Experiment 11: Simple Harmonic Motion—the Pendulum

EQUIPMENT NEEDED:

- Experiment Board
- Mass Hanger
- String
- Pivot
- Masses

Theory

Simple harmonic motion is not restricted to masses on springs. In fact, it is one of the most common and important types of motion found in nature. From the vibrations of atoms to the vibrations of airplane wings, simple harmonic motion plays an important role in many physical phenomena.

A swinging pendulum, for example, exhibits behavior very similar to that of a mass on a spring. By making some comparisons between these two phenomena, some predictions can be made about the period of oscillations for a pendulum.

Figure 11.1 shows a pendulum with the string and mass at an angle θ from the vertical position. Two forces act on the mass; the force of the string and the force of gravity. The gravitational force, **F = mg**, can be resolved into two components; $\mathbf{F_x}$ and $\mathbf{F_y}$. $\mathbf{F_y}$ just balances the force of the string and therefore does not accelerate the mass. $\mathbf{F_x}$ is in the direction of motion of the mass, and therefore does accelerate and decelerate the mass.

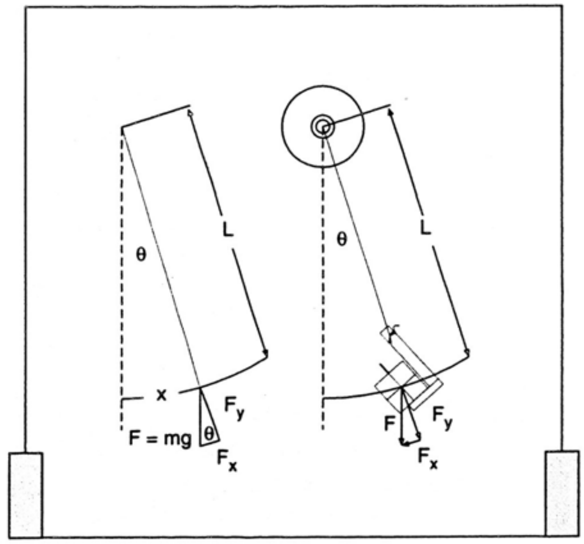


Figure 11.1 Pendulum

Using the two congruent triangles in the diagram, it can be seen that F_x = mg sinθ, and that the displacement of the mass from its equilibrium position is an arc whose distance, x, is approximately L tanθ. If the angle θ is reasonably small, then it is very nearly true that sinθ = tanθ. Therefore, for small swings of the pendulum, it is approximately true that F_x = mgtanθ = mgx/L. (Since F_x is a restoring force, the equation could be stated more accurately as F_x = -mgx/L.) Comparing this equation with the equation for a mass on a spring (F = -kx), it can be seen that the quantity mg/L plays the same mathematical role as the spring constant. On the basis of this similarity, you might speculate that the period of motion for a pendulum is just: $T = 2\pi\sqrt{\dfrac{m}{mg/L}} = 2\pi\sqrt{\dfrac{L}{g}}$;

where m is the mass, g is the acceleration due to gravity, and L is distance from the pivot point to the center of mass of the hanging mass. In this experiment, you will test the validity of this equation.

Table 11.1

Mass (g)	L (m)	# Oscillations	Time (s) (Measured)	Period (s) (Average)	Period (s) (Calculated)

Experiment

① Suspend a 50 gram mass from a 50 cm cord, using a vertical attachment. Set the mass swinging through a small arc of 10-15 degrees. Measure the time it takes to accomplish 10 full cycles. In table 11.1 record the mass (kg), pendulum length (m), and the measured time. Calculate the average period for one complete oscillation (cycle), by dividing the total time by the number of cycles observed (10) and record this value. Calculate the period using the period equation derived in the Theory section. Compare these values and calculate the percent error.

Repeat the measurement 5 times. Calculate the period for each measurement. Then add your five period measurements together and divide by 5 to determine the average period over all five measurements

Repeat your measurements using a different mass.

Use the equation given at the beginning of this Experiment to calculate a theoretical value for the period in each case ($g = 9.8$ N/m; be sure to express L in meters when you plug into the equation). Enter this value in the table.

② Does the period of the oscillations depend on the mass of the pendulum?

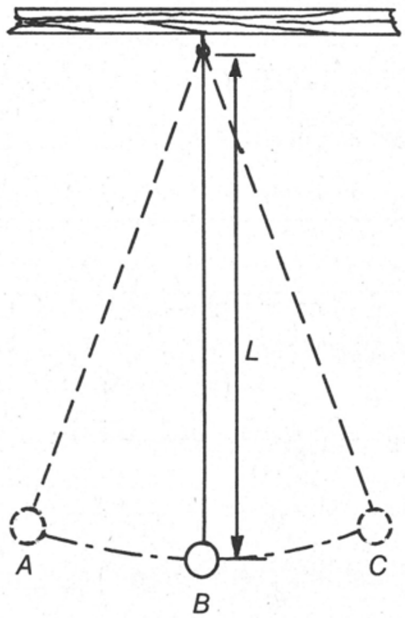
③ Does your theoretical value for the period accurately predict your experimental value?

Repeat the experiment using a significantly different string length.

④ Does the equation for the period of an oscillating mass provide a good mathematical model for the physical reality?

ANALYSIS:

When a pendulum swings through a small arc, its bob is undergoing simple harmonic motion. The force causing the bob to swing along its arc is greatest when its speed is least. The force is least when the speed of the bob is greatest.



At positions *A* and *C*:
$\bar{v} = 0$
$\mathbf{F}$ = maximum
$\mathbf{a}$ = maximum

At position *B*:
$\bar{v}$ = maximum
$\mathbf{F} = 0$
$\mathbf{a} = 0$

Pendulum length is measured to the center of the bob.

CONCLUSION:

Write a statement defining the relationship bertween the period of a pendulum and its length, the mass of the bob, and gravity. What limits the accuracy of this relatiuonship?