15 C Lab 1 Final Summary

Goals:

1. Provide an opportunity to consider the origin of the restoring force in real oscillating systems.
2. Provide an opportunity to consider what physical changes accompany oscillations and how those physical changes could be measured.
3. Illustrate that real physical systems have many modes and many resonant frequencies. Some systems can be fairly well modeled by considering a single dominant mode, whereas others cannot.
4. Highlight links between oscillation, damping, energy storage, and energy loss

Brief Theory Summary

Damped oscillator equation of motion : $d^2x/dt^2 + 2\gamma\, dx/dt + \omega_o^2\, x = 0$

Underdamped solution : $x(t) = A\, \mathrm{Exp}[-(\gamma t)]\ \cos(\omega_1 + \delta)$ where $\omega_1 = \omega_o\, \mathrm{Sqrt}(1 - \gamma^2/\omega_o^2) \sim \omega_o$

$Q = \omega_1 /(2\gamma) \sim \omega_o /(2\gamma) = (2\pi/T)/(2\gamma) = \pi/(T\gamma)$ where T is the period of the oscillation and $1/\gamma$ is the time change required for the amplitude of the oscillation has decayed to 1/e of the starting amplitude. NOTE Q is unitless. Many people divided time by frequency or visa versa

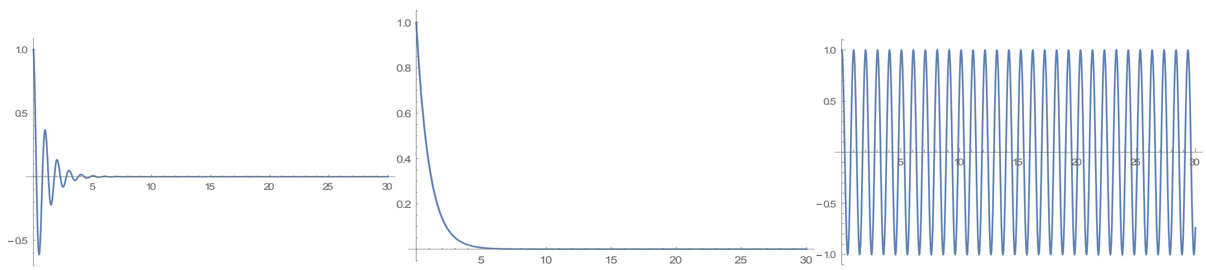
Your Results

1. Measure resonant frequency to ways and compare results
   a. Major approaches
      i. Excite the system using an impulse and then let the system evolve freely
         1. Strike a tuning fork, pluck a string, displace a mass from gravitational equilibrium, stretch a spring. After exciting, measure the resulting motion as the system evolves freely
         2. Measurements used microphones, human pitch detection, motion detectors, magnetic field detectors, cameras, and photodiodes. Use direct measurement of oscillation period or Fourier transform detection
      ii. Excite the system using a time varying signal which is swept until the resonant frequency is found
2. Measure Q two different ways
   a. Major approaches
      i. Find the time required for the signal to decay to 1/e
      ii. Measure the width of the resonance in frequency.
3. Change ω_o
   a. Change the length of the oscillating system. (e.g. shorten string or spring) Change the restoring force (e.g. string tension)
4. Change Q
   a. Increase damping by coupling the motion to a more lossy reservoir without shifting resonance (e.g. absorb energy by touching lightly with your hand)
   b. Change resonant frequency while keeping damping nearly constant

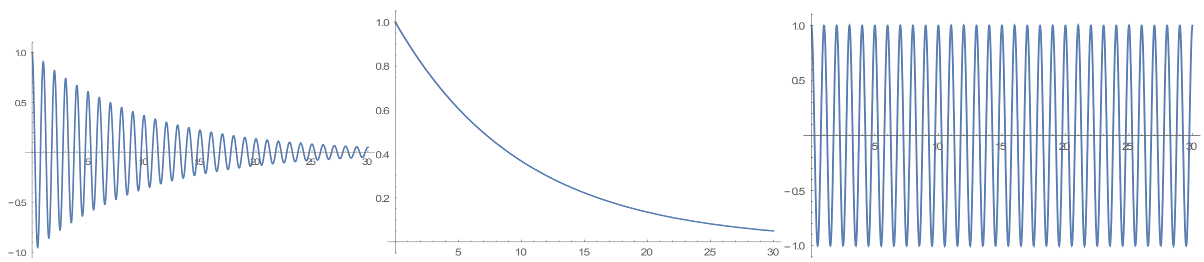
Example Results

Signal from microphone or photodiode and decomposition into oscillation and decay for a single oscillation frequency

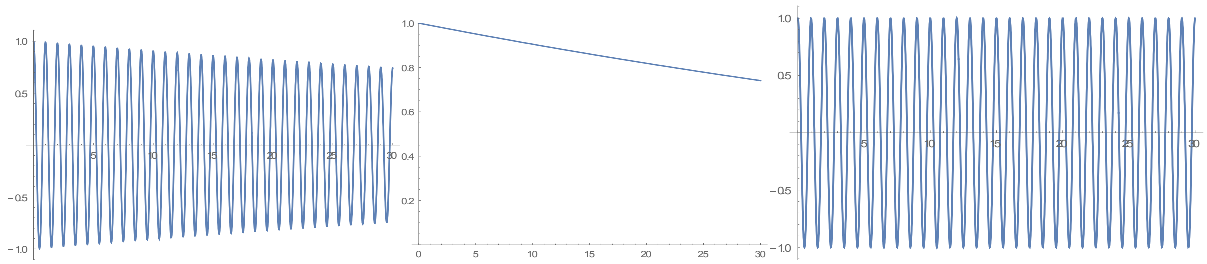
Q~3



Q~ 30



Q=300



Multiple frequencies and decay constants