MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Physics Department

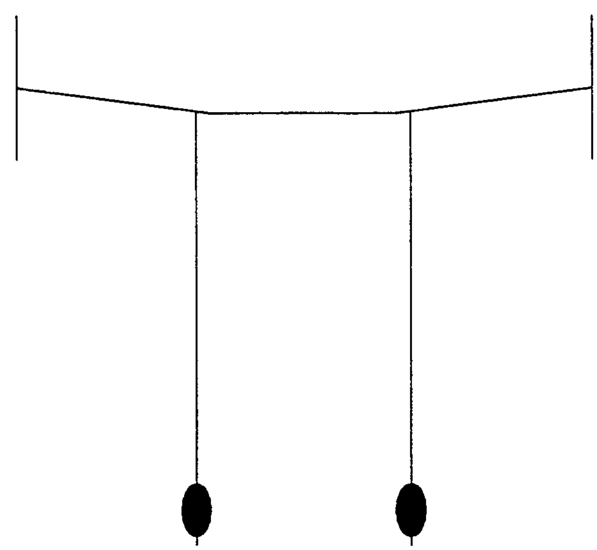
Physics: 8.03 Spring 2003

Take-Home Experiment #2

COUPLED OSCILLATORS, RESONANCE, AND NORMAL MODES

Objective A system of coupled oscillators that is easy to construct and adjust is used to demonstrate the concepts of resonance and normal modes.

Experiment Use the braided fishing line to rig a horizontal string under moderate to heavy tension between two secure end posts. Aim for a free length of about 30 cm. The legs of a desk chair work well as the end posts. Tie two lengths of line, each about 30 cm, to the horizontal string and let them hang vertically. Position them symmetrically about the center of the horizontal string. Slip a 1.5 oz weight onto each vertical string; secure it near the free end by jamming a wooden plug in the hole.

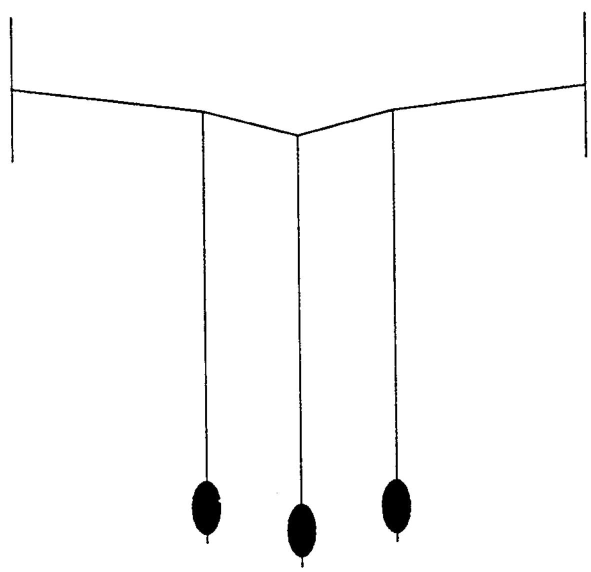


Displace one weight about 10 cm in a direction perpendicular to the horizontal string and let it go. If the two pendulums have the same length, they have the same frequency and we say they are in resonance with each other. Under these circumstances, the energy should slowly shift away from the first mass into the second. After a while the second mass will be swinging and the first will have come temporarily to rest. Then the energy will shift back again to the first. See how close you can come to this ideal situation by adjusting the position of the mass on the second string. Try changing the tension in the horizontal string. How does the tension effect the time it takes for the energy to shift from one mass to the other?

Change the position of one of the weights by about a cm and do the experiment again. Now the two pendulums are no longer exactly resonant with each other. Only a fraction of the energy in the first pendulum ever gets transferred to the second. The first mass never comes to rest. Explore the effect of successively larger detunings. Describe briefly.

Change the positions of the masses back to a resonant condition. A normal mode of a set of coupled variables is defined as pattern of motion of the system as a whole in which the relative amplitude of the variables is independent of time. All the variables oscillate at the same frequency, they differ only in maximum amplitude and in relative phase. Figure out and try to excite the two normal modes associated with motion of the two weights perpendicular to the string. Were you successful?

Now try three coupled masses. Careful adjustment is necessary to get the most pleasing results. Use the ruler to center one vertical string between the supports and to position the other two strings equal distances to the left and right of the center. When positioning the 1.5 oz. weights to attain equal uncoupled frequencies, note that the point where the center vertical string is attached to the horizontal one is somewhat lower than where the other two vertical strings are attached. Thus, to get equal pendulum lengths, the center mass will be a corresponding distance below the two outboard masses.



Displace and release the center weight. Watch the energy flow away into the outboard masses and then (hopefully) return. Displace and release one of the outer masses. The evolution of the system is now more complex because of the lack of symmetry. But the same general result should be observed. The energy flows away from the perturbed mass and eventually returns.

While the system is tuned to resonance, try to figure out and then excite the three normal modes associated with motion of the weights perpendicular to horizontal string. It will be harder to excite the modes with three masses than it was with two because the initial displacements for two of the modes require specific amplitude ratios which are hard to obtain by eye. Sketch the three modes you expect. Did you find them?

Finally, examine the effect of moving away from the complete resonant situation. Change the length of one pendulum. Excite that one and see how much of the energy gets coupled out. Excite one of the two equal length pendulums and see where the energy migrates. Make all three lengths different. Now what happens when any one of the pendulums is initially excited?