PHY138 – Waves, Lecture 5

Today's overview

- The Principle of Superposition
- Standing Waves
- The Guitar: Stringed Instruments
- The Trumpet: Wind Instruments

Doppler Effect, Section 20.7

- When the observer is stationary, and the source is moving at speed v_s directly toward or away from the observer:

$$f_+ = \frac{f_0}{1 - v_s / v} \qquad f_- = \frac{f_0}{1 + v_s / v}$$

- When the source is stationary, and the observer is moving at speed v_o directly toward or away from the source:

$$f_+ = (1 + v_o / v) f_0 \qquad f_- = (1 - v_o / v) f_0$$

Which statement is true?

Adrienne is standing in the middle of the road, as a police car approaches her at a constant speed, v. The siren on the police car emits a "rest frequency" of f_0.

A. The frequency she hears rises steadily as the police car gets closer and closer.
B. The frequency she hears steadily decreases as the police car gets closer and closer.
C. The frequency she hears does not change as the police car gets closer.

Which statement is true?

Adrienne is standing still as a police car approaches her at a constant speed, v. Suzanne is in her cadillac moving at the same constant speed, v, toward an identical police car which is standing still. Both hear a siren.

A. The frequency Suzanne hears is lower than the frequency Adrienne hears. (Actual Answer! Check eq.20.38 and 20.39!)
B. The frequency Suzanne hears is higher than the frequency Adrienne hears.
C. The frequencies that Suzanne and Adrienne hear are exactly the same. (Almost correct)

Message from Dr. Savaria….

- If you have a conflict at 6:00-7:30 PM on Dec.4 and wish to write Test 2 at an alternate time:
  - Send an email to phy138y@physics.utoronto.ca (or reply to seeley) confirming that you wish to re-register, if you registered for the alternate sitting of Test 1.

or

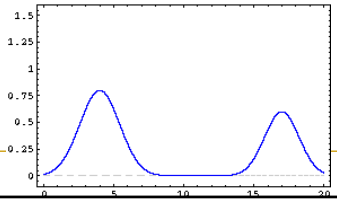
  - Visit April Seeley in MP129 or MP302 to register for the first time you will write in an alternate time.
- The deadline for confirming / registering is Nov.26 by 5:00PM.

Reading Assignment

- This week's reading assignment from the text by Knight is: **Chapter 21**, Sections 21.1-21.8
- Suggested Chapter 21 Exercises and Problems for Practice: 7, 19, 25, 31, 49, 65, 71, 83 (skip part b – just use result)
- Waves Quarter **Written Team Problem Set** is due Friday by 5:00 PM in T.A. drop box. – You must work in the teams assigned to you in tutorial.

Chapter 21: Principle of Superposition

- If two or more waves combine at a given point, the resulting disturbance is the *sum* of the disturbances of the individual waves.
- Two traveling waves can pass through each other without being destroyed or even altered!



Some *Results* of Superposition:

- 21.2-21.4: Two waves, same wavelength and frequency, opposite direction:

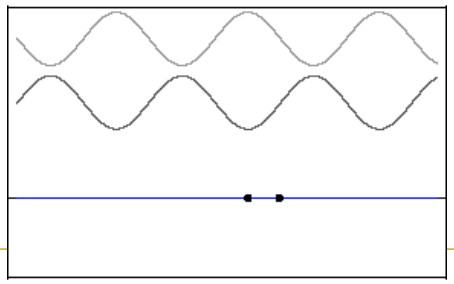
  Standing Wave
- 21.5-21.7: Two waves, same wavelength and frequency, similar direction, different phase:

  Interference
- 21.8: Two waves, same direction, slightly different frequency and wavelength:

  Beats!

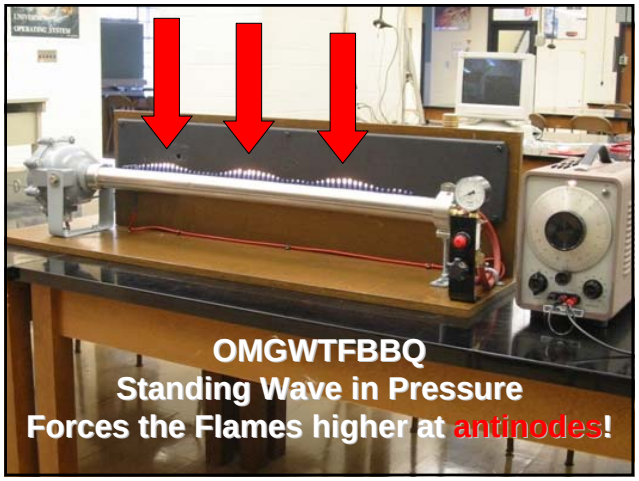
Standing Wave:

The superposition of two 1-D sinusoidal waves traveling in opposite directions.



Standing Waves

- Are a form of “resonance”
- There are multiple resonant frequencies called harmonics
- The boundary conditions and speed of waves determine which frequencies are allowed.
- The ends of the resonant cavity have forced nodes or antinodes
- With a wave on a string, it is possible to force an intermediate node



Harmonic frequencies on a violin

Transverse standing wave on a string clamped at both ends: there are nodes in displacement at both ends.

$$f_m = m\frac{v}{2L} \qquad (m = 1,2,3,...)$$

A violin and all other stringed instruments almost always operate in the m = 1 or fundamental frequency.

Violin Demonstration

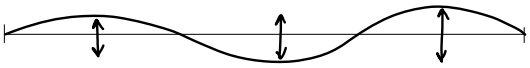
A-string, fundamental frequency (A-note)

A-string, second harmonic (m = 2, A-note)

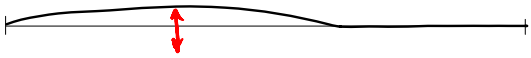
Higher octave A-note played in the normal way

Violin Demonstration

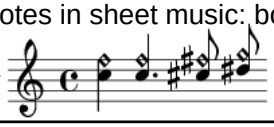
A-string, third harmonic (*m* = 3, D-note)



D-note played in the normal way



Harmonic notes in sheet music: boxes



Harmonic frequencies in air column

Standing sound wave in a tube open at both ends: there are nodes in pressure both ends.

$$f_m = m\frac{v}{2L} \qquad (m = 1,2,3,...)$$

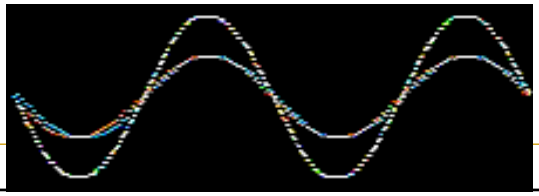
Standing sound wave in a tube closed at one end: there is a node in pressure at the open end, and an anti-node at the closed end.

$$f_m = m\frac{v}{4L} \qquad (m = 1,3,5,...)$$

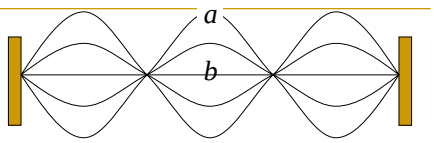
Standing Wave Quiz

The white wave is the sum of the blue and red waves. It is the

A. Fundamental Frequency (m=1)
B. Second Harmonic (m=2)
C. Third Harmonic (m=3)
D. Fourth Harmonic (m=4)
E. Fifth Harmonic (m=5)

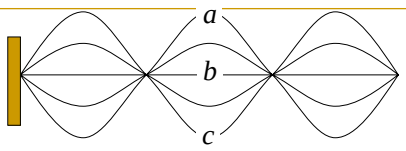


Quiz



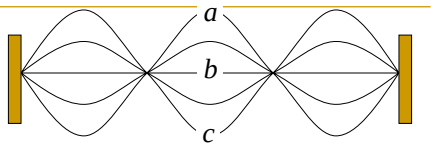
- A string is clamped at both ends and plucked so creates a standing wave. Define upward motion to be positive velocities. When the string is in position *a*, the instantaneous velocity of points along the string
- A. is zero everywhere
- B. is positive everywhere
- C. is negative everywhere
- D. depends on location

Quiz



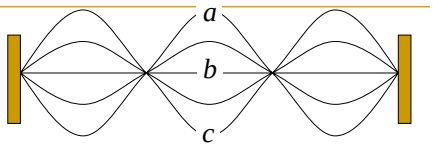
- A string is clamped at both ends and plucked so creates a standing wave. Define upward motion to be positive velocities. When the string is in position *b*, the instantaneous velocity of points along the string
- A. is zero everywhere
- B. is positive everywhere
- C. is negative everywhere
- D. depends on location

Quiz



- A string is clamped at both ends and plucked so creates a standing wave. Define upward motion to be positive velocities. When the string is in position *c*, the instantaneous velocity of points along the string
- A. is zero everywhere
- B. is positive everywhere
- C. is negative everywhere
- D. depends on location

Quiz



- A string is clamped at both ends and plucked so creates a standing wave. Define upward motion to be positive velocities. When the string is in position *b*, the instantaneous **acceleration** of points along the string
- A. is zero everywhere
- B. is positive everywhere
- C. is negative everywhere
- D. depends on location