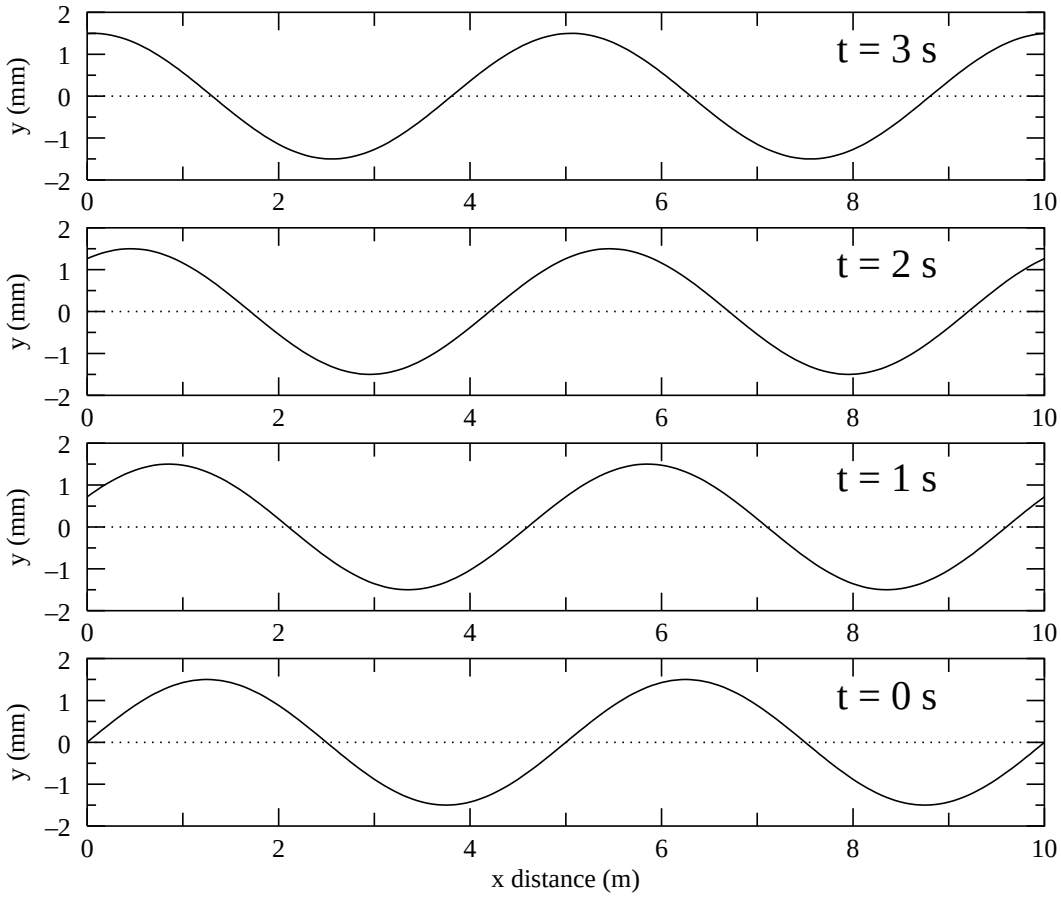
Physics 211 EXAM 1 2019 September 18

Answer four of the following six problems

**Properties of Sea Level Air:**

sound speed: $v = 340.3$ m/s
density: $\rho = 1.225$ kg/m$^3$
pressure: $p = 1$ atm $= 1.0133 \times 10^5$ Pa
temperature: 288.2 K = 15.0°C
$\gamma$ of air: 1.4

1. The below plots are frames from a movie showing the transverse displacement $y$ of a sinusoidal wave on a string at times ranging from $t = 0$ s (bottom) to $t = 3$ s (top). Write down the function $y(x, t)$ that describes this wave.




2. Three cosine functions with amplitudes and offsets: $a_1 = 5.32$, $\delta_1 = 1.253$ rad; $a_2 = 1.92$, $\delta_2 = 4.532$ rad; and $a_3 = 3.21$, $\delta_3 = 2.932$ rad; are to be added together:

$$\begin{aligned} g(t) &= a_1 \cos(\omega t + \delta_1) + a_2 \cos(\omega t + \delta_2) + a_3 \cos(\omega t + \delta_3) \\ &= A \cos(\omega t + \phi) \end{aligned}$$

Find the resulting function (i.e., $A$ and $\phi$).

3. Consider a traveling sound wave with frequency 441 Hz and displacement amplitude of 3 nm. Write down the displacement function (i.e., $y(x,t)$) describing this wave. What is the intensity (in dB) of this sound? What increase in dB would be required to make a sound wave with double the displacement amplitude?

4. An open-closed pipe is oscillating at 441 Hz which is its third harmonic.

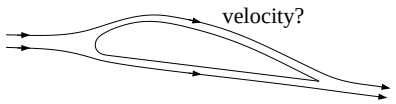
   (a) Sketch the resulting *displacement* wave i.e., $y(x,t)$ describing this standing wave. Write down the mathematical expression for the wave function $y(x,t)$ assuming the displacement amplitude at the open end of the pipe is 2 nm. (Set up your coordinate system so that $x = 0$ is the closed end of the pipe.)

   (b) How long is the pipe?

5. Consider the following situation: a Boeing 747 (i.e., a large airplane, with mass 271,000 kg) is cruising at Mach 0.543 at an altitude where the air pressure is 30.74 kPa, the air density is .466 kg/m$^3$, and the speed of sound is 303.5 m/s. The plane, in straight and level flight, is in equilibrium with the upward pressure force on the 541 m$^2$ wings balancing the force of gravity.

   (a) Making the 'spherical cow' approximation that the pressure difference between the top and bottom surface of the wings is uniform, what pressure difference is required to support the plane?

   (b) Assuming that (in the rest frame of the wing) the air speed on the bottom of the wing is Mach 0.543, what air speed on the top of the wing is required according to Bernoulli to achieve the pressure difference calculated in (a) above.




6. An F-15 approaches the 747 of problem #5 directly from the rear at a speed of Mach .763. The F-15's jet engine produces a high frequency whine at 17.1 kHz. What frequency is heard by the pilot of the 747?