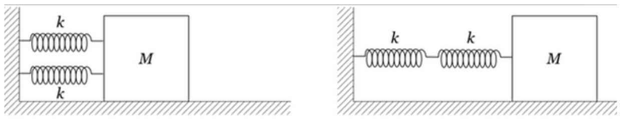
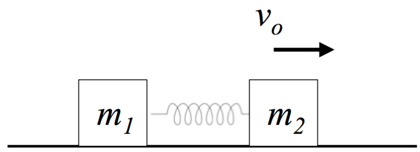
SNU Physics 2016 Spring Semester Physics 1: Problem Set #5

1. A massless spring hangs from the ceiling with a small mass (m) attached at its lower end. The mass is initially ($y = y_o$) held so that the spring is at its rest length (i.e., un-stretched). Then, the mass is released and begins to oscillate up and down with lowest position being ($y = y_o - y'$).
   (a) Express the spring constant k of the spring
   (b) Express the frequency of oscillation.

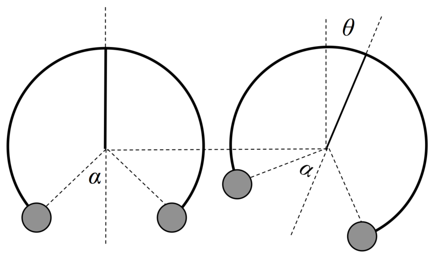
2. Consider a block of mass M is attached to two identical springs k in (R) where the springs are in series; (L) where the springs are in parallel.
   (a) Express the effective spring constant for (R) and (L).
   (b) Express the frequency of oscillation for (R) and (L).



3. Consider two blocks of equal mass m connected by a massless spring of un-stretched length l and spring constant k. At $t = 0$, someone smacks the right block m_2 so that it has an initial velocity of v_o (i.e while the block m_1 is still at rest). Express the velocity of m_1 and m_2 for $t > 0$.



4. Consider a teeter-toy fashioned from two equal masses connected by a massless arc circle of radius r and angle $(2\pi - 2\alpha)$ and a massless rod supporting the teeter-toy at the top of the arc circle to the frictionless pivot, located at the center. For cases when the teeter-toy oscillates, express ω. For a given α, express the maximum amplitude angle θ_o that the toy can oscillate.

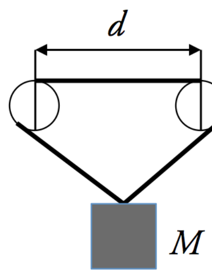


5. Consider a satellite of mass M circularly orbiting the Earth with radius r_o. At sometime, a rocket on the satellite is fired towards the center of the Earth such that its energy is changed (minimally) but not its angular momentum (l). Show that the radial distance oscillates and that the new orbit path can be approximated by $r = r_o + A\cos\theta$ where $r_o \gg A$.

6. A uniform rope of mass m and length L hangs from the ceiling. (a) Express the tension on the rope as function of y, distance from the top of the rope; (b) Show that the speed of a transverse wave is also function of y and is given as $v = \sqrt{gy}$.

7. Consider a tube of length L, which is closed at one end, and near the open end, a stretched wire (mass m and length l) is placed. The wire is fixed at both ends and oscillates in its fundamental mode. By resonance, the oscillating string sets the air column in the tube into oscillation at its fundamental frequency. (a) Express the frequency; (b) Express the tension in the wire.

8. Consider the following system. A mass M hangs in equilibrium by a string with total length l and linear mass density μ. The string is wrapped around two light frictionless pulleys, which are separated by a distance d. (a) Express the tension in the string. (b) Express the frequencies that the string between the pulleys needs to vibrate for the first three harmonics.



9. An atomic force microscope is used in many different disciplines to image surfaces near atomic-dimensions. The 'seeing' part of the microscope is a mechanical cantilever with a sharp tip. The AFM cantilever can be used in the contact mode and in the tapping mode. In the tapping mode, the cantilever is driven at its resonant frequency. We can approximate the AFM cantilever as a simple mass-spring system (mass M and spring k_s) on a frictionless surface. When we take the AFM

‘image’ we can plot changes in resonant frequency as well as changes in phase. Explain, using a simple-mass spring system analogy why the resonant frequency might change as well as why phase might change.

10. A siren emits a sound at frequency f and heard by Alice. Both the siren and Alice are at rest respect to the ground. Express the frequency heard by Alice if a wind of speed S is blowing in the direction (a) from the siren to Alice; and (b) from Alice to the siren. (c) Where is Bob?