

# Week 13 Activities Problems

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PHYS-111 2pm Lab

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## Beats

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1. The little brown bat is a common bat species in North America. It emits echolocation pulses at a frequency of  $40\text{kHz}$ , well above the range of human hearing. To allow observers to “hear” these bats, an electronic bat detector combines the bat’s sound wave with a wave created by a tunable oscillator. The resulting beat frequency is isolated, amplified, then played through a speaker. What frequency should the oscillator be set to produce an audible beat frequency of  $3.0\text{kHz}$ ?

$$\begin{aligned}f_{beat} &= |f_1 - f_2| \\f_1 &= f_{beat} \pm f_2 \\f_1 &= 3.0\text{kHz} \pm 40\text{kHz} \\&\underline{|f_1 = 43\text{kHz}, 37\text{kHz}|}\end{aligned}\tag{1}$$

## Sound Waves Interference

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1. Two identical sources emit sound of frequency  $2.00\text{kHz}$  and a speed of  $v = 343\text{m/s}$ . They are separated by  $d_{diff} = 25.7\text{cm}$ . Assume no loss in intensity with distance.
  1. Calculate the interference heard at a distance of  $5.00\text{m}$  away along the axis joining the speakers.

$$\begin{aligned}d_{diff} &= n\lambda \\ \lambda &= \frac{d_{diff}}{n} \\ f &= \frac{vn}{d_{diff}}\end{aligned}\tag{2}$$

If  $2n$  is an even integer, then it is constructive interference. If  $2n$  is an odd integer, then it is destructive interference. If  $2n$  is not an integer, it is partial interference.

$$\begin{aligned}
 f &= \frac{vn}{d_{diff}} & (3) \\
 n &= \frac{fd_{diff}}{v} \\
 n &= \frac{(2.00kHz)(25.7cm)}{343m/s} \\
 n &= 1.498542274 \approx 1.5 \\
 2n &= 3
 \end{aligned}$$

3 is odd, therefore, it is completely destructive interference.

2. You now increase the frequency of both speakers. Calculate the next frequency for which you will hear destructive interference.

$$\begin{aligned}
 2n &= 5; \quad n = 2.5 & (4) \\
 f &= \frac{vn}{d_{diff}} \\
 f &= \frac{(343m/s)(2.5)}{25.7cm} \\
 f &= 3.336575875kHz \\
 \underline{f} &= \underline{3.34kHz}
 \end{aligned}$$

3. Now return to  $2.00kHz$ . What can you do to get the opposite type of interference as in part 1.1?

Change the distance, either from the listener to the speakers, or between the speakers.

2. 2 isotropic point sources produce sound waves that are in phase with each other at the positions of the sources. Source 1 is  $d_1 = 17.1m$  from the observer, and Source 2 is  $d_2 = 41.6m$  from the observer. What are the 3 lowest frequencies in the audible range at which fully destructive interference will occur at the position of the observer? Ignore the loss of intensity. Use  $v = 343m/s$  for the speed of sound in air. Waves are in complete destructive interference when they are one half wavelength out of phase. This means that the difference between  $d_1$  and  $d_2$  has to be equal to some half-integer multiple of the wavelength. Therefore:

$$\begin{aligned}
 d_{diff} &= d_2 - d_1 = 41.6m - 17.1m = 24.5m & (5) \\
 d_{diff} &= \frac{n}{2}\lambda \\
 \lambda &= \frac{2d_{diff}}{n}
 \end{aligned}$$

Given  $v$ , we can choose  $n$  such that it fits within the human hearing range  $20Hz - 20kHz$ .

$$f = \frac{v}{\lambda} \quad (6)$$

$$f = \frac{vn}{2d_{diff}}$$

$$20Hz \leq f \leq 20kHz$$

Inputting  $f = 20Hz$  does not give us an integer  $n$ , but rather gives us guidance as to where our first value will be. The first integer above  $n_{20Hz} = 2.857...$  is 3. Thus, the 3 lowest frequencies where destructive interference will be calculated using  $f = \frac{vn}{2d_{diff}}$ , where  $n = 3, 4, 5$ .

$$\boxed{f = 21.0Hz, 35.0Hz, 49.0Hz} \quad (7)$$

## Standing Waves

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1. A string of length  $L = 2.00m$  is fixed at both ends and tightened until the wavespeed is  $40.0m/s$ .

1. What is the wavelength of the standing wave, given that the wave has 6 antinodes?

$$\lambda = \frac{2L}{n} \quad (8)$$

$$\lambda = \frac{2(2.00m)}{6}$$

$$\lambda = 0.6\bar{6}m$$

$$\boxed{\lambda = 0.67m}$$

2. What is the frequency of the standing wave stated above?

$$f = \frac{v}{\lambda} \quad (9)$$

$$f = \frac{40.0m/s}{0.67m}$$

$$\boxed{f = 60Hz}$$

3. What is the fundamental frequency of the stretched string?

$$f_0 = 10Hz$$

4. If tension in the string is  $T = 3.60N$ , what is the mass per unit length of the string?

$$\begin{aligned}
 v &= \sqrt{\frac{T}{\mu}} \\
 \mu &= \frac{T}{v^2} \\
 \mu &= \frac{3.60N}{(40m/s)^2} \\
 \underline{\underline{|\mu = 2.25 \times 10^{-3} kg/m|}}
 \end{aligned} \tag{10}$$

2. A  $m = 12.5g$  clothesline is stretched with a tension  $T = 22.1N$  between 2 poles  $L = 7.66m$  apart.

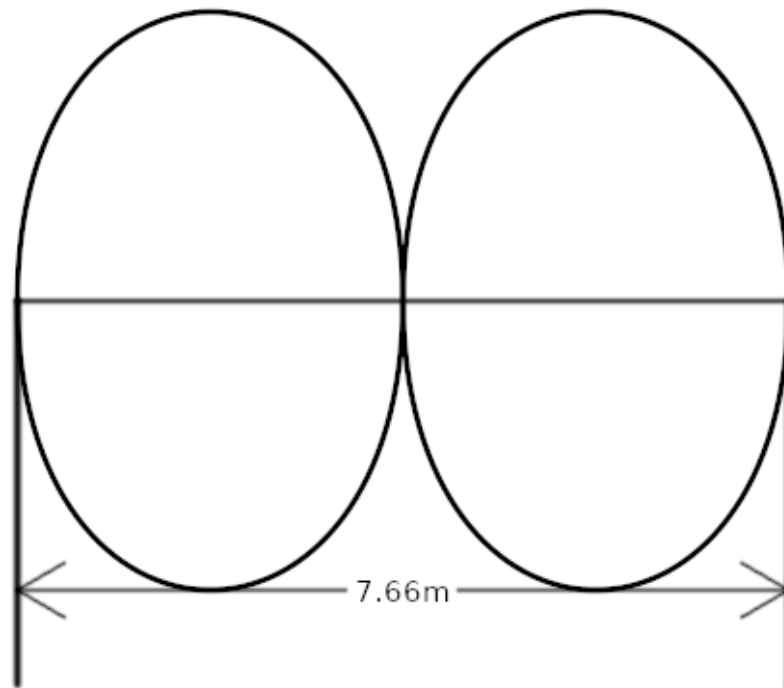
1. What is the fundamental frequency?

$$\begin{aligned}
 f &= \frac{v}{\lambda}; v = \sqrt{\frac{T}{\mu}}; \lambda = 2L; \mu = \frac{m}{L} \\
 f &= \frac{\sqrt{\frac{T}{\frac{m}{L}}}}{2L} \\
 f &= \frac{\sqrt{\frac{22.1N}{\frac{12.5g}{7.66m}}}}{2(7.66m)} \\
 f &= 7.596206281Hz \\
 \underline{\underline{|f = 7.60Hz|}}
 \end{aligned} \tag{11}$$

2. What is the frequency of the second harmonic?

$$\begin{aligned}
 f_n &= nf_0 \\
 f_n &= 2(7.60Hz) \\
 \underline{\underline{|f_n = 15.20Hz|}}
 \end{aligned} \tag{12}$$

3. Make a simple sketch of the standing wave pattern corresponding to the second harmonic.



4. If the tension in the clothesline is increased, does the frequency of the second harmonic change?

The frequency will also increase. This is because  $f = \sqrt{\frac{T}{4mL}}$ ;  $f \propto T^{\frac{1}{2}}$ .

5. If a heavier rope is used, but is stretched the same distance under the same tension, does the frequency of the second harmonic change?

The frequency will decrease. This is because  $f = \sqrt{\frac{T}{4mL}}$ ;  $f \propto \frac{1}{m^{\frac{1}{2}}}$ .