**Introduction:**

Sound, like all waves, travels at a certain speed and has the properties of frequency and wavelength. You can observe direct evidence of the speed of sound while watching a fireworks display. The flash of an explosion is seen well before its sound is heard, implying both that sound travels at a finite speed and that it is much slower than light. Today we will investigate how we perceive these properties in sound waves.

The **wavelength** of a wave is merely the distance that a disturbance travels along the medium in one complete wave cycle.

Question 1. Consider the diagram below in order to answer parts a and b.
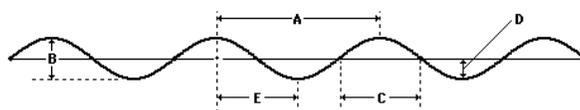
a.) The **wavelength** of the wave in the diagram above is given by letter _____.

b.) The **amplitude** of the wave in the diagram above is given by letter _____.

Question 2. Indicate the interval that represents one full wavelength. Pick all that apply.
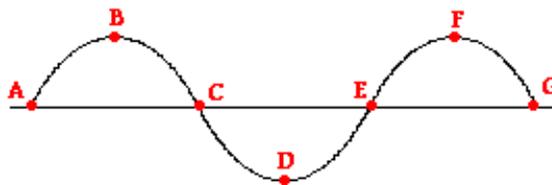
a. A to C   b. B to F   c. A to G   d. C to G

As the wave propagates through the air, one full wavelength takes a certain time period to pass a specific point in space; this period, represented by T, is usually measured in fractions of a second. The **frequency** of the sound wave is the number of wavelengths passing per second and is traditionally measured in hertz, represented by f.

Question 3. What does 1 Hz represent?

The inverse relationship between a wave's frequency and period is given by

$$f \cdot T = 1 \qquad \Longrightarrow \qquad f = \frac{1}{T}$$

The speed v is the distance the wave travels in a given time, which is one wavelength in a time of one period. In equation form, it is written as

$$v = - \qquad \Longrightarrow \qquad v =$$

Question 4. In a medium where v is constant, the higher the frequency, the smaller the _____.
On the other hand, the lower the frequency, the _____ the wavelength.

Question 5. How do we perceive frequency? That is, if two sound waves are emitted, one with a frequency of 440 Hz and one with a frequency of 1120 Hz, how can you distinguish between the two?

Question 6. Does a tuba emit a lower or higher frequency range than a flute?

Human beings can normally hear sounds with a frequency between about _____ Hz and _____ Hz. Sounds with frequencies below 20 hertz are called **infrasound**. Infrasound is too low-pitched for humans to hear. Sounds with frequencies above 20,000 hertz are called **ultrasound**. Ultrasound is too high-pitched for humans to hear.
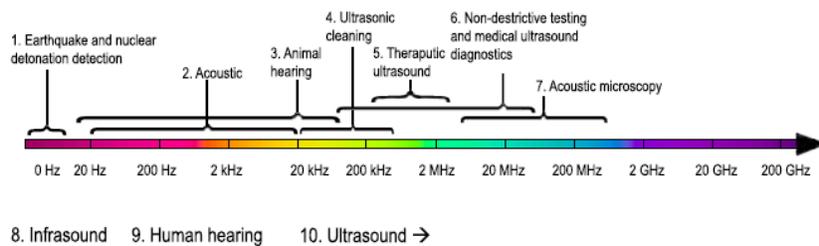
Question 7. Bats use ultrasound to navigate in the dark. Can you explain how?

Question 8. Assuming that the speed of sound in air is 331 m/s, calculate the wavelengths of sounds at the extremes of the audible range, 20 Hz and 20,000 Hz.

When two sounds with a frequency difference of greater than 7 Hz are played simultaneously, most people are capable of detecting the presence of a complex wave pattern resulting from the **interference** and **superposition** of the two sound waves. Certain sound waves when played (and heard) simultaneously will produce a particularly pleasant sensation when heard, are said to be **consonant**. Such sound waves form the basis of intervals in music.

Question 9. For example, use a virtual piano to play the note C4 and the note C5. Then play C4 and F#4. What do you notice about the difference between the two sounds? Do you prefer one sound to the other? Why do you think that is?

Question 10. Using the virtual piano, play A4 and the note A5. How do these sounds compare to C4 and C5 in the previous question? Do you notice any similarities?

Introduction:
The speed of waves propogating through a substance can be described in terms of properties of the medium. Today we will attempt to answer two main questions: What happens when you change the material through which the sound travels? Through which material does sound move faster? Why?

Question 1. What are some of the differences between light waves and sound waves?

Question 2. How does the speed of sound in solids v_s, gases v_g, and liquids v_l compare?

Question 3. Explain what it means for a substance to be more dense than another. Use the formula density $= \frac{\text{mass}}{\text{volume}}$ to support your answer.

Question 4. What two important properties determine the speed of sound? Explain in your own words.

Group Work

Question 5. Suppose you are in a long mining tunnel deep under the earth. Your friend is several thousands feet away from you in the tunnel. There are also long pipes running along the floor of the tunnel. If you asked your friend to yell and bang on the pipes at the same time, which do you think you would hear first? Why?

Question 6. If the sound waves travel faster through solid mediums than through a gaseous medium, then why does closing a door to a room with a stereo mute the sound?

Question 7. An automatic focus camera is able to focus on objects by use of an ultrasonic sound wave. The camera sends out sound waves that reflect off distant objects and return to the camera. A sensor detects the time it takes for the waves to return and then determines the distance an object is from the camera. If a sound wave (speed = 340 m/s) returns to the camera 0.150 seconds after leaving the camera, how far away is the object?

Question 8. On a hot summer day, a pesky little mosquito produced its warning sound near your ear. The sound is produced by the beating of its wings at a rate of about 600 wing beats per second.

  a.) What is the frequency in Hertz of the sound wave?

b.) Assuming the sound wave moves with a velocity of 350 m/s, what is the wavelength of the wave?

Question 9. Using the formula $v = 331\text{m/s} + 0.6\text{m/s/C} * T$, find the speed of sound at room temperature $22°$ C.

Question 10. Does doubling the frequency of a wave source double the speed of the waves? Explain your reasoning.

Question 11. How does doubling the frequency of a wave change the wavelength? To answer the second question, first use a wave simulator to make a guess. Then try to use the equation $v = f\lambda$ to justify your answer.

Introduction:
Today we will identify conditions required for the superposition of two waves, define and compare constructive and destructive interference. We will discuss how superposition impacts sound quality and creates unusual phenomenon.

Question 1. Using a wave interference simulator, set $f_1 = 232.9$ Hz and $f_2 = 231.6$ Hz. Play the sound and record what you notice. How do you think the frequency of the resulting wave compares to f_1 and f_2?

Question 2. Using a wave interference simulator, set $f_1 = 232.9$ Hz then slide f_2 until you get a tone that sounds like the ringing tone you hear when making a phone call. What is f_2?

Question 3. What is added together when two waves superimpose?

Question 4. Can you think of any examples of interference in your daily life?

Question 5. Two identical waves with an amplitude X superimpose in a way that pure constructive interference occurs. What is the amplitude of the resultant wave?

Question 6. Pure constructive interference occurs between two waves when they have the same
_____.

  a.) frequency and are in phase.

  b.) frequency and are out of phase.

  c.) amplitude and are in phase.

  d.) amplitude and are out of phase.

Question 7. When does pure destructive interference occur?

Question 8. Compute the beat frequency if the two frequencies of waves are 550Hz and 380Hz respectively.

Question 9. Draw the wave resulting from interference of the following two waves on the graph below.
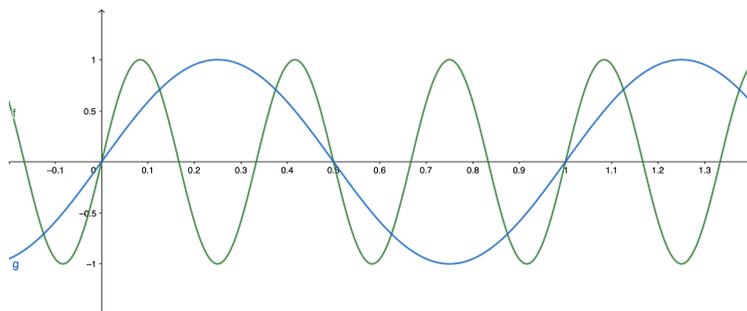
Question 10. Why do we often here reverberation in small rooms with dimensions less than 17 meters and echoes in rooms with larger dimensions?

Introduction:
Today we will explore how motion impacts wave properties like frequency. Our goal is to explain the change in observed frequency as a moving source of sound approaches or departs from a stationary observer.

Question 1. If a tuning fork is sounding and then swung over a person's head, how do you think it will sound?

Question 2. After viewing the demonstration, describe what you heard and explain what wave properties might account for the change you heard.

Question 3. *Prediction:* Draw a picture or pictures that show how the wave fronts might look while a speaker is moving towards you. Draw how it would look if the speaker were moving away from you.

Question 4. *Simulation:* Using the wave simulator posted for this assignment, answer the following questions.

  a.) From the drop down menu, select "Example: Doppler Effect 1". If the red dot represents the observer, what observable changes are occuring in the waveform as the sound source approaches the observer? What about once the sound source passes the observer?

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b.) From the drop down menu, select "Example: Doppler Effect 2". This simulation models both refraction with a moving barrier and a stationary barrier. Use your mouse to create additional waves and describe your observations here.

Question 5. How do you think the speed of the moving object influences the sound we hear? More specifically, suppose two cars speed by you, both blaring their horns, but one car is driving twice as fast the other. How will the sound of their horns differ? Or will you hear the exact same sound? Describe the differences in sound as they approach and once they've passed.

Question 6. Describe in your own words, as you might to other students, how the Doppler effect works?

Question 7. How does the Doppler effect support the belief that the universe is expanding?

A **Doppler shift** can be computed with the mathematical eqution

$$f_0 = f_s \left(\frac{v \pm v_0}{v \mp v_s} \right).$$

Use this equation the answer the following question.

Question 8. Suppose a train that has a 150-Hz horn is moving at 35.0 m/s in still air on a day when the speed of sound is 340 m/s.

a.) What frequencies are observed by a stationary person at the side of the tracks as the train approaches and after it passes?

b.) What frequency is observed by the train's engineer traveling on the train? Think about this question intuitively, then think about how the equation above can be used to support your answer.

Introduction:

To wrap up the quarter, we will discuss how frequencies eventually make music. Today we will discuss harmonics and overtones, and two simple tunings.

Question 1. Play the pure tone 262 Hz on your tone generator. Then plan C_4 on your piano. How would you compare the sounds? How are they similar? How are they different?

Question 2. Compare the wave lengths of the resulting harmonics to the string length L.
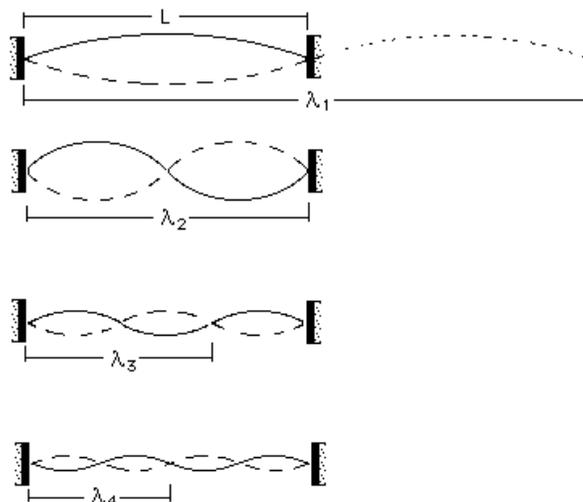
Question 3. Find the period T of $C_5 = 524$ Hz.

Question 4. Calculate the first four harmonic overtones of C_3 (130.8 Hz).

a.) If you play C_3 on the piano, what frequency is the pitch of the note closest to?

Question 5. Using a tone generator, play a few examples of frequencies f_1 and f_2 that first statisfy (a), then satisfy (b). Describe what you hear. Does one sound better than the other?

(a) f_1 is twice f_2, or $f_1 = 2f_2$

(b) f_2 is 100 more than f_1, or $f_2 = f_1 + 100$.

Question 6. The "Just Scale" occurs naturally as a result of the overtone series. Give the ratios for the following C major scale.

Note	Ratio to Fundamental	Just Scale Frequency
C_4	1	261.63 Hz
D_4		294.33 Hz
E_4		327.03 Hz
F_4		348.83 Hz
G_4		392.44 Hz
A_4		436.05 Hz
B_4		490.55 Hz
C_5	2	523.26 Hz