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HOOKE'S LAW AND OSCILLATIONS

OBJECTIVE

To measure the effect of amplitude, mass, and spring constant on the period of a spring-mass oscillator.

INTRODUCTION

The force which restores a spring to its equilibrium shape is equal to the one that deformed it, but in the opposite direction. Frequently we find that the deviation from equilibrium position is proportional to the applied force. For one dimensional motion, we can express this behavior mathematically as:

$$\mathbf{F} = -k\mathbf{x}, \qquad (1)$$

where **F** is the restoring force (boldface type to indicate a vector), **x** is the displacement away from equilibrium, and k is a constant that depends on the material and its shape.

The negative sign reminds us that the restoring force acts in the opposite direction from the displacement, so as to bring the body back to its original shape. Eq. (1) is called **Hooke's Law** and describes a surprisingly large number of physical situations.

Systems such as a mass on the end of a spring can be described with Hooke's law. They oscillate as simple harmonic oscillators with a displacement x given by

$$x = x_0 \cos 2\pi \frac{t}{T}, \qquad (2)$$

and a period of vibration T given by

$$T = 2\pi\sqrt{\frac{m}{k}}. \qquad (3)$$

Thus, if we know that a system consisting of a mass on a spring, obeys Hooke's law and if we can determine the spring constant k, then we know a great deal about how the system will behave.

ACTIVITY 1

1. Place a lab stand on your lab table. Attach a horizontal crossbar to the stand using a clamp. Suspend a spring from the crossbar with the smaller end at the top.

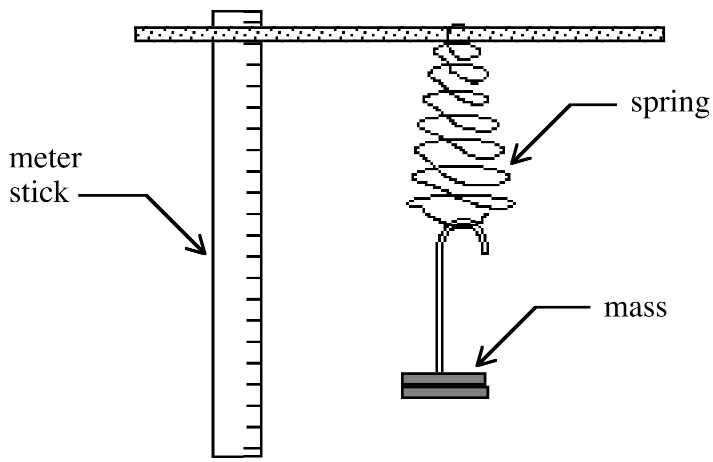

Fig. 1. A coil spring suspended from the crossbar. Note that the spring is suspended from the smaller end.

2. **Record the initial position** of the bottom of the weight hanger.

ACTIVITY 2

3. Adding 50 grams at a time, **record the positions and total mass** until you have added 250 grams. *Don't forget to include the mass of the weight hanger when recording the masses.*

   You must add 50 g each time, not make 150 g by taking off two 50 g masses and putting a 100 g and a 50 g mass back on. Place the masses gently so that the spring won't start oscillating.

4. **Now remove the masses 50 g at a time and record the position and mass.**

ACTIVITY 3

5. **Calculate the gravitational force due to the masses. Record these values.**

6. **Plot a graph of force vs. displacement and draw the line which best fits the points. Use DataStudio™ to draw the graph and to get the fit.** If the resulting line (or a portion of it) is straight, we say that Hooke's law is obeyed in that region.

7. **Determine *k* from your graph. Show all calculations.**

ACTIVITY 4

8. Put 50 g on the weight hanger for a total mass of 100 g. Stretch the spring a short distance and release it. Measure the period of oscillation T by timing a number of oscillations with the stopwatch. **Record all values and show any calculations used.**

9. Repeat step 8 with a total mass of 150 g.

10. Repeat step 8 with a total mass of 200 g.

11. Repeat step 8 with a total mass of 250 g.

12. Using data from steps 8-10, **plot a graph of T^2 against m and comment on the validity of Eq. 3.**

13. **Extrapolate the line on the previous plot to determine the effective mass of the spring**.

14. Weigh the spring and compare the measured value with the effective mass found in step 13.

15. Based on your observations of the oscillating spring, **does the spring and mass behave like a harmonic oscillator? Explain your answer.**

ACTIVITY 5

16. Repeat Activities 2-4 for two springs connected end to end.

17. **Compare the spring constant value with that determined for a single spring**.

18. Measure the period of oscillation for several values of the total applied mass and **determine the effective mass of the combination.**

19. **Compare the effective mass of the springs combined in series with that determined for the single spring**.

ACTIVITY 6

20. Connect two springs in parallel with the notched wooden dowel provided. Repeat Activities 2-4.

21. **Compare the spring constant value with that determined for a single spring**.

22. Measure the period of oscillation for several values of the total applied mass and **determine the effective mass of the parallel combination.**

23. **Compare the effective mass of the springs combined in parallel with that determined for the single spring and explain**.

ACTIVITY 7

24. Can you infer any general conclusions about the overall spring constant of springs combined in series and in parallel?

Hand in these data sheets. Name ____________________

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DATA SHEETS

ACTIVITY 1 & 2 & 3

Record the positions of the bottom of the weight hanger for different masses.

	Increasing mass		Decreasing mass	
Mass (g)	**Height (cm)**	**Force (N)**	**Height (cm)**	**Force (N)**

Graph force *vs.* displacement using DataStudio. Determine *k*.

k **=** __________________

ACTIVITY 4

Measure the period for different masses. Compute T^2.

Mass (kg)	Period T (s)	Period^2 (s^2)

Graph T^2 vs. m. **Effective mass =** ____________________

ACTIVITY 5

Repeat activities 1-4 for two springs connected end-to-end.

	Increasing mass		**Decreasing mass**	
Mass (g)	**Height (cm)**	**Force (N)**	**Height (cm)**	**Force (N)**

Graph force *vs.* displacement using DataStudio.

***k* = ________________________**

Compare *k* for two springs to the *k* for one spring.

Measure the period for different masses. Compute T^2.

Mass (kg)	**Period T (s)**	**Period² (s^2)**

Graph T^2 vs. m.

Effective mass = ____________________

Compare effective mass for two springs to that for one spring.

ACTIVITY 6

Repeat activities 1-4 for two springs connected in parallel.

	Increasing mass		**Decreasing mass**	
Mass (g)	**Height (cm)**	**Force (N)**	**Height (cm)**	**Force (N)**

Graph force *vs.* displacement using DataStudio.

k **= ________________________**

Compare *k* for two springs to the *k* for one spring.

Measure the period for different masses. Compute T^2.

Mass (kg)	**Period T (s)**	**Period^2 (s^2)**

Graph T^2 vs. m.

Effective mass = ____________________

Compare effective mass for two springs to that for one spring.

ACTIVITY 7

What general conclusions can you draw about the effective spring constants for two springs in parallel or two spring in series?