**Experiment 5: Compound Pendulum**

**OBJECTIVE:**

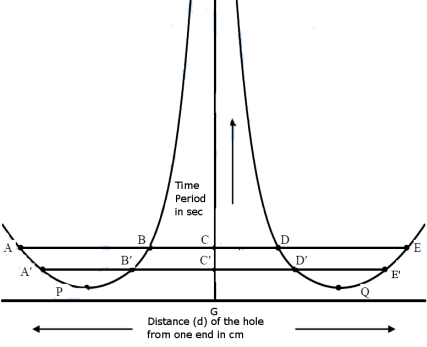
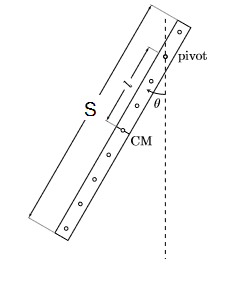
1. To determine the, the acceleration due to gravity.
2. To determine k, the radius of the gyration of the pendulum.

**APPARATUS:**

1. Compound pendulum
2. Meter rule
3. Stop watch
4. Digital weigh machine

**THEORY:**

A physical pendulum or compound pendulum is a rigid object, which is free to rotate about a fixed horizontal axis. In this experiment, we use a special type of compound pendulum which is symmetric about its center of mass. This compound pendulum is nothing but a metal bar, containing a number of holes with equal intervals. The pendulum can be suspended by the help of knife edge passing through different holes. The point of suspension is known as pivot point. If we swing the bar from different holes then the moment of inertia of the pendulum and the time period will change.



Allowing the bar to swing it will approximately follow a simple harmonic motion. According to Newton’s 2nd law of motion for rotation:

…(1)

where, I is the moment of inertia of the pendulum about the axis of rotation, and the angular acceleration. Torque is given by **,** here is the distance of the pivot from the center of the pendulum.

For very small angle of rotation () can be approximated by ∅,

…(2)

Where, I is the moment of inertia of the bar about the pivot. This 2nd order differential equation describes the simple harmonic motion.

…(3)

[ , ]

Therefore we can deduce about the time period:

…(4)

But it is difficult to find the moment of inertia of the pendulum about the pivot point. Using “Parallel Axis Theorem (moment of inertia, , of an object about an axis parallel to the axis that passes through the center of mass is , where the moment of inertia of the object about the axis through the center of mass, is the total mass of the objet, and is the distance between the axes)”, the Moment of Inertia can be determined as:

…(5)

where is the moment of inertia of the bar about its center of mass.

…(6)

Here is the radius of gyration about the axis passing through the

Substituting Eq. 4 and Eq.5 in Eq.3 we get,

…(7)

Comparing the Time period formula for simple pendulum of length L, , we can deduce,

…(8)

From the above equation we can obtain a quadratic equation of, which has 2 roots and such that

…(9)

…(10)

The value of *K* and *g* can be determined from

…(11)

…(12)

Since the “effective length L is composed of two roots l\_1 and l\_2, so there are infinite ways to combine and to make the same.

In this experiment, we will determine the length L graphically [see figure].

If we plot a graph using table (), two curves symmetric about the position of COM should appear. Both the curves tend to infinity for , as no oscillation occurs if someone place the pivot at the center of mass. Horizontal lines in the lower portion will intersect the curves in four points. and can be determined by measuring the distances from the COM position. Using average L in eqn. (9), Gravitational acceleration g can be found.

You can even determine the Standard Deviation of g using the formula that you’ve learnt in experiment 1.

**PROCEDURE:**

1. With the help of the knife edge suspend the metal bar by passing through the hook to the hole closer to the edge A.
2. Measure the distance d from the edge A to the edge of the hole.
3. Oscillate the metal bar with an angle less than 4°.
4. Record the time for 20 oscillations using a stopwatch. Repeat it for three times and obtain the average time period for that slot.
5. Repeat the procedure 1-4 for other holes until the center of mass of the bar.
6. After procedure 5 again repeat the procedure 1-4 by inverting the metal bar for all the holes until the center of mass.
7. Draw the graph .
8. Draw a suitable horizontal line parallel to x axis. Mark A, B, D and E to the four points of intersection with the graph. Measure the length AD and BE, then find the *L* . Find the corresponding for the line and then find the value of .
9. Repeat the procedure 8 for several times by drawing horizontal lines to different points and find the values of . Calculate the mean of .
10. To calculate the value , determine the length AC, BC or CD, CE of the line ABCDE. The line meets a vertical line at C which is parallel to the y axis and meets the x axis at the point of center of mass. The graph is symmetrical about this vertical line. By using the formula or . Repeat the procedure for all the lines and then find the average value of K.

* Minimum 5 holes should be used to get curves like the figure attached in the file.(if there are in the apparatus)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Serial** | | **Distance**  **d (cm)** | **Time for 20 oscillations**  **(s)** | **Mean time t for 20 oscillations**  **(s)** | **Time Period**  **T= (s)** |
| **No. of holes from edge A until center of mass** | **1** |  |  |  |  |
|  |
|  |
| **2** |  |  |  |  |
|  |
|  |
| **3** |  |  |  |  |
|  |
|  |
| **4** |  |  |  |  |
|  |
|  |
| **5** |  |  |  |  |
|  |
|  |
| **No. of holes from edge B**  **until center of mass** | **1** |  |  |  |  |
|  |
|  |
| **2** |  |  |  |  |
|  |
|  |
| **3** |  |  |  |  |
|  |
|  |
| **4** |  |  |  |  |
|  |
|  |
| **5** |  |  |  |  |
|  |
|  |

**TABLE 1**

**TABLE 2**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **No. of experiment** | **(m)** | **(sec)** | **(m/** | **Mean**  **(m/)** | **(m)** | **Mean**  **(m)** |
| 1. **ABCDE** |  |  |  |  |  |  |
| 1. **A’B’C’D’E’** |  |  |  |  |  |  |
| 1. **A’’B’’C’’D’’E’’** |  |  |  |  |  |  |