Lecture 21

Review for Exam 2

Ch. 15-17

Key concepts to review

- simple harmonic motion, transfer of potential & kinetic energy
- pendulum, both ideal w/ massless string & point mass @ end, as well as physical pendulum w/ complicated mass distribution & moment of inertia
- uniform circular motion
- transverse wave traveling on a string, period, wavelength, wave speed

- wave speed on a stretched string in terms of tension & linear density
- standing waves for a string attached to a wall, nodes & antinodes, resonant frequencies, harmonics
- traveling sound waves (longitudinal) interference, path length differences
- intensity and sound level of sound waves, variation of intensity w/ distance (for a point source)
- standing sound waves in pipes, what are harmonics when both ends are open, when one end is open?

beats - $f_{beat} = f_1 - f_2$

Doppler effect -

detector moving toward stationary source

$$f' = \frac{v+v_D}{v} f$$

detector moving away from stationary source

$$f' = \frac{v-v_D}{v} f$$

source moving toward stationary detector

$$f' = \frac{v}{v-v_s} f$$

Source moving away from stationary detector

$$f' = \frac{v}{v+v_s} f$$

Example problems

Quiz questions

equation for wave traveling on a string:

$$y(x,t) = 4 \sin(3x + 8t)$$

what is wave speed?

general form is

$$y_m \sin(kx \pm \omega t)$$

- y_m ↑ amplitude
- k ↑ wave number $k = \frac{2\pi}{\lambda}$ $\frac{\text{radians}}{\text{m}}$
- ω ← angular freq. $\omega = \frac{2\pi}{T}$ $\frac{\text{radians}}{\text{sec}}$

wave speed $v = \frac{\omega}{k} = \frac{\lambda}{T}$ check units!

$$\Rightarrow v = \frac{8}{3} \text{ m/s}$$

What is direction of travel?

$\sin(kx - \omega t)$ to the right $(+x)$

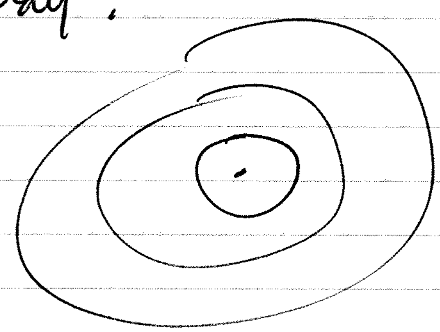
$\sin(kx + \omega t)$ to the left $(-x)$

<u>Intensity</u>

sound wave created by point source @ 1W

What is intensity @ distance 100 m away?

$$I = \frac{P}{A}$$



conservation of energy implies equal ~~power~~ energy @ each wavefront

- but larger spheres have larger surface area, $I = P \,/\,$ surface area of sphere

$$I = \frac{1W}{4\pi (100m)^2} = 7.96 \times 10^{-6} \frac{W}{m^2}$$

From homework:

Ambulance w/ a siren emitting a whine @ 1600 Hz overtakes + passes a cyclist pedaling a bike @ 2m/s in same direction

After being passed, cyclist hears frequency of 1590 Hz. speed of sound 343 m/s

How fast is ambulance moving?

$$f' = \frac{v \pm v_D}{v \pm v_S} f$$

which one?

detector is cyclist moving toward
(action increases freq.)

Source is ambulance moving away
(action decreases freq.)

$\Rightarrow \quad f' = \dfrac{v + v_D}{v + v_S} f$

$1590\,\text{Hz} = \dfrac{343 + 2}{343 + v_S} 1600\,\text{Hz}$

$\Rightarrow \quad \cancel{\dfrac{1590}{1600}} \cdot \quad 343 + v_S = \dfrac{345 \cdot 1600}{1590}$

$\Rightarrow \quad v_S = 4.17\ \text{m/s}$

Checkpoint question on page 495

pipe A has length L & pipe B has length 2L. Both have open ends. Which harmonic of pipe B has the same frequency as the fundamental of pipe A?

1) fundamental of pipe A is

$$f_{n,A} = \frac{nv}{2L} \quad \text{w/ } n=1 \text{ \& } v = 343\,m/s$$

$$f_{1,A} = \frac{v}{2L}$$

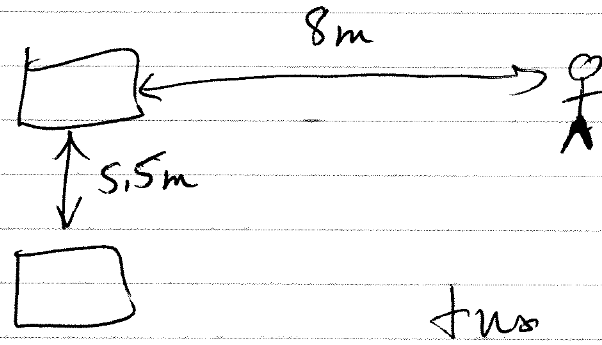
resonant frequencies of pipe B are

$$f_{n,B} = \frac{nv}{2\cdot(2L)}$$

$$= \frac{nv}{4L}$$ then $n=2$ gives $f_{2,B} = \frac{v}{2L}$

so second harmonic of pipe B is the same

Problem 2 from Spring 2018



Mardi Gras parade

two floats play music @ 330 Hz

a) What is angular freq.? of sound waves

$$\omega = 2\pi f = 2\pi \cdot 330\,\text{Hz}$$

$$= 2073.45 \text{ rad/s}$$

b) Calculate phase difference between waves that reach Bob.

$$\phi = \Delta L \frac{2\pi}{\lambda}$$

ΔL is path length difference between sources

$L_1 = 8m$

$L_2 = \sqrt{(8)^2 + (5.5)^2}$

$= 9.71$

$\Delta L = 9.71_m - 8m$

$= 1.71m$

$v = f\lambda \Rightarrow \lambda = \frac{v}{f} = \frac{343 m/s}{330 Hz}$

$\Rightarrow \phi = \frac{1.71m}{343/330} \cdot 2\pi = 10.34$ rad

displacement amplitude of sound emitted by chariots is $9 \times 10^{-7} m$. What is displacement amplitude of wave that Bob hears?

$s'(x,t) = \underbrace{2 s_m \cos(\phi/2)}_{\text{new disp. amplitude}} \cos(kx - \omega t + \phi/2)$

$$2 s_m \cos(\phi/2) = 2 \cdot (9 \cdot 10^{-7} m) \cdot \cos\left(\frac{10.34}{2}\right)$$

$$= 7.95 \cdot 10^{-7} m$$

last part is a Doppler question

2019 Question 11

String w/ linear density 2 g/m tied to sinusoidal oscillator & runs over support, stretched by a weight that provides tension τ, If length is 1.5m & oscillator freq. is 210 Hz, what tension leads to 4th harmonic?

4th harmonic $n=4$

$$\Rightarrow f_n = \frac{n v}{2L} \qquad v = \sqrt{\frac{\tau}{\mu}}$$

$$v = \lambda_n f_n$$

$f_4 = 210\ \text{Hz}$

$$\lambda_4 = \frac{v}{f_4} = \frac{v}{4v} \cdot 2L = L/2$$

$$\Rightarrow \lambda_4 = L/2 = \frac{1.5}{2} = .75\ \text{m}$$

$\Rightarrow$ Then using $v = \sqrt{\frac{\tau}{\mu}}$

$$\Rightarrow v^2 \cdot \mu = \tau$$

$$\Rightarrow (\lambda_4 \cdot f_4)^2 \cdot \mu = \tau$$

$$(.75\ \text{m} \cdot 210\ \text{Hz})^2 \cdot .002\ \text{kg/m}$$

$=$

49.6 N