

Physics 1408/1420 – General Physics 1

Week of October 31st, 2022

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Hello Fellow Physicists,

I am Jorge Martinez, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring sessions, so be sure to visit the tutoring center or visit <https://baylor.edu/tutoring>.

PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Monday from 6:30-7:30 pm in the Sid Richardson building basement, Room 74. See you there!

In the past two weeks, your professors will have covered oscillations. This week, you will finish studying waves and sound.

Keywords: Sound, Standing Waves in Strings and Tubes, Doppler Effect

Important Notes

Important Conventions

Sound:

Sound is a longitudinal wave that travels through a medium. It always requires a medium for propagation. Due to this characteristic, sound travels through different substances at different velocities. The closer the molecules of the substance are, the faster the propagation of sound.

Hence, sound travels faster in solids than air. Due to this quality, the speed of sound in air also varies due to the temperature of air. The velocity can be calculated using the following

$$v \approx (331 + 0.60T)$$

As sound is a wave, the characteristics of the wave can affect the sound. Loudness is related to the intensity of the wave. The pitch of a sound is determined by the frequency of the wave. The intensity is the energy transported by a wave.

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

This relationship is used to quantify the sound level(β) using decibels. It is measured in reference to a chosen intensity level. For humans it is 10^{-12} W/m²

Example:

At a busy street corner, the sound level is 75 dB. What is the intensity of sound there?

Solution

$$\beta = 10 \log (I / I_0)$$

$$75/10 = \log (I / 10^{-12})$$

$$10^{7.5} = I / 10^{-12}$$

$$I = 3.2 \times 10^{-5} \text{ W/m}^2$$

Strings:

Stringed instruments like guitars, violins, and pianos all depend on the production of standing waves. As we saw last week, standing waves depend on the fundamental frequency of the strings. The order of the standing wave determines the frequency of the sound produced. Using this fact and its relation to the wave speed, length of the string, and tension in the string, musical instruments are designed to produce the various notes they do. The frequency of the standing waves and their wave speed are calculated using the following equations.

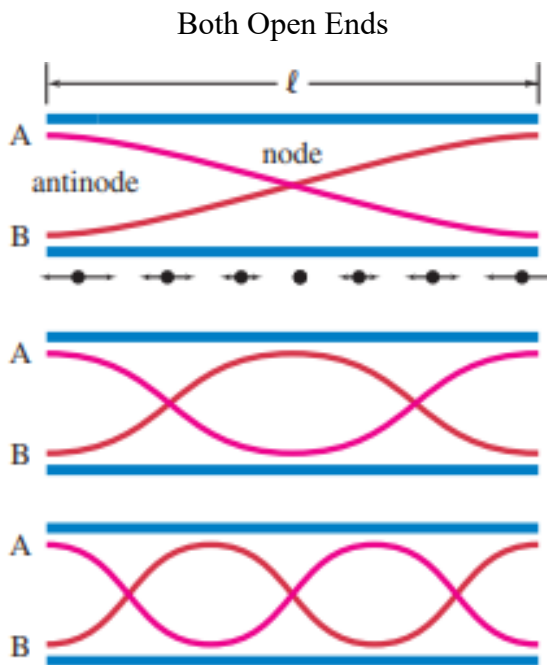
$$f_n = n f_1 = n \frac{v}{2\ell}, \quad n = 1, 2, 3, \dots \quad v = \sqrt{F_T / \mu}.$$

The F_T is the tension of the string. The μ is the mass per unit length for the string.

μ = mass/length.

Wind:

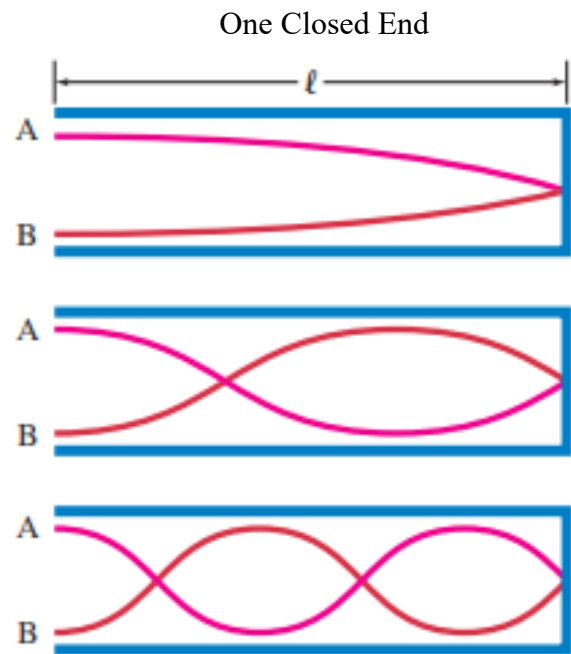
In wind instruments, sound still travels as waves. The behavior of the waves is affected by the morphology of the tube that it travels in. either both ends can be open or one of the ends can be closed. Due to this, the formation of standing waves in wind instruments changes its behavior.



$$\text{Length } (l) = (n/2) \lambda_n$$

$$f_n = (n/2) (v/l) = nf_1$$

$$n = 1, 2, 3, \dots$$



$$\text{Length } (l) = (n/4) \lambda_n$$

$$f_n = (n/4) (v/l) = nf_1$$

$$n = 1, 3, 5, \dots$$

The conditions for standing waves are indicated below the diagram. **It is important to keep these characteristics for the wave straight and to remember that in one closed end tube, the order for the wave is odd for each sequential harmonic.**

Example

What will be the fundamental frequency for a 26 cm long organ pipe at 20°C if both ends are open and if one end is closed?

Solution

Open: $f_1 = v/2l$

$$= 343 / 2(0.26)$$

$$= 660 \text{ Hz}$$

Closed: $f_1 = v/4l$

$$= 343 / 4(0.26)$$

$$= 330 \text{ Hz}$$

Doppler Effect:

When the source of sound is no longer stationary, the pitch of the sound changes for an observer based on the direction of motion of the source relative to the observer. This effect is known as the Doppler Effect and it occurs with light and sound. When the source is moving toward the observer, the frequency of the wave is higher for the observer. When the source is moving away from the observer, the frequency of the wave decreases for the observer. When it is sound, the pitch increases when the source moves toward the observer and the pitch decreases when moving away from the observer. To calculate the new frequency for the observer, we use the following equations.

$$f' = \frac{f}{\left(1 - \frac{v_{\text{source}}}{v_{\text{snd}}}\right)} \quad \left[\begin{array}{l} \text{source moving toward} \\ \text{stationary observer} \end{array} \right]$$

$$f' = \frac{f}{\left(1 + \frac{v_{\text{source}}}{v_{\text{snd}}}\right)} \quad \left[\begin{array}{l} \text{source moving away from} \\ \text{stationary observer} \end{array} \right]$$

Example

The Siren of a police car at rest emits at a predominant frequency of 1600 Hz. What frequency will you hear if you are at rest and the police car moves at 25 m/s.

- (a) Toward you
- (b) Away from you

Solution

$$(a) \quad f' = \frac{f}{\left(1 - \frac{v_{\text{source}}}{v_{\text{snd}}}\right)} = \frac{1600 \text{ Hz}}{\left(1 - \frac{25.0 \text{ m/s}}{343 \text{ m/s}}\right)} = 1726 \text{ Hz}$$

$$(b) \quad f' = \frac{f}{\left(1 + \frac{v_{\text{source}}}{v_{\text{snd}}}\right)} = \frac{1600 \text{ Hz}}{\left(1 + \frac{25.0 \text{ m/s}}{343 \text{ m/s}}\right)} = 1491 \text{ Hz}$$

This chapter requires lots of practice with using these equations. I recommend you use the practice questions in the textbook to reinforce using each of them

CHECK YOUR LEARNING

1. A stone is dropped from the top of a cliff. The splash it makes when striking the water below is heard 5 s later. How high is the cliff?
2. What resonant frequency would you expect from blowing across the top of an empty soda bottle that is 17 cm deep, if you assumed it was a closed tube?
3. The string on a violin has a fundamental frequency of 300 Hz. The length of the vibrating portion is 28 cm and it has a mass of 0.5g. Under what tension must the string be placed?
4. The predominant frequency of a certain fire truck is 1400 Hz when at rest. What frequency do you detect if you move with a speed of 20 m/s (a) toward the fire truck, (b) away from it?

THINGS YOU MAY STRUGGLE WITH

1. Visualize the sound wave. Remember from last week, sound waves are longitudinal, and they are composed of compressions and expansions. Most important of all is what a wave is. Waves are the transmission of energy through a medium. Hence sound is a longitudinal wave.
2. Remember the various frequency modes for the different systems. Remember to keep the rules in mind for strings vs air columns and for air columns, open vs closed. The most common mistake is not identifying the right type of medium, so be sure to practice with questions to make sure you remember all the rules.
3. The Doppler Effect equation is another point where errors can occur. Remember to keep track of the direction of motion of the observer and the source. Also remember to keep the sign conventions for the velocities straight. Once those are correctly assigned, the equations are just plug and chug!

I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at:

<https://baylor.edu/tutoring>.

Answers: 1) 107.6 m, 2) 504.4 Hz, 3) 50.4 N, 4) (a)1481 Hz (b) 1318 Hz