Experiment 11
Simple Harmonic Motion (Spring 2021 version)

Advanced Reading
University Physics-Vol 1 (Openstax)
Chapter 15, Sections 15.1 & 15.4

Equipment

Triple Beam Balance	Meter stick
Spring	Masses
Metal Ball	String
Wood Ball	Stop watch
Pendulum Clamp & Rod	Table clamp

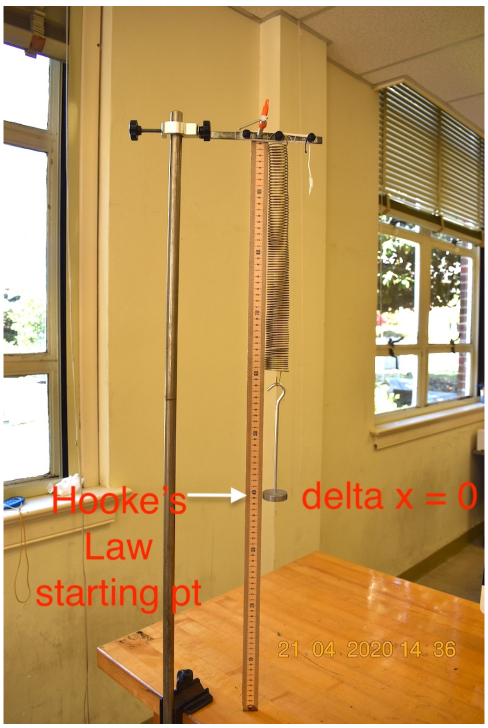

Figure 11-1

Objective

The objective of this experiment is to observe how the periods of two types of simple harmonic oscillators (a pendulum and a spring-mass system) vary with certain parameters.

Theory

Periodic motion is defined as "motion of an object that regularly returns to a given position after a fixed time interval."

A special kind of motion occurs in mechanical systems when the force acting on an object is proportional to the position of an object relative to some equilibrium position. If this force is always directed towards the equilibrium position, the motion is called simple harmonic motion. *An object moves with simple harmonic motion whenever its acceleration is proportional to its position and is oppositely directed to the displacement from equilibrium.*

The period of an oscillator is defined as the time needed for the oscillator to complete one cycle of motion. The period of a simple pendulum (using small angle approximation) is

$$T = 2\pi\sqrt{{}^{l}/_{g}}\,, \qquad (1)$$

where T is the period, L is the length of the pendulum, and g is the acceleration due to gravity.

For a spring that obeys **Hooke's law** ($F = -k\Delta x$) its period is

$$T = 2\pi\sqrt{{}^{m}/_{k}}\,, \qquad (2)$$

where m is the mass acted on by the spring, Δx is the displacement from an equilibrium position and k is the spring constant of the spring. It should be noted the relationship above assumes a "massless" spring.

Procedure

Part 1: Simple pendulum

The first part of this experiment is to test the *length* and *mass* dependence of the period of a simple pendulum.

1. Construct a pendulum approximately 80 cm long using the metal ball. Mass of metal ball is ~66 g. It is important that the pendulum pivot from only one point. Measure the length L of the

pendulum from ***bottom*** **of the support (pivot point) to the *center* of the ball.** See data table 1.

2. Measure the period T of the pendulum by timing the pendulum through 20 swings and dividing by the number of oscillations. This should be done for small amplitudes (approximately 10 degrees or less).

See data table 1 on page 3 of procedure.

3. Repeat step 2 for pendulums of approximate lengths of 60, 40 and 20 cm. **Plot T^2 vs. L and determine the slope. When plotting all data should be in SI units.**

4. Make an 80 cm pendulum using the wooden ball instead of the metal ball. Time for 20 oscillations. Mass of wooden ball is ~6 g.

Record data in table 1.

Part 2: Hooke's Law

5. Hang the spring from the support rod. The wider end of the spring should point down. Place a weight hanger on the spring and measure the height from the bottom of the weight hanger to the top of the table or some other reference (e.g., top of a stool). **This is your reference (or starting) point.** (See Fig. 11-1).

Place 50 grams on the weight hanger and measure the height again. Continue this process in 50 gram increments until a total of 250 g (i.e., 50g hanger + 200 g of masses). See table 2.

6. Graph F vs. Δx, where F is the weight hanging from the spring and Δx **is the total displacement (from the starting or reference point) caused by the added masses.**

Determine the spring constant k, which is the slope of the best-fit line of this graph.

Part 3: Spring-mass oscillator

7. **Assume the mass of the spring is 162g.** (You will use this mass in table 3 below.)

Place a **50 mass hanger** *(which has a mass of 50 grams)* **on the spring** and start the spring oscillating by pulling the hanger down **(a small amount)** and releasing it.

Measure (& record in table 3) the time for the apparatus to complete twenty (20) oscillations.

Calculate the period and put in table also.

8. Repeat step 7 with 50, 100 and 150 grams added to the spring. See table 3 below.

9. Plot T^2 vs. m (*this mass should consist of the hanging mass plus 1/3 of the mass of the spring including hanger*) and determine the slope of the best-fit line through the data.

Your plot should be a (straight) line, which means that the **slope** = $\mathbf{4\pi^2/k}$

Post Lab Questions/Conclusions

1. You measured the period of the metal ball and wood ball with a string length of 80 cm. Assuming a fractional uncertainty of 2% are your periods the same? **Show all calculations.**

Write both periods including uncertainty. If they are not the same, what might be the reason(s).

What can you conclude about the effect of mass on the period of a pendulum?

2. Determine the acceleration of gravity using your plot of T^2 **vs. L**. Show all work.

Your plot should be a (straight) line, which means that the **slope** = $\mathbf{4\pi^2/g}$

3. You calculated the spring constant of the spring by two different methods. Calculate the percent difference (of the two spring constants) and briefly discuss which method you think is "better".

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Table 1
Data for Part 1- Simple Pendulum

Metal ball				Wooden ball			
Pendulum Length (m)	Measured Time (20 oscillations) (s)	Period T (s)	Period^2 T^2 (s^2)	Pendulum Length (m)	Measured Time (20 oscillations) (s)	Period T (s)	Period^2 T^2 (s^2)
0	0	0	0	0	0	0	0
0.20				xxxxxx	xxxxxx	xxxxxx	xxxxxx
0.40				xxxxxxx	xxxxxxx	xxxxxxx	xxxxxxx
0.60				xxxxxxx	xxxxxxx	xxxxxxx	xxxxxxx
0.80				0.80			

Table 2
Data for Part 2- Hooke's Law

Mass added to Hanger (grams)	**Height** of hanger *bottom* (cm)	**Distance** of hanger from equilibrium position, Δx (cm)	**Distance** of hanger from equilibrium position, Δx **(m)**	**Force** (N) *Be sure and covert mass to kilograms for force*
0		0		
50				
100				
150				
200				

Table 3
Data for Part 3 - Spring Mass Oscillator

Mass added to spring (g)	**Total oscillating mass** (column 1 mass + 1/3 mass of spring (g)	**Total oscillating mass** (column 1 mass + 1/3 mass of spring **(kg)**	**Measured time for 20 oscillations (s)**	**Period** (s)	**Period^2** (s^2)
50 (hanger only)					
100 (hanger + 50g)					
150 (hanger + 100g)					
200 (hanger + 150g)					

Results
(include units)

Spring constant using Hooke's Law__________

Spring constant by Spring mass oscillation method__________

% difference _______

Acceleration of gravity from plot of **T^2 vs. L** ____

% error using 9.800 m/s^2 as reference g

You need only to turn in data tables, plots and post-lab questions

Any sample calculations below