23 Simple Harmonic Motion
A Wrenching Experience

Purpose

To investigate the simple harmonic motion of a spring.

Required Equipment and Supplies

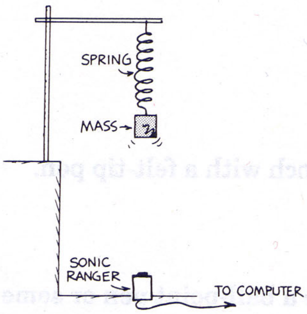
ring stand assembly
rod clamp and horizontal rod or pendulum clamp
spring (for best results use Cat. #75490 from Central Scientific Co.)
slotted weights
string
unknown mass, such as a wrench or hammer
felt-tip pen
fulcrum
stopwatch *or*
  Apple II Series computer
  Super Sonic Plus ultrasonic ranging system
  Data Plotter graphing program

Discussion

Stretch a spring, then let it go, and it will vibrate to and fro. Since the restoring force responsible for vibration is directly proportional to the spring's displacement ($F \sim \Delta x$), the to-and-fro motion you observe is *simple harmonic motion*. We'll investigate this type of motion by observing an oscillating wrench or other massive object suspended by a spring.

Part A: Oscillation of a Spring

Procedure



Step 1. Hang a known mass from the spring. Gently pull down on the spring and mass and release them so that they oscillate together. You should not pull so hard as to cause the mass to move other than up or down with the spring. It might be helpful to tack the mass to the spring with a small piece of masking tape. Use either a stopwatch or *Super Sonic Plus* ultrasonic ranging system to measure the period of oscillation, T, of the mass on the spring. If you use a stopwatch, measure the time for the mass to oscillate 5 cycles and divide by 5 to calculate the period. Repeat, allowing the mass to oscillate 10, 15, and 20 cycles. Record the average period for each mass. Repeat for several masses. Record the value of the period for each mass in the first two columns of Data Table 23.1.

Data Table 23.1

	MASS (kg)	PERIOD (s)
1		
2		
3		
4		
5		

Step 2. Use *Data Plotter* to make a graph of the period vs. mass. Is your graph a straight line? If not, select the "Graph Set-Up" option and vary the powers of the period and mass as you did in the Computer Activity "Trial and Error" until they re-plot as a straight line. What combination of powers for the period and mass re-plot as a straight line?

Step 3. Now suspend an unknown mass, such as a wrench, from the spring as you did the known masses. Be careful that the unknown does not exceed the elastic limit of the spring. Measure the period of the unknown mass. Interpolate your graph or form ratios to determine the mass of the unknown.

$T_{unknown}$ = _______

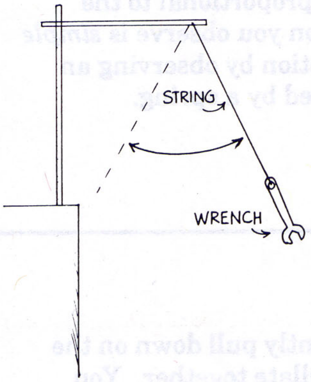
$m_{unknown}$ = _______

Step 4. Compare the determined mass by measuring it directly with a triple-beam balance. Compute the percentage difference.

$m_{measured}$ = _______

percentage difference = _______

Part B: Oscillation of a Pendulum



Step 5. Tie a string, about one meter long, to the wrench. Attach the other end of the string to the ring stand assembly and allow the wrench to swing to and fro as a pendulum. Use either a stopwatch or the *Super Sonic Plus* ultrasonic ranging system to measure its period. If you use a stopwatch, measure the time for the wrench to oscillate 10 cycles and divide by 10 to calculate the period.

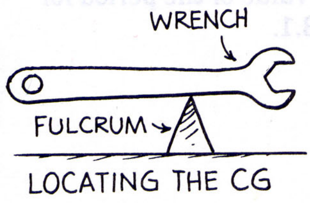
T = _______

Step 6. Determine the *effective* length of the pendulum (from the pivot to the CG of the wrench) from its period of oscillation. Calculate the effective length of the pendulum from the equation,

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Mark the effective location of the CG on the wrench with a felt-tip pen.

l_{eff} = _______



Step 7. Untie the string from the wrench and use a ball-point pen or some other readily available fulcrum to verify the effective length of the pendulum by balancing the wrench at its CG. Mark the actual location of the CG with a felt-tip pin.

location of the CG = _______

Analysis

1. Compare the effective length of the pendulum as determined by the period of oscillation and by balancing the wrench to find its CG. Compute the percentage difference of the two lengths.

percentage difference = ________

Going Further

Step 8. Hang various masses from a spring attached to a ring stand assembly and determine its spring constant, k. (If you are unsure about how to do this, read the lab "It's Spring Time!" and refer to the section on Hooke's Law in your text.) Be sure to attach the proper units to the spring constant.

k = ________

Step 9. Now, hang an unknown mass such as a wrench from the spring. Gently pull down on the mass and spring and release them so that they oscillate together. You should not pull so hard as to cause the wrench to move other than up and down with the spring. Use either a stopwatch or *Super Sonic Plus* ultrasonic ranging system to measure the period of oscillation, T, of the wrench on the spring. If you use a stopwatch, measure the time for the wrench to oscillate 5 cycles and divide by 5 to calculate the period. Repeat, allowing the mass to oscillate 10, 15, and 20 cycles. Record the average period for the wrench.

T = ________

From the period, calculate the frequency, f, from the equation

$$f = \frac{1}{T}$$

and the angular frequency, ω, from the equation $\omega = 2\pi f$.

f = ________ ω = ________

Calculate the value of the unknown mass using either the equation

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

or

$$\omega = \sqrt{\frac{k}{m}}$$

Show your calculations.

$m_{unknown}$ = ________

Step 10. Finally, use a triple-beam balance to measure the mass. How does it compare to your calculated value? What is the percentage difference?

percentage difference = ________

Analysis

2. Which method yields more accurate results for the mass of the unknown—interpolation of your period vs. mass graph or calculating the spring constant? Offer explanations why.

3. In this experiment, calculations are made assuming the spring has no mass. If the mass of the spring were appreciable compared to the slotted weights suspended from them, how would this affect your calculations?