Engineering Physics I — Name ____________________

PHYS 1210 — Spring 2015

Discussion 13 – Waves and Sound (Ch 15-16)

Equations

$v = f\lambda$

$$y(x,t) = A\cos\left[\omega\left(\frac{x}{v} - t\right)\right] = A\cos 2\pi f\left(\frac{x}{v} - t\right) \quad (15.3)$$

$$y(x,t) = A\cos 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right) \quad (15.4)$$

$$y(x,t) = A\cos(kx - \omega t) \quad (15.7)$$

where $k = 2\pi/\lambda$ and $\omega = 2\pi f = vk$

$$\frac{\partial^2 y(x,t)}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y(x,t)}{\partial t^2} \quad (15.12)$$

$$v = \sqrt{\frac{F}{\mu}} \quad \text{(waves on a string)} \quad (15.13)$$

$$p_{max} = BkA$$

(sinusoidal sound wave)

$$v = \sqrt{\frac{B}{\rho}}$$

(longitudinal wave in a fluid)

$$v = \sqrt{\frac{\gamma RT}{M}}$$

(sound wave in an ideal gas)

$$v = \sqrt{\frac{Y}{\rho}}$$

(longitudinal wave in a solid rod)

$$I = \tfrac{1}{2}\sqrt{\rho B}\,\omega^2 A^2 = \frac{p_{max}^2}{2\rho v} = \frac{p_{max}^2}{2\sqrt{\rho B}} \quad (16.12), (16.14)$$

(intensity of a sinusoidal sound wave)

$$\beta = (10\text{ dB})\log\frac{I}{I_0} \quad (16.15)$$

(definition of sound intensity level)

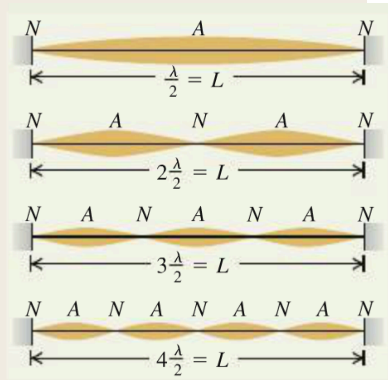
$$y(x,t) = (A_{SW}\sin kx)\sin\omega t \quad (15.28)$$

(standing wave on a string, fixed end at $x = 0$)

$$f_n = n\frac{v}{2L} = nf_1 \; (n = 1, 2, 3, \ldots) \quad (15.33)$$

$$f_1 = \frac{1}{2L}\sqrt{\frac{F}{\mu}} \quad (15.35)$$

(string fixed at both ends)

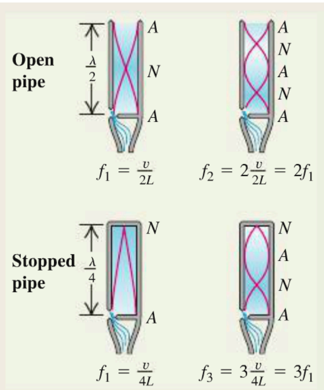


$$f_n = \frac{nv}{2L} \quad (n = 1, 2, 3, \ldots) \quad (16.18)$$

(open pipe)

$$f_n = \frac{nv}{4L} \quad (n = 1, 3, 5, \ldots) \quad (16.22)$$

(stopped pipe)



$$f_{beat} = f_a - f_b$$

(beat frequency)

$$f_L = \frac{v + v_L}{v + v_S} f_S$$

$$\sin\alpha = \frac{v}{v_S}$$

Problems (Young & Freedman 13e)

1) For at least one stringed instrument brought to class, calculate the tension in one of the strings. **State any assumptions you need to make.** You can double check with the first overtone, which can be played without the fundamental by placing your finger just above the string at the halfway point – do not touch the string while it isn't plucked, but once the string is plucked you will feel it hit your finger with the vibrations. This damps out the fundamental (and all odd-numbered harmonics), but leaves the first overtone (second harmonic) as the loudest remaining pitch.

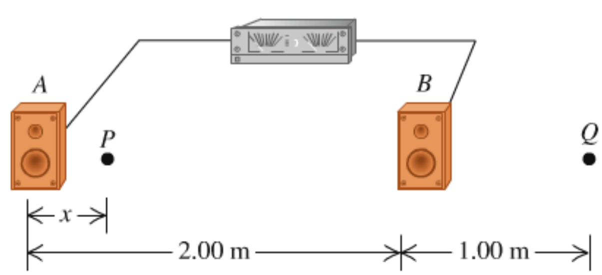
2) For at least one wind instrument brought to class, calculate the fundamental frequency and check using a phone app or other device (e.g., PanoTuner for iOS). Also calculate the 1st overtone (also called the 2nd harmonic). For wind instruments, the first overtone can be played without the fundamental by overblowing (blowing somewhat harder than usual). **State any assumptions you need to make.**

15.27 • **Energy Output.** By measurement you determine that sound waves are spreading out equally in all directions from a point source and that the intensity is 0.026 W/m^2 at a distance of 4.3 m from the source. (a) What is the intensity at a distance of 3.1 m from the source? (b) How much sound energy does the source emit in one hour if its power output remains constant?

15.28 • A fellow student with a mathematical bent tells you that the wave function of a traveling wave on a thin rope is $y(x, t) = 2.30\text{ mm}\cos[(6.98\text{ rad/m})x + (742\text{ rad/s})t]$. Being more practical, you measure the rope to have a length of 1.35 m and a mass of 0.00338 kg. You are then asked to determine the following: (a) amplitude; (b) frequency; (c) wavelength; (d) wave speed; (e) direction the wave is traveling; (f) tension in the rope; (g) average power transmitted by the wave.

16.33 • Two loudspeakers, A and B (Fig. E16.33), are driven by the same amplifier and emit sinusoidal waves in phase. Speaker B is 2.00 m to the right of speaker A. Consider point Q along the extension of the line connecting the speakers, 1.00 m to the right of speaker B. Both speakers emit sound waves that travel directly from the speaker to point Q. (a) What is the lowest frequency for which *constructive* interference occurs at point Q? (b) What is the lowest frequency for which *destructive* interference occurs at point Q?

Figure **E16.33**



16.50 • A railroad train is traveling at 30.0 m/s in still air. The frequency of the note emitted by the train whistle is 262 Hz. What frequency is heard by a passenger on a train moving in the opposite direction to the first at 18.0 m/s and (a) approaching the first and (b) receding from the first?

3) 51 Peg b is the first exoplanet that was detected around another star, and it was done so using the Doppler shift. (See http://en.wikipedia.org/wiki/Doppler_spectroscopy for a summary of the method.) Using the graph provided, answer the following.

a) Assuming the rest wavelength of the light was 656.3 nm, what was the range of observed wavelengths?
b) Using the period of the orbit, and assuming the mass of the host star (51 Peg) is 1.11 times that of the Sun, how far away from the star is the planet 51 Peg b located?
c) How fast is the planet moving? (Use orbital speed.)
d) Using momentum and the above information, what is the planet's mass?