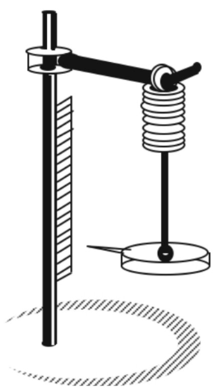
Lab 7
Harmonic Oscillator: Resonance and Damping

Purpose: use simple mechanical oscillators to illustrate several concepts important to music:

a) for a harmonic oscillator, the frequency is independent of amplitude;
b) the wave shape (displacement vs. time) is sinusoidal,
c) the oscillations are damped – there is a decay time (damping time) t ;
d) the resonance curve has a cartain width Df. More damping produces wider resonance and shorter decay t.

Experiment Part I (if lab time permits or if Part II of the experiment is shortened):



Equipment:
Harmonic oscillator: mass on spring, weights, clock.
Non-harmonic oscillators: U-shaped and V-shaped track with steel ball, flat bowl with ball, bouncing superball on table. Instead of tracks made of bent aluminum channel one could use bowls of different shapes.

Non-harmonic oscillator vs. harmonic oscillator:: we compare the frequency of a ball rolling in three different tracks: a parabolic U-shaped track (harmonic oscillations – frequency independent of amplitude), V-shaped track (frequency decreases with amplitude), and flat-bottomed U-shaped track (frequency increases with amplitude). Also: bouncing ball on table – frequency increases with decreasing amplitude. Conclusion – not all periodic oscillations are harmonic.

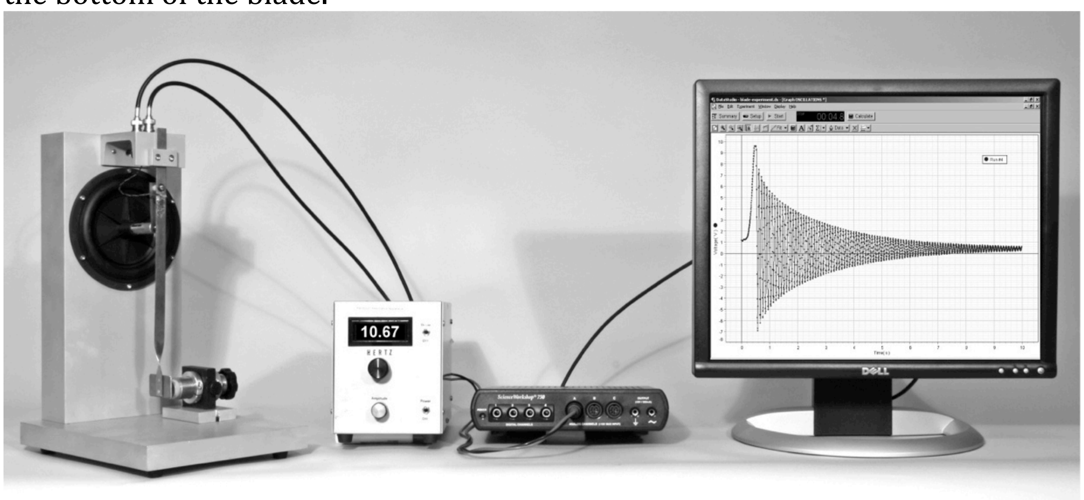
Exercises:

1. Compare frequency vs. amplitude for harmonic oscillator vs various non-harmonic oscillators – timing of oscillations by clapping hands.
   we compare the frequency of a ball rolling in three different tracks: a parabolic U-shaped track (harmonic oscillations – frequency independent of amplitude), V-shaped
   track (frequency decreases with amplitude), and flat-bottomed U-shaped track (frequency increases with amplitude).
   Conclusion – not all periodic oscillations are harmonic.
2. Observe special property of harmonic oscillator (mass on spring): elongation is proportional to force.
3. If time permits: measure spring constant for a mass on a spring, measure frequency of oscillation, compare to frequency formula.
4. Reduce mass by a factor of 4 – observe frequency <u>increase</u> by a factor of ….?

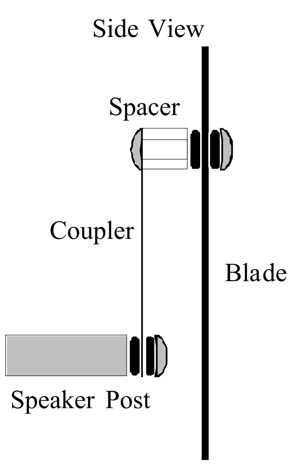
Experiment Part II:

Equipment:

Idea: mechanical oscillator allows students to see what is happening. But frequency must be high enough, e.g. 10 Hz, to reduce time to reach a steady state. Damping should be adjustable to study effect of damping on resonance curve. After various tries, our solution is to use oscillators built in-house, consisting of a stainless steel blade driven by a loudspeaker: a post glued to the loudspeaker is loosely coupled to the blade near the clamped end. Motion of blade detected by stain gauge attached to blade near supported end. Signal from strain gauge (Wheatstone bridge circuit) displayed on computer screen (we use Pasco Data Studio). Variable damping provided by permanent magnet placed near a rectangular copper paddle attached to the bottom of the blade.



The above photograph shows the overall arrangement. On the left is the oscillating blade which is clamped at the top. The black circular object is the speaker, which is coupled to the blade as shown below.



Two blade configurations tested recently produce good results. Both use 10.5”-long, 0.058”-thick, 340 Stainless Steel blades. A rectangular copper paddle 0.058”-thick (or 0.032”-thick) is attached at the bottom end of the blade with a permanent magnet nearby to provide adjustable damping.

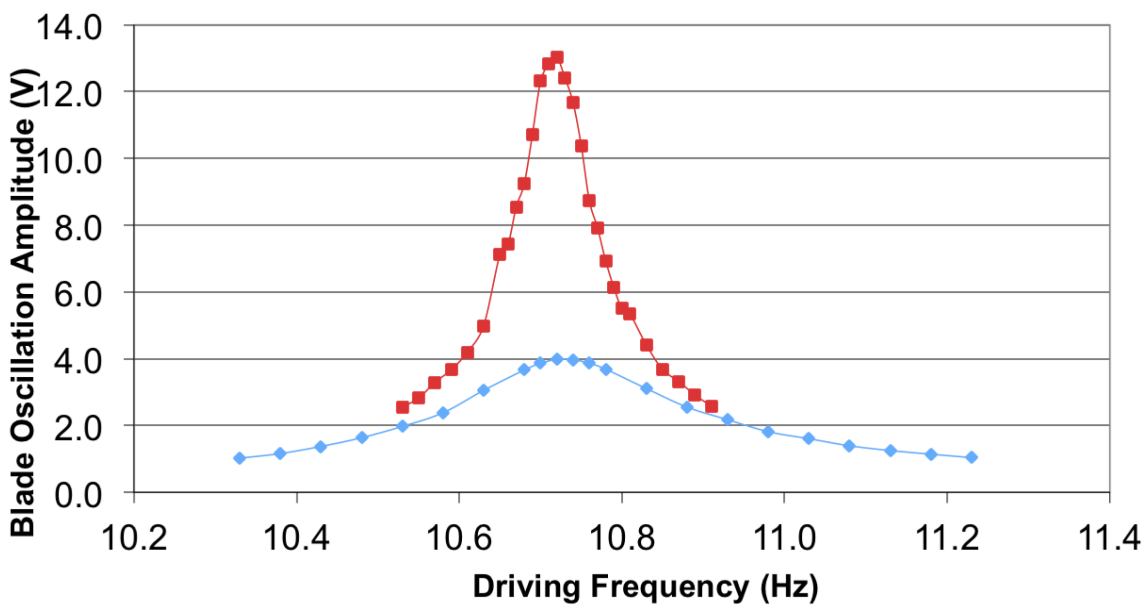
Other details include:

- 0.010"-thick steel coupler, connecting the speaker driving post with the blade
- 3/8"-long nylon spacer
- O-rings placed at two joints: one between the speaker driving post and the coupler, and the other at the driven point on the blade.
- driving point on the blade is located 1" below the clamped point, which is at the top of the blade.

Exercises:

1. Set driving frequency to be near resonance – turn off driving force and measure time t for amplitude to decrease to 1/2, 1/4 and 1/8 of initial amplitude.
2. Carefully measure the period of the oscillation as the amplitude decreases. In what sense does the oscillation "slow down" with time?
2. Measure resonance curve. Determine full width at half-maximum Df.
3. Compare product Dfxt to expected value (see text book by Gilbert-Haeberli).
4. Repeat for increased damping.

An example of measured resonance curve is shown below:



Comment: the construction of the above apparatus is fairly time consuming. A simpler way for students to observe resonance is by acoustic resonance e.g. of a coffee cup or a wooden box such as those used as resonator for tuning forks. We have done this as a lecture demonstration by placing a small loudspeaker some 10 cm from the box and placing a small microphone deep inside the box.