Physics **Week 9(Sem. 2)** Name______________________

Chapter Summary

Waves and Sound Cont'd 2

Principle of Linear Superposition

Sound is a pressure wave. Often two or more sound waves are present at the same place and the same time. For example, if both pulses approaching each other are up on a transverse wave the result is the sum of the shapes of the individual pulses. Therefore, the result of the two up pulses is a wave pulse of twice the height. Likewise, if the two approaching waves are up and down at the overlap they momentarily cancel. The adding together of individual pulses to form a resultant pulse is an example of a more general concept called principle of linear superposition. This principle can be applied to all types of waves.

Constructive and Destructive Interference

Suppose that the sounds from two speakers overlap in the middle of a listening area and that each speaker produces a sound wave of the same amplitude and frequency. Assuming the speakers produce sound waves in phase (they move in at the same time and out at the same time) and the wavelength is 1m. If the distance from the overlap point is the same for both at 3 m, then the condensations of each wave meets and the rarefactions of each wave meet. Therefore the listener at the overlap point hears a sound with twice the amplitude of the separate waves. This phenomena when the combined pattern is the sum of the individual patterns is called the principle of linear superposition. When the waves meet condensation to condensation or rarefaction to rarefaction they are exactly in phase and exhibit constructive interference.

Now considering if one speaker is moved a distance of 0.5 m (half the wavelength). Then the rarefaction of one wave meets the condensation of the other at the overlap point. Thus, according to the principle of linear superposition, the result will be a constant pressure (a point where there is no rarefaction or condensation for a moment). For this situation, the two waves are said to be exactly out of phase (180 degrees out of phase) and to exhibit destructive interference. In summary, for two wave sources vibrating in phase, a difference in path length that is an integer (1,2,3…) of wavelengths leads to constructive interference; a difference in path lengths that is a half integer number (1 ½ , 2 ½ , 3 ½ …) of wavelengths leads to destructive interference. For any listener moving about a room, there will be a few points of constructive interference and other points of destructive interference. As well as these two extremes, there will be points of partial canceling and partial amplification.

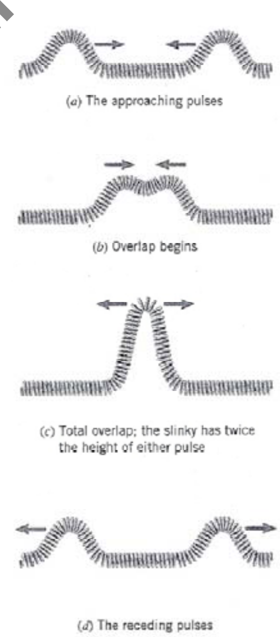


Figure 17.1 Two transverse "up" pulses passing through each other.

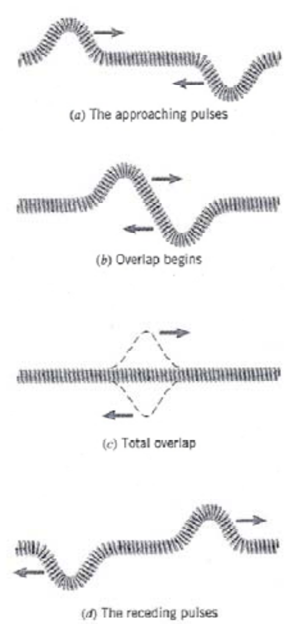
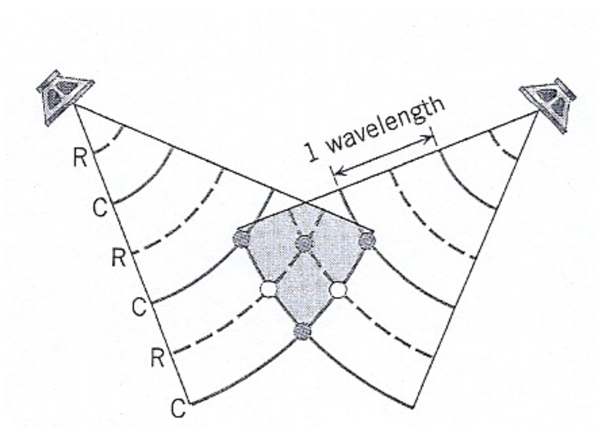


Figure 17.2 Two transverse pulses, one "up" and one "down," passing through each other.

Diffraction

The principle of linear superposition can be applied to diffraction as well. When a wave encounters an obstacle or the edges of an opening, it bends around them. The bending of the waves is called diffraction, if this didn't happen only listeners directly opposite the opening could hear the noise. Because of the way that sound waves spread out and transfer energy there will be a point directly outside of the opening that reaches the highest maximum and then other spots where there will be a weaker maximum and a zero point.



For a single slit (or doorway), where the height is considered to be much larger than the width of the slit, θ defines the location of the first minimum intensity point on either side of the center.

$$\sin\theta = \frac{\lambda}{D}$$

In the above equation θ is the angle from direct center, λ is the wavelength of the wave, and D is the width of the slit. For circular openings, the diffraction equation becomes

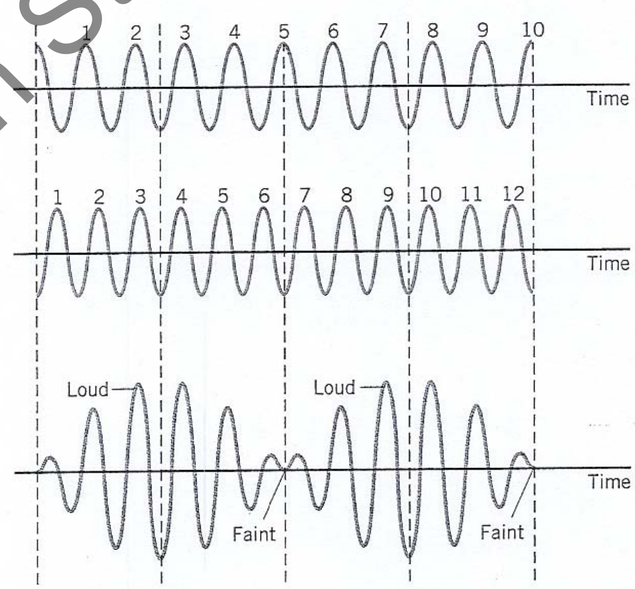
$$\sin\theta = 1.22\,\frac{\lambda}{D}$$

Where D is the diameter of the opening (circular only). If the ratio of $\lambda/_D$ is small then the wave is said to have narrow dispersion, this happens often with high frequency waves (short wavelength). For longer wavelength, low frequency waves, they tend to have a wide dispersion. Energy is conserved in this process, the energy is only redistributed as a result of diffraction.

All kinds of waves exhibit diffraction, not just sound waves, this includes light.

Beats

Up to this point two waves, either in phase or out of phase, with the same frequency were discussed. Now consider what happens when two overlapping waves with slightly different frequencies interact according to the principle of superposition. If two tuning forks with a frequency of 440 Hz were used, one had a slight mass added to make its' frequency 438 Hz. When the forks are struck at the same time, the resulting sound rises and falls periodically – faint, loud, faint, loud, etc. These periodic variations in loudness are called beats. The number of times that the loudness rises and falls is called the beat frequency and is the difference between the two sound frequencies. See figure 17.19 for a pictorial representation of beats and beat frequencies heard within one second.



Transverse Standing Waves

A standing wave is another interference effect that can occur when two waves overlap. For a transverse wave, where one end is repeatedly moved back and forth and the other end is fixed. On each wave, there are places where there appears to be no vibration (or vertical movement) these are called the antinodes. Meanwhile the points of maximum displacement or vibration are called the nodes. Each standing wave pattern is produced using a unique frequency of vibration. For example for a series with the smallest frequency of 10 Hz, the frequency needed to get a two antinode pattern would be 20 Hz (2*f'). While the frequency needed to produce a three antinode pattern would be 30 Hz or 3*f', the frequencies in this series are called harmonics. The lowest frequency is called the first harmonic (fundamental freq.), the second highest frequency is called the second harmonic (or the first overtone), etc.

Standing waves arise because identical waves travel on the string in opposite directions because of the principle of linear superposition. They are called standing waves because they don't just travel in one direction or the other direction, but rather in both directions. So as one upward wave is sent down the string, it hits the wall, while another upward wave is produced. Now the first upward wave hits the wall and is reflected downward returning toward the oncoming second upward wave. Therefore, a standing wave is produced if the frequency is

$$f_1 = v/2L$$

The frequency at which resonance occurs is often called the natural frequency. For a string fixed at both ends (one end vibrating), the series of natural frequencies would be

$$f_n = n(v/2L)$$

Where n=1,2,3,4… Standing waves and their natural frequencies are very important to instruments such as guitars.

Longitudinal Standing Waves

When sound waves reflect on a wall bouncing backwards and forwards the result is a longitudinal standing wave. Consider a slinky compressing and expanding in the direction of wave propagation producing a longitudinal wave. The nodes are identified as the points that have no vibration or displacement and the antinodes are the points that have maximum displacement or vibration. These standing waves are used for the woodwind instruments. If the frequency of the tuning fork matches the frequency of the air column, the downward and upward traveling waves create a standing wave. This creation of a standing waves is evident by the markedly louder sound of the tuning fork. So for an air column, a tube, open at both ends the natural frequencies would be

$$f_n = n(v/2L)$$

Again, where n=1,2,3,4… At these frequencies, large amplitude standing waves develop within the tube due to resonance.

Standing waves can also exist in an air column or tube only open at one end. Here the waves have an antinode at the open end and a node at the closed end (air molecules not free to move at the closed end). Since the distance between node and an adjacent antinode is one-fourth the wavelength, the natural frequency for a tube opened at one end becomes

$$f_n = n(v/4L)$$

Again where n=1,3,5… A tube open at only one end can only develop waves at the odd harmonics. For a tube opened at both ends needs to be twice as long as a tube opened only at one end to produce the same fundamental frequency. Energy is conserved for all standing waves, the energy of the standing wave is the sm of the energies of the individual waves comprising the standing wave. Interference will create areas of larger energy (antinodes) and no energy (nodes).

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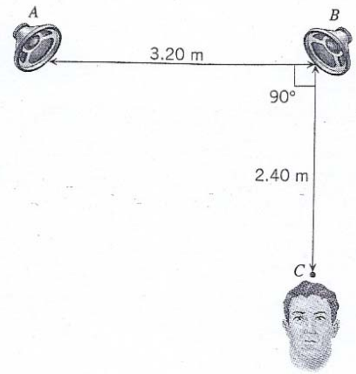


Figure 17.9 Example 1 assumes that the speakers are vibrating in phase and discusses whether this setup leads to constructive or destructive interference at point C for 214-Hz sound waves.

EXAMPLE 1 • What Does a Listener Hear?

In Figure 17.9 two in-phase loudspeakers, A and B, are separated by 3.20 m. A listener is stationed at point C, which is 2.40 m in front of speaker B. The triangle ABC is a right triangle. Both speakers are playing identical 214-Hz tones, and the speed of sound is 343 m/s. Does the listener hear a loud sound or no sound?

Reasoning The listener will hear either a loud sound or no sound, depending upon whether the interference occurring at point C is constructive or destructive. To determine which it is, we need to find the difference in the distances traveled by the two sound waves that reach point C and see whether the difference is an integer or half-integer number of wavelengths. In either event, the wavelength can be found from Equation 16.1 ($\lambda = v/f$).

Solution Since the triangle ABC is a right triangle, the distance AC is given by the Pythagorean theorem as $\sqrt{(3.20\text{ m})^2 + (2.40\text{ m})^2} = 4.00\text{ m}$. The distance BC is given as 2.40 m. Thus, we find that the difference in the travel distances for the waves is 4.00 m − 2.40 m = 1.60 m. The wavelength of the sound is

$$\lambda = \frac{v}{f} = \frac{343\text{ m/s}}{214\text{ Hz}} = 1.60\text{ m} \qquad (16.1)$$

Since the difference in the distances is one wavelength, constructive interference occurs at point C, and ***the listener hears a loud sound.***

EXAMPLE 3 • Designing a Loudspeaker for Wide Dispersion

(a) A 1500-Hz sound and a 8500-Hz sound each come from a loudspeaker whose diameter is 0.30 m. Assuming that the speed of sound in air is 343 m/s, find the diffraction angle θ for each sound. (b) A second speaker is to be designed for the 8500-Hz sound. The goal is to produce this sound with the same wide dispersion that the 0.30-m speaker gives to the 1500-Hz sound. What should be the diameter of the second speaker?

Reasoning The diffraction angle θ for each sound wave is given by $\sin\theta = 1.22(\lambda/D)$. In part (a), we will use this equation to find the angles. In part (b), knowing the angle, we will use the equation to find the diameter. In either case, it is first necessary to calculate the wavelengths of the sounds from $\lambda = v/f$ (Equation 16.1).

Solution

(a) The wavelengths of the two sounds are

$$\lambda_{1500} = \frac{343\text{ m/s}}{1500\text{ Hz}} = 0.23\text{ m} \quad \text{and} \quad \lambda_{8500} = \frac{343\text{ m/s}}{8500\text{ Hz}} = 0.040\text{ m}$$

The diffraction angles can now be determined:

1500-Hz sound

$$\sin\theta = 1.22\frac{\lambda_{1500}}{D} = 1.22\left(\frac{0.23\text{ m}}{0.30\text{ m}}\right) = 0.94 \qquad (17.2)$$

$$\theta = \sin^{-1} 0.94 = \boxed{70^\circ}$$

8500-Hz sound

$$\sin\theta = 1.22\frac{\lambda_{8500}}{D} = 1.22\left(\frac{0.040\text{ m}}{0.30\text{ m}}\right) = 0.16 \qquad (17.2)$$

$$\theta = \sin^{-1} 0.16 = \boxed{9.2^\circ}$$

Figure 17.15 illustrates these results.

(b) To find the speaker diameter that will give a $\theta = 70^\circ$ dispersion to the 8500-Hz sound, we again use the relation $\sin\theta = 1.22(\lambda/D)$:

$$D = \frac{1.22\,\lambda_{8500}}{\sin\theta} = \frac{1.22(0.040\text{ m})}{\sin(70^\circ)} = \boxed{0.052\text{ m}}$$

This result shows that high-frequency sound can have a wide dispersion, *provided the diameter of the speaker is small enough.* Accordingly, loudspeaker designers use a small diameter speaker called a tweeter to generate high-frequency sound, as Figure 17.16 indicates.

EXAMPLE 4 • Playing a Guitar

The heaviest string on an electric guitar has a linear density of $m/L = 5.28 \times 10^{-3}$ kg/m and is stretched with a tension of $F = 226$ N. This string produces the musical note E when vibrating along its entire length in a standing wave at the fundamental frequency of 164.8 Hz. (a) Find the length L of the string between its two fixed ends (see Figure 17.23*a*). (b) A guitar player wants the string to vibrate at a fundamental frequency of 2×164.8 Hz $= 329.6$ Hz, as it must if the musical note E is to be sounded one octave higher in pitch. To accomplish this, he presses the string against the proper fret and then plucks the string (see part *b* of the drawing). Find the distance L between the fret and the bridge of the guitar.

Reasoning The fundamental frequency f_1 is given by Equation 17.3 with $n = 1$: $f_1 = v/(2L)$. Since f_1 is known in both parts (a) and (b), the length L in each case can be calculated directly from this expression, once the speed v is known. The speed, in turn, is related to the tension F and the linear density m/L according to Equation 16.2.

Solution

(a) The speed is

$$v = \sqrt{\frac{F}{m/L}} = \sqrt{\frac{226\ \text{N}}{5.28 \times 10^{-3}\ \text{kg/m}}} = 207\ \text{m/s} \qquad (16.2)$$

According to $f_1 = v/(2L)$, the length of the string is

$$L = \frac{v}{2f_1} = \frac{207\ \text{m/s}}{2(164.8\ \text{Hz})} = \boxed{0.628\ \text{m}}$$

(b) The distance L that locates the fret can be determined exactly as in part (a) by using the wave speed $v = 207$ m/s and noting that the frequency is now $f_1 = 329.6$ Hz: $\boxed{L = 0.314\ \text{m}}$. This length is exactly half that determined in part (a), because the frequencies have a ratio of 2 : 1.

EXAMPLE 6 • Playing a Flute

When all the holes are closed on one type of flute, the lowest note it can sound is a middle C, whose fundamental frequency is 261.6 Hz. (a) The air temperature is 293 K, and the speed of sound is 343 m/s. Assuming the flute is a cylindrical tube open at both ends, determine the distance L in Figure 17.27, that is, the distance from the mouthpiece to the end of the tube. (This distance is only approximate, since the antinode does not occur exactly at the mouthpiece.) (b) A flautist can alter the length of the flute by adjusting the extent to which the head joint is inserted into the main stem of the instrument. If the air temperature rises to 305 K, to what length must a flute be adjusted to play a middle C?

Reasoning The fundamental frequency f_1 is given by Equation 17.4 with $n = 1$: $f_1 = v/(2L)$. This expression can be used to calculate the length as $L = v/(2f_1)$.

When the speed of sound v changes, as it does when the temperature changes, the length of the flute must be changed. The effect of temperature on the speed of sound in air is given by $v = \sqrt{\gamma kT/m}$ (Equation 16.5), assuming air behaves as an ideal gas. Thus, the speed is proportional to the square root of the Kelvin temperature ($v \propto \sqrt{T}$), a fact that we can use to find the speed at the higher temperature.

Solution

(a) At a temperature of 293 K, when the speed of sound is $v = 343$ m/s, the length of the flute is

$$L = \frac{v}{2f_1} = \frac{343\ \text{m/s}}{2(261.6\ \text{Hz})} = \boxed{0.656\ \text{m}}$$

(b) Since $v \propto \sqrt{T}$, it follows that

$$\frac{v_{305\ \text{K}}}{v_{293\ \text{K}}} = \frac{\sqrt{305\ \text{K}}}{\sqrt{293\ \text{K}}} = 1.02$$

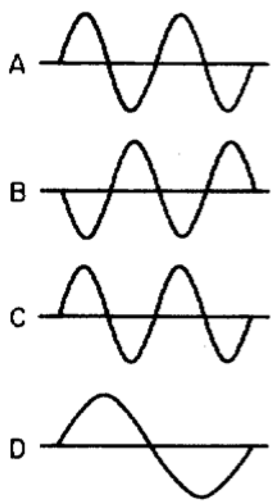
As a result, $v_{305\ \text{K}} = 1.02(v_{293\ \text{K}}) = 1.02(343\ \text{m/s}) = 3.50 \times 10^2$ m/s. The adjusted flute length is

$$L = \frac{v}{2f_1} = \frac{3.50 \times 10^2\ \text{m/s}}{2(261.6\ \text{Hz})} = \boxed{0.669\ \text{m}}$$

Thus, to play in tune at the higher temperature, a flautist must lengthen the flute by 0.013 m.

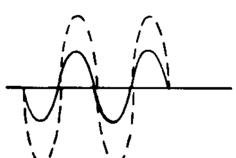
1. As the phase difference between two superposed waves changes from 180º to 90º, the amount of destructive interference
   (1) decreases
   (2) increases
   (3) remains the same

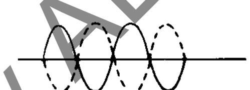
2. The diagrams below show four waves that pass simultaneously through a region.

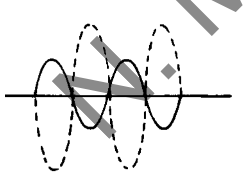


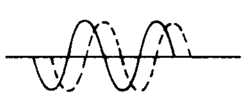
   Which two waves will produce maximum constructive interference if they are combined?
   (1) *A* and *C*
   (2) *A* and *B*
   (3) *B* and *C*
   (4) *C* and *D*

3. Which pair of waves will produce a resultant wave with the smallest amplitude?

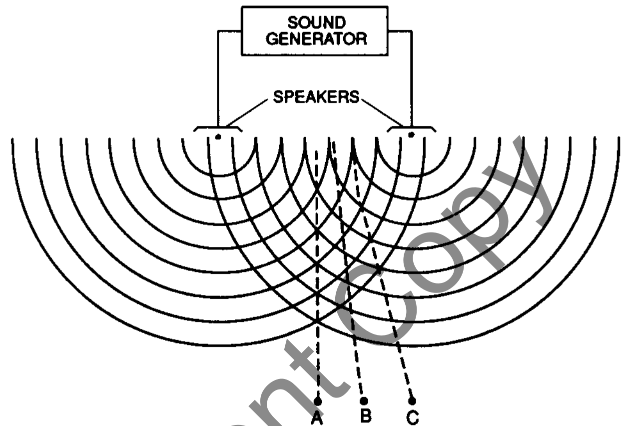

(1)


(3)


(2)

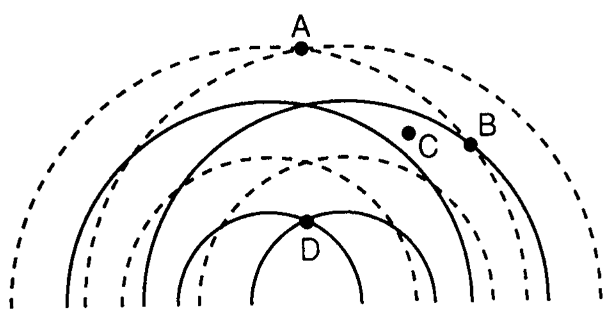

(4)

4. In the diagram below, two speakers are connected to a sound generator. The speakers produce a sound pattern of constant frequency such that a listener will hear the sound very well at *A* and *C*, but not as well at point *B*.



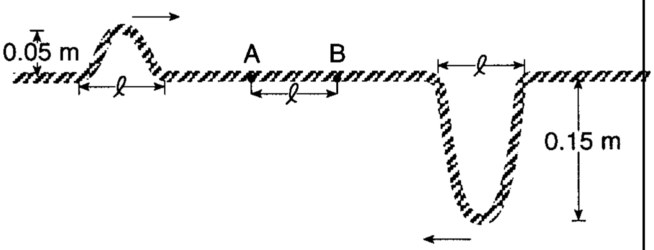
   Which wave phenomenon is illustrated by this experiment?
   (1) interference
   (2) polarization
   (3) reflection
   (4) refraction

5. Two wave sources operating in phase in the same medium produce the circular wave patterns shown in the diagram below. The solid lines represent wave crests and the dashed lines represent wave troughs.

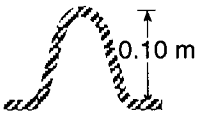


   Which point is at a position of maximum destructive interference?
   (1) *A*
   (2) *B*
   (3) *C*
   (4) *D*

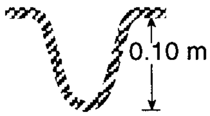
6. The diagram below shows two pulses, each of length *l*, traveling toward each other at equal speed in a rope.



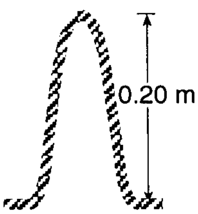
Which diagram best represents the shape of the rope when both pulses are in region *AB*?



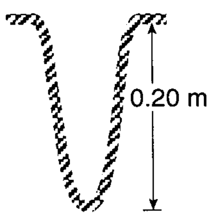
(1)



(3)

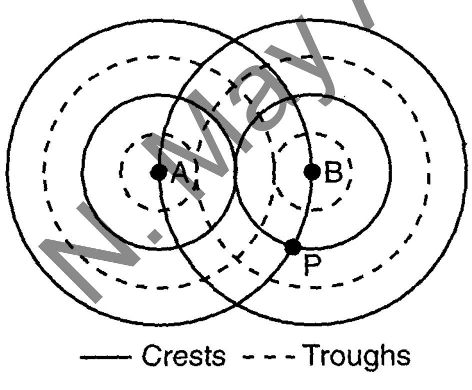


(2)



(4)

7. The diagram below shows two sources, *A* and *B*, vibrating in phase in the same uniform medium and producing circular wave fronts.



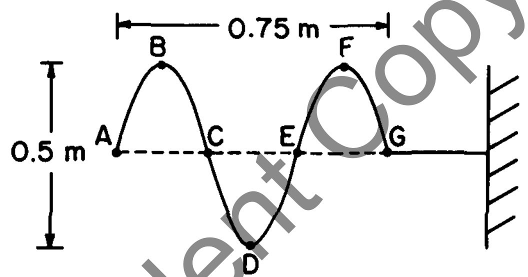
Which phenomenon occurs at point *P*?

(1) destructive interference
(2) constructive interference
(3) reflection
(4) refraction

8. Two waves having the same frequency and amplitude are traveling in the same medium. Maximum constructive interference occurs at points where the phase difference between the two superposed waves is

(1) 0° (3) 180°
(2) 90° (4) 270°

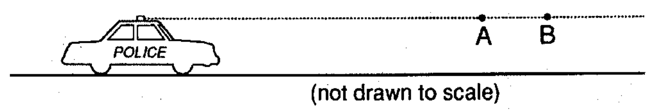
9. Base your answer to the following question on the diagram below which represents a wave traveling to the right along an elastic medium.



Which point on the wave is in phase with point *A*?

(1) *B* (3) *D*
(2) *C* (4) E

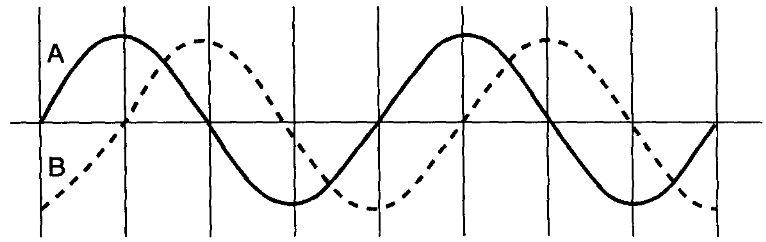
10. Base your answer to the following question on on the diagram below which shows a parked police car with a siren on top. The siren is producing a sound with a frequency of 680 hertz, which travels first through point *A* and then through point *B*, as shown. The speed of the sound is 340 meters per second.



If the sound waves are in phase at points *A* and *B*, the distance between the points could be

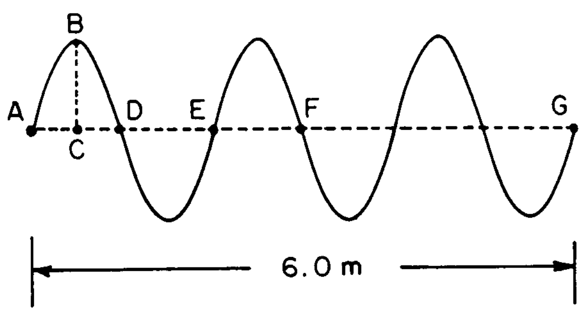
(1) 1 λ (3) 3/2 λ
(2) 1/2 λ (4) 1/4 λ

11. The diagram below shows two waves, *A* and *B*.



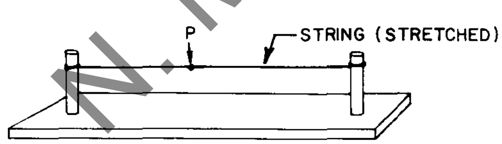
The phase difference between *A* and *B* is
(1) 0° (2) 45º (3) 90º (4) 180º

12. Base your answer to the following question on the diagram below which represents a vibrating string with a periodic wave originating at *A* and moving to G a distance of 6.0 meters.



Which phenomenon would occur if the waves were reflected at G and returned back to *A* through the oncoming waves?
(1) diffraction (3) standing waves
(2) dispersion (4) Doppler effect

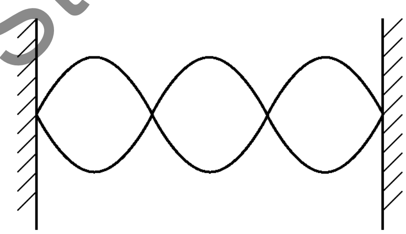
13. When the stretched string of the apparatus represented below is made to vibrate, point *P* does not move.



Point *P* is most probably at the location of
(1) a node
(2) an antipode
(3) maximum amplitude
(4) maximum pulse

14. Standing waves are most commonly produced when periodic waves arriving at a fixed boundary of a medium are
(1) reflected (3) diffracted
(2) refracted (4) dispersed

15. How many nodes are represented in the standing wave diagram below?



(1) 1 (3) 3
(2) 6 (4) 4

16. An echo is strong evidence that sound can be
(1) amplified (3) dispersed
(2) diffracted (4) reflected

17. The distance between two consecutive minimums (nodes) in a sound-wave pattern is
(1) 1 λ (3) 1/2 λ
(2) 2 λ (4) 1/4 λ

18. When the sound made by one tuning fork causes another tuning fork to vibrate, the principle demonstrated is
(1) reflection (3) interference
(2) refraction (4) resonance

19. As the difference between the frequencies of two sound waves increases, the number of beats per second
(1) decreases
(2) increases
(3) remains the same

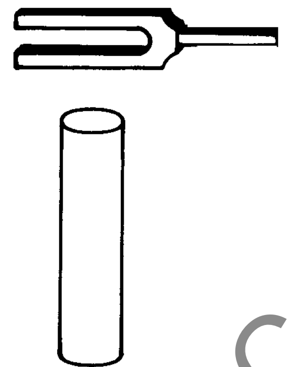
20. A tuning fork has a frequency-of 440 vibrations per second. If another tuning fork is sounded at the same time, 4 beats per second are heard. What are the possible frequencies of the second fork?
(1) 444 and 448
(2) 432 and 336
(3) 436 and 444
(4) 440 and 444

21. Two tuning forks, when struck, produce 8 beats per second. If one of the forks has a frequency of 160 cycles per second, the other may be
(1) 8 cycles per second
(2) 20 cycles per second
(3) 152 cycles per second
(4) 1,280 cycles per second

22. A student in a band notices that a drum vibrates when another instrument emits a certain frequency note. This phenomenon illustrates
(1) reflection
(2) resonance
(3) refraction
(4) diffraction

23. A girl on a swing may increase the amplitude of the swing's oscillations if she moves her legs at the natural frequency of the swing. This is an example of
(1) the Doppler effect
(2) destructive interference
(3) wave transmission
(4) resonance

24. Base your answer to the following question on on the diagram and information below. When a vibrating tuning fork is placed over an air column 16 centimeters long and closed on one end, the sound becomes louder.



The wavelength of the sound produced is
(1) 64 cm
(2) 32 cm
(3) 16 cm
(4) 4.0 cm

25. A student blows air across the end of a pipe that is open at both ends. If the wavelength of the note produced was 1.4 meters, what was the length of the pipe?
(1) 2.8 m
(2) 14 m
(3) 0.70 m
(4) 0.35 m

26. The length of a vibrating air column is shortened. The sound wave produced by the shortened air column will have an increase in
(1) frequency
(2) wavelength
(3) amplitude
(4) speed

27. A 2-meter tube closed at one end will produce a sound wave whose wavelength is
(1) 8 m
(2) 2 m
(3) 0.5 m
(4) 4 m

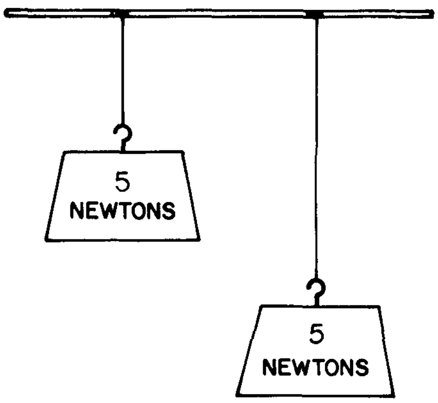
28. Compared to the length of a closed air column, the wavelength of the sound which produces resonance is
(1) one-half as great
(2) twice as great
(3) one-fourth as great
(4) four times as great

29. A closed pipe 2 meters long will produce a sound wave having a wavelength of
(1) 1 m
(2) 2 m
(3) 8 m
(4) 4 m

30. What is the wavelength of a sound produced by a tuning fork resonating with a 16 centimeter air tube that is open at both ends?

(1) 128 cm
(2) 64 cm
(3) 32 cm
(4) 24 cm

31. As shown in the diagram below, two 5-newton weights are suspended by wires that are identical except for length. Which of the following statements is true about the sound produced when the wires are plucked?



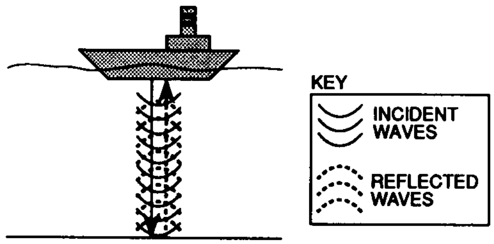
(1) The shorter wire will produce the lower pitched sound.
(2) The longer wire will produce the lower pitched sound.
(3) Both wires will produce a sound of the same pitch.
(4) The "relative" pitches cannot be determined from the information given.

32. As the tension of a vibrating string is decreased, the pitch of the sound produced will

(1) decrease
(2) increase
(3) remain the same

33. Base your answer to the questions below on the following information:

The sonar of a stationary ship sends a signal with a frequency of 5.0×10^3 hertz down through water. The speed of the signal is 1.5×10^3 meters per second. The echo from the bottom is detected 4.0 seconds later.



a What is the wavelength of the sonar wave? [Show all calculations, including the equation and substitution with units.]
b What is the depth of the water under the ship? [Show all calculations, including the equation and substitution with units.]

Base your answers to questions **34** and **35** on the information below.

A 0.12-meter-long electromagnetic (radar) wave is emitted by a weather station and reflected from a nearby thunderstorm.

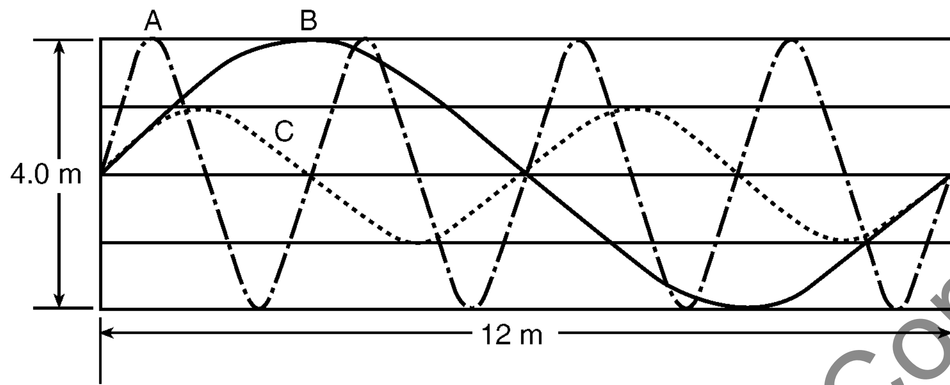
34. Determine the frequency of the radar wave. [Show all calculations, including the equation and substitution with units.]

35. The thunderstorm is moving toward the weather station. Using one or more complete sentences, explain how the Doppler effect could have been used to determine the direction in which the storm is moving.

36. Two monochromatic, coherent light beams of the same wavelength converge on a screen. The point at which the beams converge appears dark. Which wave phenomenon best explains this effect?

37. Base your answer to the following question on the information and diagram below.

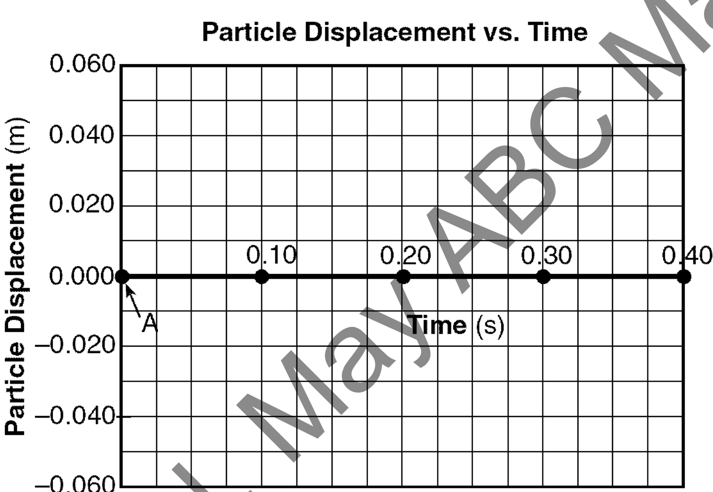
Three waves, *A*, *B*, and *C*,travel 12 meters in 2.0 seconds through the same medium as shown in the diagram below.



What is the amplitude of wave *C*?

38. Base your answer to the following question on the information below.

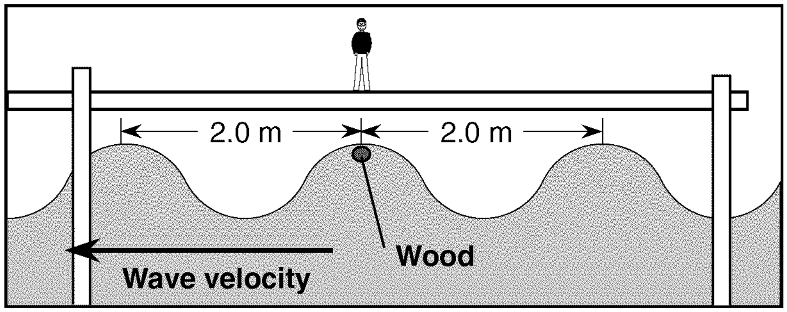
A periodic wave traveling in a uniform medium has a wavelength of 0.080 meter, an amplitude of 0.040 meter, and a frequency of 5.0 hertz.



Determine the period of the wave.

39. Base your answer to the following question on the information and diagram below.

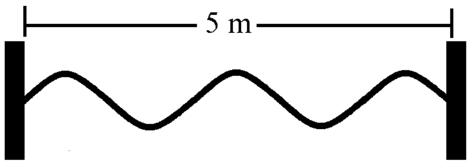
A student standing on a dock observes a piece of wood floating on the water as shown below. As a water wave passes, the wood moves up and down, rising to the top of a wave crest every 5.0 seconds.



(Not drawn to scale)

Calculate the speed of the water waves. [Show all work, including the equation and substitution with units.]

1. Base your answer to the following question on a standing wave with frequency 30 Hz that is set up on a string 5 meters in length and fixed at both ends as shown below.



The speed at which waves propagate on the string is

(1) 60 m/s (4) 150 m/s
(2) 6 m/s (5) 15 m/s
(3) 100 m/s

2. A string, fixed at both ends, supports a standing wave with a wavelength of 4 m and a total of 3 nodes. What is the length of the string?

(1) 4 m (4) 8 m
(2) 12 m (5) 2 m
(3) 6 m

3. A 10 m long rope is fixed at both ends and supports a standing wave with a total of 5 nodes. If a transverse wave travels at 15 m/s down the rope, determine the frequency of the standing wave.

(1) 3 Hz (4) 5 Hz
(2) 0.3 Hz (5) 2.5 Hz
(3) 0.5 Hz

4. A 12 m long string is fixed at both ends and supports a 4 Hz standing wave. If a transverse wave travels down this string at 32 m/s, find the total number of nodes in the standing wave.

(1) 6 (4) 5
(2) 2 (5) 4
(3) 3

5. An instrument consisting of a pipe open at both ends has a length of 1.7 m. If the speed of sound is 340 m/s in the pipe, what is the fundamental frequency of the instrument?

(1) 34 Hz (4) 100 Hz
(2) 17 Hz (5) 340 Hz
(3) 170 Hz

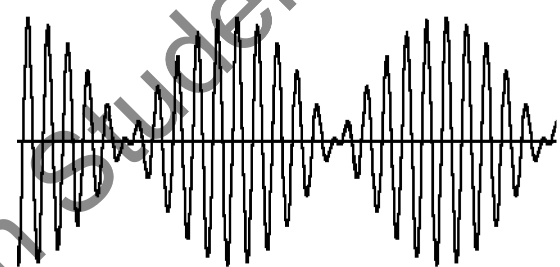
6. A string stretched between two fixed points supports traveling waves with a fundamental wavelength of 3.0 m that travel at 4 m/s. The ratio of the frequency of the sixth harmonic frequency to the fourth harmonic frequency is

(1) 4:3 (4) 2:3
(2) 2:1 (5) 3:2
(3) 3:4

7. Which of the following is NOT associated with the damaging of a bridge by wind?

(1) diffraction
(2) standing waves
(3) natural frequency
(4) resonance
(5) reflection and interference

8.



Two sinusoidal waves are combined to obtain the result in the figure above. Which of the following can best be explained by this figure?

(1) Doppler shift (4) beats
(2) polarization (5) refraction
(3) diffraction

9. Two wave pulses are approaching each other, one with an amplitude *a* and one with amplitude *b*. As they pass each other, the maximum amplitude achieved is

(1) b/a (4) $a + b$
(2) $2a - b$ (5) ab
(3) $(a + b)/2$

10. A rope is stretched between two walls and the ends are fixed in position. The linear mass density of the rope is 0.6 kg/m. The tension in the rope is 240 N.

If a 10 Hz traveling wave is sent along this rope determine
(a) The velocity of the traveling wave.
(b) The wavelength of the traveling wave.

The rope can support traveling waves with lengths of 5 m and 4 m, whose harmonic numbers are consecutive integers.

(c) Determine
(i) the length of the rope
(ii) the mass of the rope
(d) Find the total number of nodes of the 5 m standing wave.
(e) Draw a sketch of the 5m standing wave, labeling the nodes and antinodes.