hanging, Wall support for hanging, stop clock, meter scale, knife edge for measuring the center of mass of the bar.

Purpose of experiment:

To measure the acceleration due to gravity (g) by small oscillations of a bar pendulum.

Theory

The period of oscillations T of a body constrained to rotate about a horizontal axis for small amplitudes is given by the expression

$$T = 2\pi\left(\frac{I}{mgd}\right)^{\frac{1}{2}} \quad (1)$$

where m is mass of the body , d is the distance between center of mass (CM) and the axis of rotation and I is the moment of inertia (MI) about the axis of rotation given by (from parallel axis theorem)

$$I = I_0 + md^2 \quad (2)$$

where, I_o is the moment of inertia about parallel axis through center of mass .
If k is the radius of gyration (i.e. $I_0 = mk^2$). Then from eqs (1) and (2)

$$T^2 d = \frac{4\pi^2}{g}\left(k^2 + d^2\right) \quad (3)$$

By recording the period of oscillations T as a function d we can determine the values of gravitational acceleration g as well as moment of inertia I_o of the body . The plot of T Vs d , shows a minimum time period at $d= K$,given by

$$T_{\min} = 2\pi\left(\frac{2k}{g}\right)^{\frac{1}{2}} \quad (4)$$

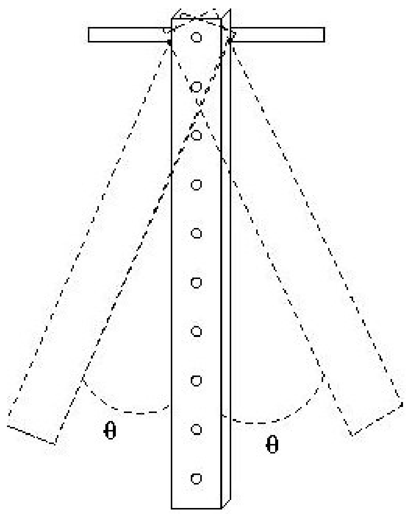

Fig.1 Bar Pendulum

Experimental Set-Up

In this experiment the rigid body consists of a rectangular mild steel bar with a series of holes drilled at regular interval to facilitate the suspension at various points along its length (see Fig.1). The steel bar can be made to rest on screw type knife-edge fixed on the wall to ensure the oscillations in a vertical plane freely. The oscillations can be monitored accurately using a telescope. The radius of gyration for this bar is

$$k^2 = \frac{l^2 + b^2}{12} \quad (5)$$

where l & b are the length & breath of the bar respectively.

Experimental Procedure:

1. Determine the center of mass (CM) by balancing the bar on a knife-edge. Measurement of d is made from this point to the point of suspension for each hole.

2. Suspend the bar by means of knife-edge.

3. Focus the telescope on to the marker marked on the pendulum. There should not be any parallax between the image of the marker and the cross wire in the eyepiece of the telescope.

4. Measure the time for 10 to 20 oscillations for different d (only on one side of CM). Repeat each observation several times.

Plot T Vs d. Calculate k and g from this graph.

Plot $T^2 d$ Vs d^2. Using linear regression technique fit the data and determines k and g from it.

Estimate maximum possible error in g.

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Observations and Results

Least count of the measuring scale used = ………………….
Least count of the stop watch used = ………………….

Table I

S. No.	Distance from CM of axis (d) in cm	No. of oscillations (n)	Time period for n oscillations (Tn)	Time period (T) for 1 oscillation (Tn/n)	T^2d	d^2
1 (i)						
(ii)						
(iii)						
2 (i)						
(ii)						
(iii)						
3						
4						
5						
6						
7						
8						
9						

Calculation:

T_{min} from the graph =….at d=……

At T_{min} , d=k=…

$T_{min}=2\pi\sqrt{\frac{2k}{g}}$, so, g =…….

From the plot of T^2d vs. d^2 , find the slope and intercept from linear regression.

From the Slope $(4\pi^2/g)$, g can be calculated and from the intercept $[(4\pi^2/g)k^2]$, k can be calculated.

k can be calculated using the formula $\left(\frac{l^2+b^2}{12}\right)^{1/2}$ and compared with the value derived from the graph. Why are the two k values different?

Results:

'g' value from T vs. d plot is ……
'g' value from T^2d vs. d^2 plot is …….
Average value of 'g' = …..

(Two graph papers required).

References:

1. Haliday, Resnick and Walker, "Fundamentals of Physics", 6th Ed. (John Wiley, Singapore, 2001), Chap. 16.