Intro:
Last week we finished by deriving the equation of motion for waves on a string – the wave equation. This week we look into standing waves, harmonics, energy in waves, Fourier series, and, perhaps, start on the wave properties of sound...
I’ll be away at a quantum gravity workshop this week. Brian Collett and Gordon Jones will be teaching the class this week. There will be great demos and I am sorry that I will miss them!

Reading:
• Friday: HRW 16.5 - 16.7
• Monday: HRW 16.3 and 17.1 - 17.3
• Wednesday: HRW 17.4 - 17.8

Physics Topics:
• Transverse waves
• Standing waves
• Harmonics
• Sound

Math Topics:
• Wave equation (in 1 dimension)
• Boundary conditions and phase shifts
• Superposition
• Fourier series

Problems:
These problems will be due in class Wednesday February 28. Given the two weeks, Guide 6 will include these problems and will likely be a bit longer than usual. Getting started early is best!

1. Click over to the Phet resonance simulator and check that there is a single mass and that the mass is \( m = 2.533 \text{ kg} \), spring constant \( k = 100 \text{ N/m} \), and damping constant \( b = 0.1 \text{ Ns/m} \). Add a ruler. Play with the sim to get used to what it does.
   (a) Find \( \omega_0 \).
   (b) Add some more damping so that \( b = 1.0 \text{ Ns/m} \). What is the resonant angular frequency?
   (c) Find \( Q \) with these settings.
   (d) Explore the relative phase between the driver and the mass, \( \delta \) and make a plot of this function as you vary the driving frequency. I find that putting the ‘marker bugs’ on the ruler at the centers of the oscillations to be helpful. Slow-mo is also handy.
   (e) Compare this to what you expect from expression for \( \delta(\omega) \) in the solution of the driven damped harmonic oscillator.

2. What kind of waves did the wind excite on the Tacoma Narrows Bridge?

3. A 9.40 \( \pm 0.02 \) m length of the string you use in lab this week has a mass of 11.7 \( \pm 0.1 \) g. During the lab, the hanging mass on the end of the string, which provides the tension, will be 1050 \( \pm 1 \) g.
   (a) Determine the linear density of the string (in SI units).
(b) Determine the tension in the string.
(c) Calculate the wave speed in m/s.
(d) Find the uncertainty in the speed using error propagation.
(e) Write the speed in standard form to the correct precision.

(4) An ice covered electrical transmission line has length 347 m, linear density 3.35 kg/m and a tension of $6.52 \times 10^7$ N. What is the frequency of the fundamental? What is the frequency difference between successive modes?

(5) Let $z = x^3y + e^{xy^2}$.
   (a) Compute $\frac{\partial z}{\partial x}$.
   (b) Compute $\frac{\partial z}{\partial y}$.
   (c) Compute $\frac{\partial^2 z}{\partial x \partial y}$ and $\frac{\partial^2 z}{\partial y \partial x}$. Comment on this.
   (d) Compute $\frac{\partial^2 z}{\partial x^2}$.

(6) HRW 16.8
(7) HRW 16.22
(8) HRW 16.57

(9) A sinusoidal wave traveling on a string in the negative $x$ direction has amplitude 1.00 cm, wavelength 3.00 cm, and frequency 200 Hz. At $t = 0$, the particle of string at $x = 0$ is displaced a distance 0.80 cm above the origin and is moving upward.
   (a) Sketch the shape of the wave at $t = 0$.
   (b) Determine the function $y(x, t)$ describing the wave.

(10) **BONUS** Show that, for any “suitably nice function” (one you differentiate twice and it is still takes on finite values) $f$, $y(x, t) = f(kx + \omega t)$ satisfies the wave equation if $v = \omega/k$. This explains the observation from class that we could have very funny shaped wave pulses that still behaved as waves moving with a well-defined speed.

**Lab:**
Waves on a String: Investigating harmonics, speed of propagation, and other properties of 1D waves. It will be useful to have read 16.12-16.13 before lab.

**A look ahead...**
Fields! See Chapter 21.