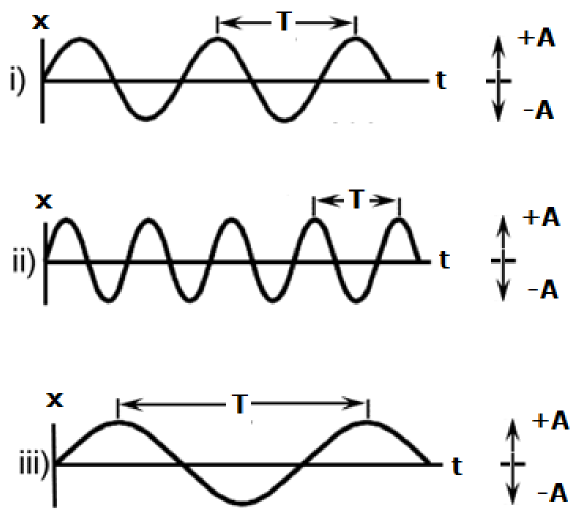
PHYSICS

PHYSICS 20 **LAB 7: Simple Harmonic Oscillator** **2 HOURS**

INTRODUCTION:

A mass attached to a vertical spring, that is oscillating up and down, is an example of Simple Harmonic Motion (SHM) or motion that repeats itself in a given time. The Displacement as a function of Time, is characterized as a sinusoidal wave with a Period (T) and an Amplitude (A).



The SHM motion of a such a system is due to the Restoring Force of the spring that always pushes or pulls the mass towards its equilibrium position. The period (T) of this repeating motion depends on mass (m) attached to the spring and the stiffness of the spring, which is quantified as the spring constant (k).

OBJECTIVE:

- **To determine the spring constant k_1 of a vertical spring from the relationship between the force applied to the spring and the displacement of the spring from equilibrium.**
- **To determine the spring constant k_2 of the same spring from the relation between the period of the oscillation and the effective mass of the system.**
- **To determine the % Diff for the average spring constant k_{avg}.**

  % Diff < 10 %

APPARATUS:

1 Cenco spring
1 lab stand one metre tall
1 clamp whose single jaw supports the spring
1 set of hooked masses ranging from 200 g to 500 g
1 stop watch to time the oscillations
1 square plastic metre stick
1 thin strip of a piece of masking tape to place a marker on the spring

THEORY:

When a mass "m" is attached to a spring (either vertical or horizontal) its natural position (at rest) is called its equilibrium position ($\vec{x} = 0\ m$). If the spring is stretched or compressed away from its equilibrium position, the "restoring force" ($\vec{F}$) of the spring always is towards its equilibrium position. The spring's stiffness is described by its spring constant "k" in N/m.

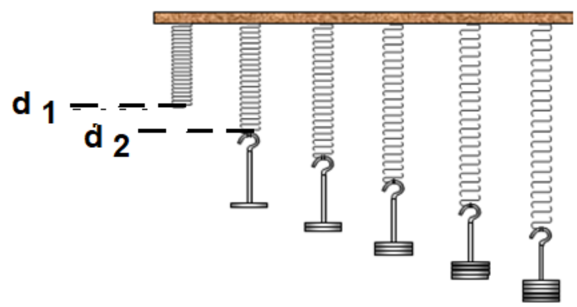
$$\vec{F}_R = -k\vec{x} \quad \text{(Hooke's Law) where k is N/m}$$

For example, if k = 10.0 N/m for a given spring, then it takes 10.0 N of force to stretch the spring 1.00 m; while if k = 155 N/m for a given spring, then it takes 155 N of force to stretch the spring 1.00 m. The larger "k" is, the stiffer the spring is; and the smaller "k" is, the looser the spring is.

The spring constant "k" can be determined by hanging the spring vertically and suspending a mass (m) to the end so the system is motionless, so that the force of gravity (m·g) is balanced by the restoring force (k·x) pulling the mass down.

$$F_R = k \cdot x \quad \text{(Hooke's Law) where k is N/m}$$

$$F_g = m \cdot g \text{ where g = 9.81 N/kg}$$



When a mass (m) is attached to vertical spring with a spring constant (k) and allowed to oscillate up and down, the time it takes for one oscillation or cycle is called the period (T) and given by the formula:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

For most questions in class, we assume the mass of the actual spring is zero and does not need to be accounted for. In reality, given the spring not only has to move the mass attached to it, but also the spring itself, the mass used for the formula needs to be altered to include the mass of the spring itself. It has been found experimentally that the mass that should be used in the formula is called the "Effective Mass" which is defined as $M_{eff} = m + 1/3 \cdot m_s$, where m is the suspended mass and m_s is the mass of the spring, and the formula needed is given by:

$$T = 2\pi\sqrt{\frac{M_{Eff}}{k}} \quad \text{or} \quad k = \frac{4\pi^2 \cdot M_{Eff}}{T^2}$$

PROCEDURE:

Part A: Stationary Vertical Spring

1. **Mount the spring from to a stand so that the top of the spring is about 800 mm above the lab bench.**

2. **To measure the marker position of the spring, a mark must be placed on the lowest spiral of the spring so that the distance from the top of the bench to the mark may be measured easily. A slice of masking tape 1 mm or so wide is wrapped in a ring at a convenient location on the very bottom spiral of the spring. When the spring is hanging vertically, the dash of the marker must be horizontal or parallel to the wire. The bottom wire twists a bit as the spring is loaded so the mark must be at or above the center line of the wire on the outside of wire.**

3. **To measure the response of the spring, hooked masses starting at 0 grams and ranging to 300 grams in intervals of 50 grams are suspended in turn from the spring. For each separate weight, measure and record the mass and marker position in the Initial Data Table provided.**

Part B: Oscillating Vertical Spring

4. **Suspend 200 g from the spring and displace it to a small amplitude. Measure and record the time for 10 complete oscillations. Do this three times and record the measurements in the Initial Data Table.**

5. **Repeat Step 4 suspending 300 g, 400 g and 500 g and respectively.**

6. **Create a Title section named: Calculations. Show only one ”calculation for any repetitive calculation.**

7. **For each trial in Table 1, calculate the elongation (x_j) of the spring from its original position by subtracting the initial position (d_1) from each marker position (d_j).**

8. **For each trial in Table 1, calculate the force of gravity (F_g) acting on the mass.**

9. **Using the values in Steps 8 and 9, calculate the spring constant k_1 for each trial.**

10. **Using the values in Step 9, calculate the average spring constant k_{1avg} for Part 1.**

11. **For each trial in Table 2, calculate the effective mass.**

12. **For each trial in Table 2, calculate the average time for 10 cycles.**

13. **Using the times from Step 12, calculate the period for each trial.**

14. **For each trial in Table 2, calculate the spring constant k_2.**

15. **Calculate the average spring constant k_{2avg} for Part 2.**

16. **Calculate the % Difference for the average k values.**

17. Complete the Final Results Table provided.

18. Compile and submit your completed lab to your instructor by the due date. No conclusion is needed for this lab!

Your completed lab should contain:

Initial Data Tables

Calculations

Final Results Tables

See your lab instructor for a more detailed format for the completed lab submission.

PHY20 **Lab 7: Simple Harmonic Motion**

INITIAL DATA TABLE

Note: For the online course, use the Common Data Set at the end of the lab.

Initial Data

Part 1

Trial	Mass: m (kg)	Marker Position: d (m)
1	0	
2	0.050	
3	0.100	
4	0.150	
5	0.200	
6	0.250	
7	0.300	

Part 2

Trial	Mass: m (kg)	Time 10 Cycles:t_1 (s)	Time 10 Cycles:t_2 (s)	Time 10 Cycles:t_3 (s)
1	0.200			
2	0.300			
3	0.400			
4	0.500			

CALCULATIONS:

Part 1

Determining Force

$$F = m \cdot g \quad \text{where } g = 9.81\ \text{N/kg}$$

Determining Elongation

$$x = |d_j - d_1| \quad \text{for } j = 1, 2, \ldots, 7$$

Determining k_1

$$k_1 = \frac{F}{x} \cdot m$$

Determining Average k_1

$$k_{1avg} = \frac{(k_{12} + \cdots + k_{17})}{6}$$

Part 2

Determining Effective Mass

$$M_{Eff} = m + m_s \quad \text{where m is the suspended mass and } m_s \text{ is the mass of the spring}$$

Determining Average Time for 10 Cycles

$$t_{10} = \frac{(t_1 + t_2 + t_3)}{3}$$

Determining Period

$$T = \frac{t_{10}}{10} \quad \text{where } t_{10} \text{ is the time for 10 cycles}$$

Determining k_2

$$k_2 = \frac{4\pi^2 \cdot M_{Eff}}{T^2}$$

$$k_{2avg} = \frac{(k_{21} + \cdots + k_{24})}{4}$$

Determining Average k_{avg}

$$k_{avg} = \frac{(k_{1avg} + k_{2avg})}{2}$$

Determining % Difference

$$\%\,Diff = \frac{|k_{1avg} - k_{2avg}|}{k_{avg}} x100\ \%$$

PHY20 **Lab 7: Simple Harmonic Motion**

FINAL RESULTS TABLES

Part 1

Trial	Mass: m (kg)	Marker Position: d (m)	Elongation: x (m)	Force: F (N)	Spring Constant: k_1 (N/m)
1	0		0	0	
2	0.050				
3	0.100				
4	0.150				
5	0.200				
6	0.250				
7	0.300				

k_{1avg} =____________

Part 2

Trial	Avg. Time for 10 Cycles: t (s)	Period: T (s)	Mass: m (kg)	Spring Constant: k_2 (N/m)
1			0.200	
2			0.300	
3			0.400	
4			0.500	

k_{2avg} =____________

Combined

k_{avg} = __________

% Diff = __________

Common Data Set

Part 1

Trial	Mass	Position
1	0 kg	0.335 m
2	0.050 kg	0.374 m
3	0.100 kg	0.401 m
4	0.150 kg	0.456 m
5	0.200 kg	0.468 m
6	0.250 kg	0.522 m
7	0.300 kg	0.563 m

Part 2

Mass of Spring	0.105 kg

Trial	Mass	Time 1	Time 2	Time 3
1	0.200 kg	8.47 s	8.59 s	8.43 s
2	0.300 kg	10.25 s	10.17 s	10.01 s
3	0.400 kg	11.42 s	11.38 s	11.57 s
4	0.500 kg	12.73 s	12.69 s	12.74 s