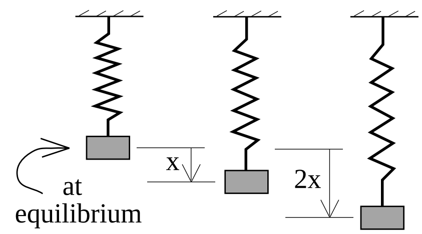
Vibratory Motion -- Conceptual Questions

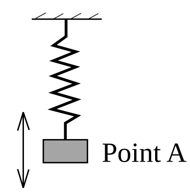
1.) An ideal spring attached to a mass *m = .3 kg* provides a force equal to -kx, where *k = 47.33 nt/m* is the spring's *spring constant* and *x* denotes the spring's displacement from its equilibrium position. Let's assume that when such a spring is displaced a distance *x = 1 meter*, the period of oscillation (this is defined as the amount of time required for the system to oscillate through one complete cycle) is *T = .5 seconds per cycle*.



a.) When the mass is displaced a distance *2x = 2 meters*, what is its new period?

b.) Given the numbers in the original statement of the set-up, would it have been possible for the period to have been *any other number* other than *.5 seconds per cycle*? Explain.

2.) A vertical spring/mass system oscillates up and down. At *t = 0*, the mass is at *Point A* moving downward. Through how many cycles will the system have moved by the time the mass has passed by *Point A* five times, not including its first passage at *t = 0*?



3.) When you attach a mass to an ideal spring, the force *F* provided to the mass by the spring will be proportional to the displacement *x* of the mass/spring system from its equilibrium position. Algebraically, that proportionality can be written as an equality equal to $F = -kx$, where *k* is the proportionality constant and is called *the spring constant*. One of the things that is interesting about the oscillatory motion of the mass attached to an ideal spring is that the mass's motion will have a single period *T*. That is, it will always take the same amount of time for the mass to oscillate through one cycle, no matter what the initial displacement was. Having said that:

a.) Sketch the *Force versus Displacement* graph for an ideal spring. Remember that the displacement of a spring from its equilibrium position can be either positive or negative.

b.) Briefly, explain why the period of an ideal spring/mass system doesn't change if the initial displacement of the mass is increased or decreased.

c.) Now for the fun part. Consider a second, *non-ideal* spring whose force expression is $-bx^3$, where *b* is some spring constant. On the graph you produced in *Part a*, make an approximate sketch of the *Force versus Displacement* graph for this spring force (don't get anal about this--you don't need numbers, just show the trend of the force as *x* goes positive and negative).

d.) Attach the non-ideal spring to the same mass you used in *Part a* and *b*. It is possible to displace this spring/mass system so that when released, it oscillates with the same period as was the case with the ideal spring used in *Part a*. Take that displacement, double it, displace the system that doubled distance, and release. Will the period of the resulting oscillation be greater than, less than, or the same as T?

4.) Can a spring have a force function of $-kx^4$? Explain.

5.) You have access to Geppetto's Workshop, complete with Newton scales, meter sticks, balances--all sorts of science-y things. Someone gives you an ideal spring and asks you to determine its spring constant. How might you do that?

6.) Most people know that frequency measures the number of cycles through which an object oscillates per unit time. What does *angular frequency* measure?

7.) A fixed length of string is cut and loops are made at both ends. The upper end-loop is placed over a ceiling hook while the lower end-loop is used to support a hook-mass m. The mass is pulled to the side and released making a pendulum that swings back and forth. The period is measured as T. The original mass is removed and a second hook-mass from the same mass set, this one of mass $10m$, is placed on the string and made to swing back and forth with the same amplitude. The new period is found to be larger than T.

a.) Does this mean the pendulum is swinging faster or slower?

b.) Some students look at the data and conclude that the pendulum's period is a function of the bob's mass. In fact, this isn't true! What is probably causing the disparity in the periods?

8.) Newton's Second Law is used to sum up the forces acting on an oscillating mass. The resulting expression is then manipulated and found to have the form $(d^2x/dt^2) + bx = 0$. Having access to this expression:

a.) What can you say about the system's angular frequency of the system?

b.) What can you say about the system's frequency?

c.) What can you say about the system's period?

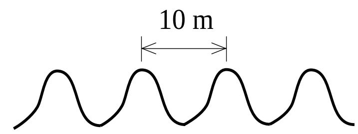
9.) What is the single characteristic that is common to all vibrating (oscillatory) systems?

10.) The acceleration of gravity on earth is approximately six times that of the acceleration on the moon. A pendulum on earth has a period of *1 second per cycle*. Will the pendulum's period change if it is used on the moon? If so, how so?

11.) Double the length of a pendulum arm. How will the pendulum's frequency change? How will the pendulum's period change?

12.) How are frequency and period related?

13.) You are sitting on a jetty. You notice ocean waves are coming in approximately 10 meters apart. It takes 30 seconds for *three crests* to pass you by. What is the frequency, period, and angular frequency of the wave train?



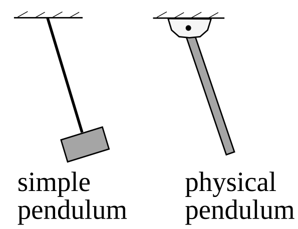
14.) A spring with spring constant $k = .25$ *newtons per meter* vibrates with frequency $\nu = .5$ *hertz*. Across the lab, a string with a small mass $m = .15$ *kg* attached to it is made into a simple pendulum.

a.) If the frequency of the pendulum and the frequency of the spring are to be the same, approximately how long must the string be?

b.) Why are you being asked for an approximate answer? That is, given what you know, why can't you give an exact answer?

c.) For the frequency to be good, is there any limit on the size of the oscillations of the pendulum?

15.) What is the difference between a simple pendulum and a physical pendulum of same mass and length? What approach would you use to derive from scratch an expression for the period of either?



16.) You live in California (Los Angeles). You're a physics teacher, complete with sadistic streak. You have your students calculate the period of a pendulum system. They determine that value to be T. You then claim that no matter how good and precise your students' set-up is, its period will never exactly equal the theoretically calculated value, *even if your students do the experiment in a vacuum*. What are you talking about? (Note: This isn't obvious--think about the parameters that determine a pendulum's period, and how they might be off). Once you've figured out the problem, approximate by how much your theoretical period will be off (note that the latitude of LA is approximately 22^o). Is this going to be noticeable?

17.) Consider the expression $x = A \sin(\omega t + \delta)$.

a.) What does the A term do for you ?

b.) What does the ω term do for you?

c.) What does the δ term do for you?

d.) What does the expression in general do for you?