AP1 Waves

1. A fire truck is moving at a fairly high speed, with its siren emitting sound at a specific pitch. As the fire truck recedes from you which of the following characteristics of the sound wave from the siren will have a smaller measured value for you than for a fireman in the truck? Choose two characteristics.

(A) frequency
(B) wavelength
(C) speed
(D) intensity

Answer: (A) and (D) frequency and intensity.

Doppler effect shifts frequency to a lower measured value as fire truck recedes and a longer wavelength
There is no change in the sound's speed. Intensity is lower for you because the siren is further away from you than the fireman.

EK: 6.B.5 The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 6.B.5.1 The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.

2. A student tunes her guitar by striking a 110-Hertz A-note on a tuning fork, and simultaneously playing the 5th string on her guitar. Listening closely, she hears the amplitude of the combined sound oscillating twice per second. Which of the following is most likely the current frequency of the 5th string on her guitar?

(A) 108 Hertz
(B) 114 Hertz
(C) 220 Hertz
(D) 440 Hertz

Answer: (A) 108 Hertz

The beat frequency is the difference in frequency between the two waves.

EK: 6.D.1 Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition. 6.D.5 Beats arise from the addition of waves of slightly different frequency. Because of the different frequencies, the two waves are sometimes in phase and sometimes out of phase. The resulting regularly spaced amplitude changes are called beats. Examples should include the tuning of an instrument. The beat frequency is the difference in frequency between the two waves.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 5.1 The student can analyze data to identify patterns or relationships.

LO: 6.D.1.1 The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses. 6.D.5.1 The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.

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3. A transverse wave travels in medium X with a speed of 800 m/s and a wavelength of 4 m. The wave then moves into medium Y, traveling with a speed of 1600 m/s.

(a) Determine the frequency of the wave in medium Y.
(b) Determine the wavelength of the wave in medium Y.

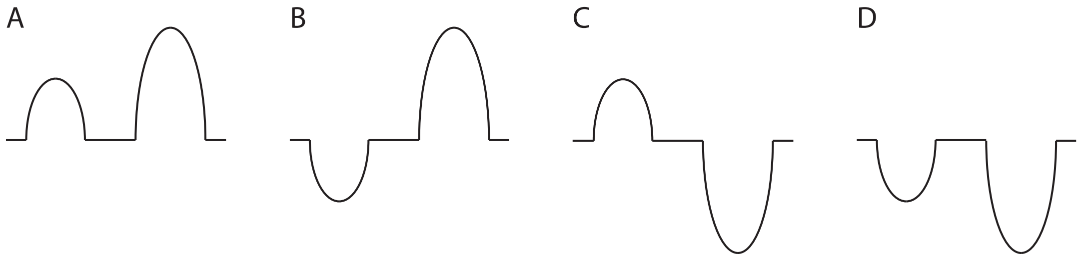
Answer:
(a) 200 Hz (frequency does not change when a wave enters a new medium).
(b) $\lambda = \frac{v}{f} = \frac{1600 \, {}^{m}\!/_{s}}{200\,Hz} = 8m$

EK: 6.B.4 For a periodic wave, wavelength is the ratio of speed over frequency.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 6.B.4.1 The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.

4. Wave pulses travel toward each other along a string as shown below. Answer the following questions in terms of the resulting superposition of the pulses when their centers are aligned.



(A) Rank the maximum amplitude of the resulting superposition from smallest to largest.
(B) Rank the magnitude of the maximum amplitude of the resulting superposition from smallest to largest.

Answer: (A) D, C, B, A (B) B=C, A=D

EK: 6.D.1 Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 5.1 The student can analyze data to identify patterns or relationships.

LO: 6.D.1.1 The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.

5. A string on a musical instrument is fixed at both ends. If the length of the string is 0.3 meters and waves travel through the string with a speed of 450 m/s, which of the following frequencies would you expect to hear from the string? Select two answers.

(A) 570 Hz
(B) 750 Hz
(C) 1125 Hz
(D) 1500 Hz

Answer: (B) 750 Hz and (D) 1500 Hz

The frequencies produced by waves on a string are given by $f=nv/(2L)$.

EK: 6.D.4 The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

LO: 6.D.4.2 The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.

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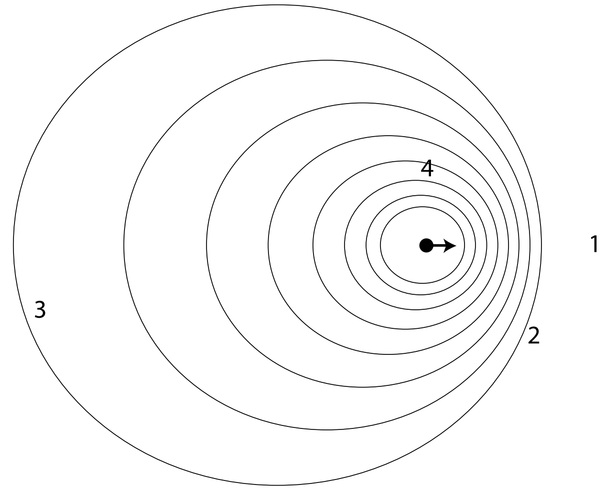
6. A baseball is moving to the right with a speed of v. At four different positions people have radar guns pointed at the ball to measure a Doppler shift in frequency in order to determine the baseball's speed, as shown in the diagram at right (note that wave fronts are NOT drawn to scale). Rank the measured shift in frequency of the radar beam from lowest to highest based on the position of the radar gun.



(A) 3 < 4 < 2 < 1
(B) 3 < 1 < 2 < 4
(C) 1 < 2 < 4 < 3
(D) 4 < 2 < 3 < 1

Answer: (D) 4 < 2 < 3 < 1

The amount of shift depends on relative velocity in the line of motion of the baseball. Position 1 is directly in line, whereas position 4 has no component of the velocity coming at it. Position 3 has a relatively large component and position 2 a small component.

EK: 6.B.5 The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 6.B.5.1 The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.

7. Sound waves are traveling through air when they encounter a steel barrier. Some of the sound waves are reflected and inverted, while the rest are transmitted through the steel barrier. The restoring forces within the steel are significantly higher than that of air. Which of the following changes occur to the sound waves at the air/steel boundary? Select two answers.

(A) their amplitude decreases in the steel because some of the waves are reflected.
(B) their speed increases in the steel because the restoring forces are higher.
(C) their frequency decreases in the air because the restoring forces are lower.
(D) their wavelength decreases in the air because the reflected waves are inverted.

Answer: (A) and (B)
(A) true b/c transmitted wave has less energy
(B) true b/c speed is proportional to the square root of the restoring force
(C) false b/c frequency does not change at all
(D) false b/c wavelength doesn't depend on phase

EK: 6.B.4 For a periodic wave, wavelength is the ratio of speed over frequency.

SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 6.1 The student can justify claims with evidence. 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

LO: 6.B.4.1 The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.

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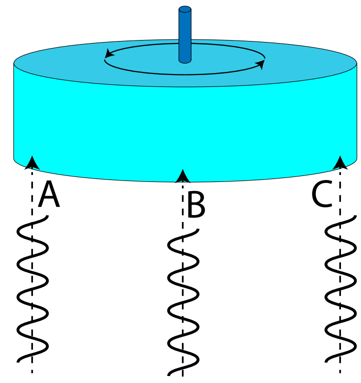
Light waves A, B, and C all have the same frequency. They are sent through a vacuum into the plane of the page, striking a rotating cylinder at various points as shown in the diagram at right. When the waves strike the cylinder, they are reflected back toward their source by tiny mirrors on the surface of the cylinder kept perpendicular to the incoming waves. Rank the observed frequency of the reflected waves from highest frequency to lowest frequency.



(A) A, B, C
(B) C, B, A
(C) A, C, B
(D) C, A, B

Answer: A

The Doppler Effect will lead to the highest observed frequency at A, no shift at B, and the lowest observed shift at C.

EK: 6.B.5 The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.

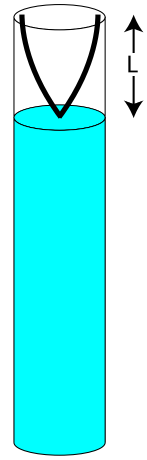
SP: 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

LO: 6.B.5.1 The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.

 Difficulty: 1

AP1 Waves

8. Students are attempting to determine the speed of sound in air using tuning forks and tubes which are closed at one end. In this procedure, the tube is filled with water, and a tuning fork of known frequency is struck. The vibrating tuning fork is then held over the tube filled with water, and the water is slowly drained out of the tube while students listen for the loudest possible sound at the first resonant condition. Once the loudest possible sound is heard (the first harmonic), the distance from the top of the tube to the water's surface (L) is measured and recorded. This procedure is repeated for five tuning forks of varying frequencies. Data is recorded in the table below.

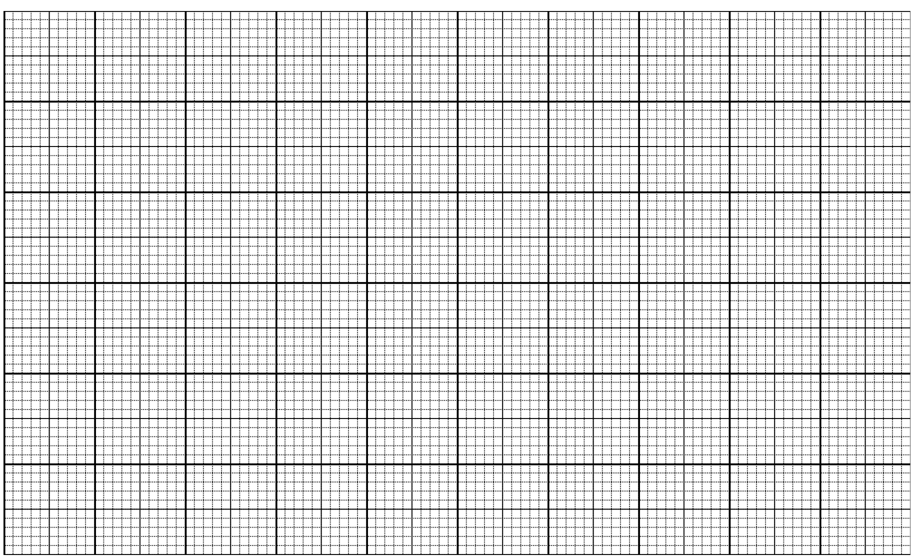


Trial	1	2	3	4	5	6
Freq (Hz)	128	256	288	384	426.6	512
Period (s)						
L (m)	.65	.33	.29	.23	.19	.17
λ (m)						

(a) Determine the period of oscillation (T) for each of the five trials and fill in the data table above.

(b) Write an equation for the wavelength of the sound wave (λ) as a function of L.

(c) Use the grid below to plot a linear graph of wavelength (λ) as a function of period (T). Use the empty boxes in the data table to record any calculated values you are graphing. Label the axes as appropriate.



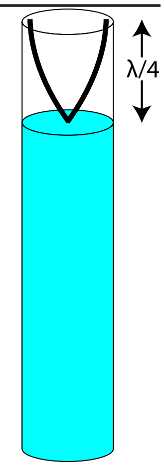
(d) Draw a best-fit line on your graph. Using your best-fit line, determine the speed of the sound waves in air.

(e) Describe how your procedure and analysis would change if you used the third harmonic instead of the first harmonic to determine the speed of sound. Indicate specifically any changes in calculations.

Answer:

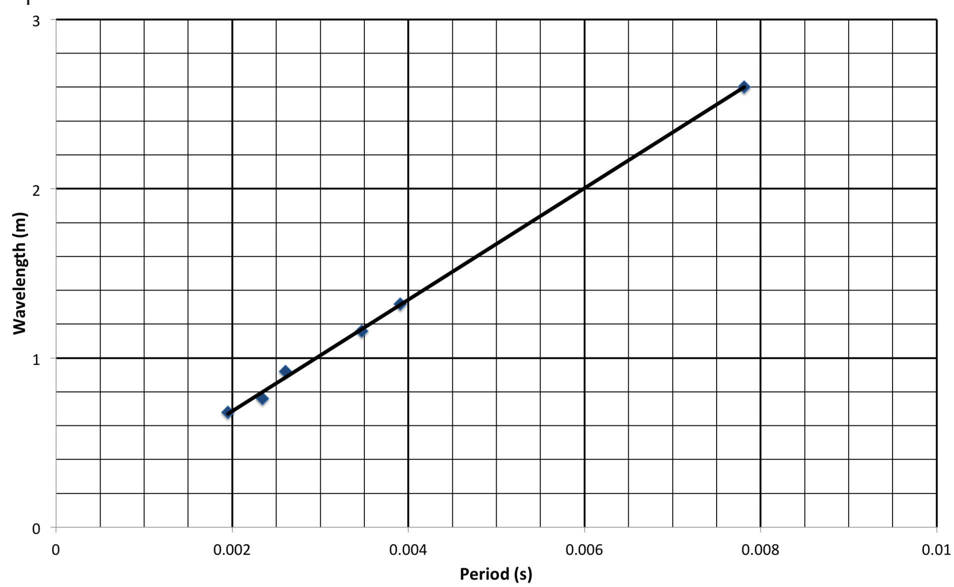
(a) Data is recorded in the table below.

Trial	1	2	3	4	5	6
Freq (Hz)	128	256	288	384	426.6	512
Period (s)	0.00781	0.00391	0.00347	0.00260	0.00234	0.00195
L (m)	0.65	0.33	0.29	0.23	0.19	0.17
λ (m)	2.6	1.32	1.16	0.92	0.76	0.68



(b) Equation: $\lambda=4L$

(c)



(d) slope=v=335 m/s

(e) In utilizing the third harmonic, you would continue to drain the water from the tube until the second time you heard the increase in amplitude. Then, you would determine the wavelength using $\lambda=4L/3$.

EK: 6.D.3 Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string, and sound waves in both closed and open tubes. 6.D.4 The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.

SP: 4.1 The student can justify the selection of the kind of data needed to answer a particular scientific question. 5.1 The student can analyze data to identify patterns or relationships. 5.2 The student can refine observations and measurements based on data analysis. 5.3 The student can evaluate the evidence provided by data sets in relation to a particular scientific question.

LO: 6.D.3.2 The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. 6.D.3.3 The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air. 6.D.4.2 The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.