Solution:

(a) The particles of the medium vibrate perpendicular to the direction of wave motion. Thus, the wave is transverse.

(b) The at-rest position is represented by the horizontal dashed line. Displacement is the vertical distance from the at-rest position to the curve. Therefore, the maximum displacement is $\frac{1}{2}$ the vertical height of the diagram or 1.2 m.

(c) Three complete wavelengths are shown. Divide the given length by 3.

$$\lambda = \frac{6.0\ \text{m}}{3} = 2.0\ \text{m}$$

(d) Use the relationship $T = \frac{1}{f}$. Substitute the known values and solve.

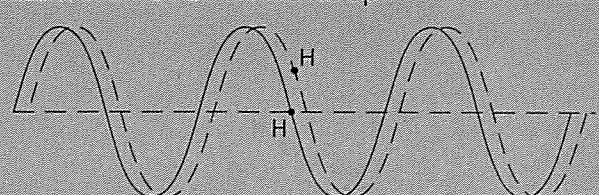
$$T = \frac{1}{f} = \frac{1}{2.0\ \text{Hz}} = 0.50\ \text{s}$$

(e) Use the relationship $v = f\lambda$. Substitute the known values and and solve.

$v = (2.0\ \text{Hz})(2.0\ \text{m}) = 4.0\ \text{m/s}$

(f) Notice that points B and C are moving in the same direction and are the same distance from the at-rest position of the medium, but they do not have the same displacement and thus are out of phase. Points B and F have the same displacement from the at-rest position, but are moving in opposite directions, up and down, respectively, and therefore are out of phase. B and G are in phase because they have the same displacement and are moving in the same direction.

(g) The dashed line in the following diagram shows how the entire waveform would appear in the next instant of time. Point H moves up.

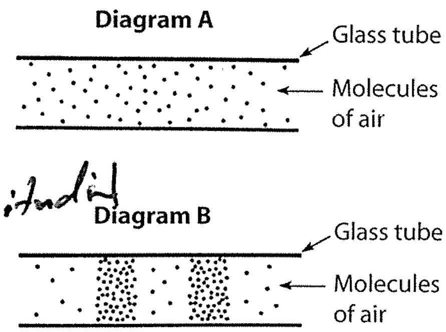


Review Questions

1. A single vibratory disturbance that moves from point to point in a medium is called a (1) period (2) periodic wave (3) wavelength (4) pulse

2. What generally occurs when a pulse reaches a boundary between two different media? (1) All of the pulse is reflected. (2) All of the pulse is absorbed. (3) All of the pulse is transmitted. (4) Part of the pulse is reflected, part is absorbed, and part is transmitted.

3. Diagram A shows a glass tube containing undisturbed air molecules. Diagram B shows the same glass tube as a wave passes through it. What type of wave produced the disturbance shown in Diagram B?



4. When a transverse wave moves through a medium, what is the action of the particles of the medium?
(1) They travel through the medium with the wave.
(2) They vibrate in a direction parallel to the direction in which the wave is moving.
(3) They vibrate in a direction perpendicular to the direction in which the wave is moving.
(4) They remain at rest.

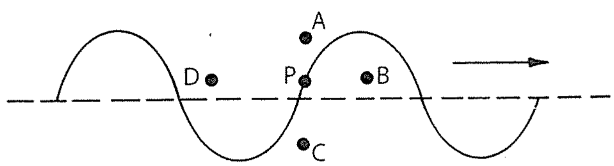
5. Compression waves in a spring are an example of (1) longitudinal waves (2) transverse waves (3) elliptical waves (4) torsional waves

6. Wave motion in a medium transfers (1) energy only (2) mass only (3) both energy and mass (4) neither energy nor mass

7. Periodic waves are produced by a wave generator at the rate of one wave every 0.50 second. What is the period of the wave to the correct number of significant figures?

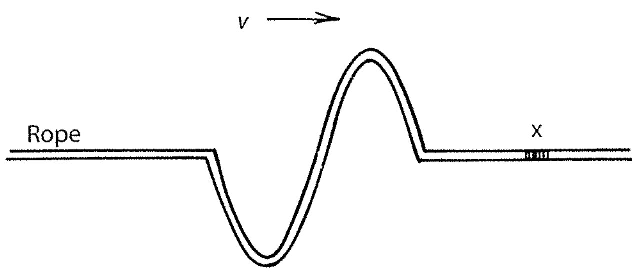
8. Which phrase best describes a periodic wave?
(1) a single pulse traveling at constant speed
(2) a single pulse traveling at varying speed in the same medium
(3) a series of pulses at irregular intervals
(4) a series of pulses at regular intervals

9. In the following diagram, the solid line represents a wave generated in a rope. As the wave moves to the right, point P on the rope is moving towards which position? (1) A (2) B (3) C (4) D



10. In the following diagram, a transverse wave is moving on a rope. In which direction will segment x move as the wave passes through it?

(1) down only
(2) up only
(3) down, then up, then down
(4) up, then down, then up



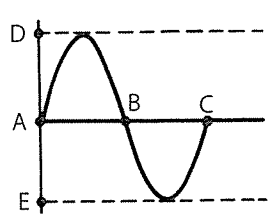
11. Which wave characteristic is defined as the number of cycles of a periodic wave occurring per unit time?

12. If the frequency of a sound wave is 440. cycles per second, its period is closest to

(1) 2.27×10^{-3} second/cycle
(2) 0.752 second/cycle
(3) 1.33 seconds/cycle
(4) 3.31×10^{2} seconds/cycle

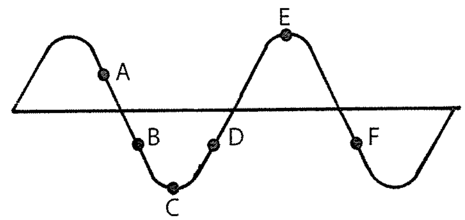
13. If the frequency of a sound wave is doubled, the period of the sound wave is (1) halved (2) doubled (3) unchanged (4) quadrupled

14. The following diagram represents a transverse wave. The amplitude of the wave is represented by the distance between points (1) A and B (2) A and C (3) A and D (4) D and E

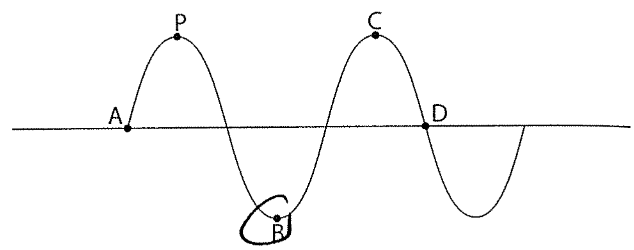


15. If the frequency of a sound wave in air at STP remains constant, the wave's energy can be varied by changing its (1) amplitude (2) speed (3) wavelength (4) period

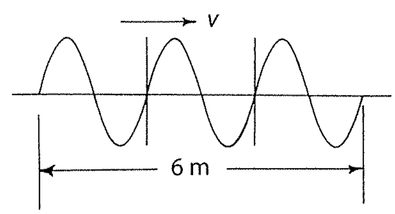
16. The following diagram shows a transverse wave. Which two points on the wave are in phase?
(1) A and E (2) B and F (3) C and E (4) D and F



17. The following diagram shows a transverse wave. Which point on the wave is 180° out of phase with point P?



18. The diagram that follows shows a train of waves moving along a string. What is the wavelength?

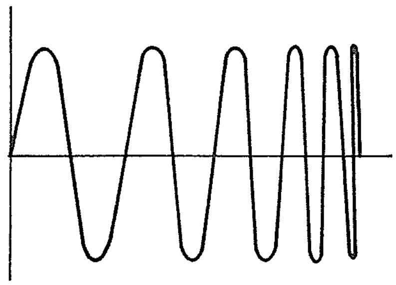


19. The wavelength of the periodic wave shown in the following diagram is 4.0 meters. What is the distance from point B to point C to the correct number of significant figures?

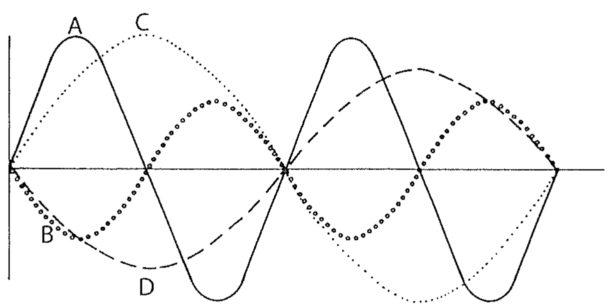
20. An 8.0-meter long ocean wave passes the end of a dock every 5.0 seconds. What is the speed of the wave?

21. A sound wave travels at 340 meters per second. After 0.50 second, how far from the source of the wave has the wave traveled?

22. The following diagram represents a wave traveling in a uniform medium. Which characteristic of the wave is constant? (1) amplitude (2) frequency (3) period (4) wavelength



Base your answers to questions 23 through 25 on the following diagram, which represents four transverse waves in the same medium.



23. Which two waves have the same amplitude?

24. Which two waves have the same wavelength?

25. Which two waves have the same frequency?

26. A wave has a frequency of 2.0 hertz and a speed of 3.0 meters per second. The distance covered by the wave in 5.0 seconds is (1) 30. m (2) 15 m (3) 7.5 m (4) 6.0 m

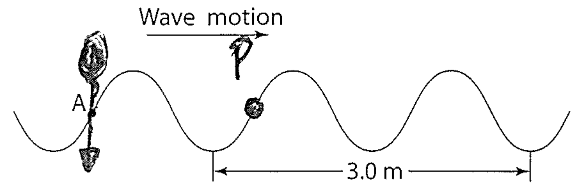
27. A wave traveling at 5.00×10^4 meters per second has a wavelength of 2.50×10^1 meters. What is the frequency of the wave? (1) 1.25×10^6 Hz (2) 2.00×10^3 Hz (3) 5.00×10^{-4} Hz (4) 5.00×10^3 Hz

28. Sound waves with constant frequency of 250 hertz are traveling through air at STP. Determine the wavelength of the sound waves.

29. What total distance will a sound wave travel in air in 3.00 seconds at STP?

Base your answers to questions 30 through 33 on the information and diagram that follow.

A periodic wave, having a frequency of 40. hertz, travels to the right in a uniform medium as shown.



30. On the diagram, draw one or more arrows to indicate the direction of motion of point A in the next instant of time.

31. On the diagram, label a point P that is in phase with point A.

32. Determine the speed of the wave.

33. Determine the period of the wave.

34. What type of wave is sound traveling in water?

Base your answers to questions 35 and 36 on the following information.

The elapsed time between successive crests of a transverse wave passing a given point is 0.080 second.

35. Determine the period of the wave.

36. Determine the frequency of the wave.

Base your answers to questions 37 through 39 on the following information.

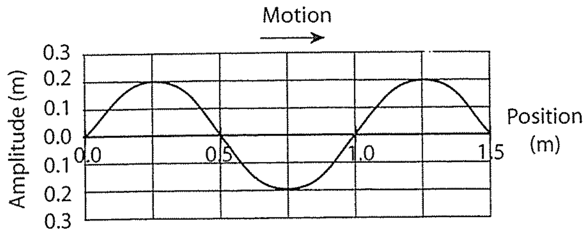
The distance from one crest of a water wave to the next crest is 4.0 meters. One crest passes an observation point every 2.5 seconds.

37. Determine the speed of the wave.

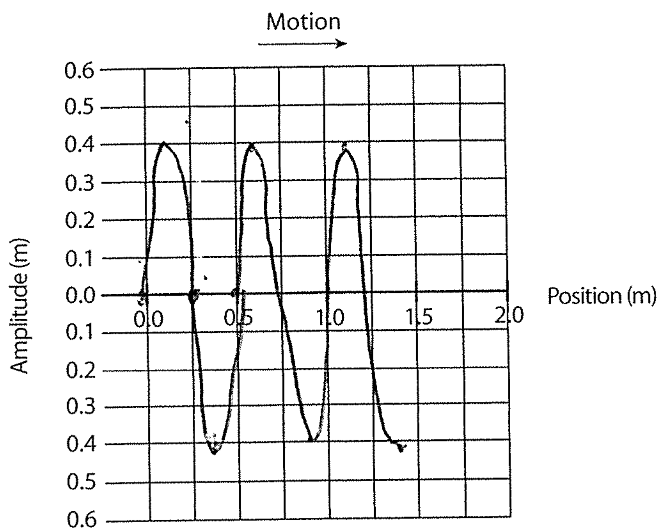
38. How much time is required for the wave to travel 50. meters?

39. How far will the wave travel in 4.0 seconds?

40. The diagram below shows a periodic wave W traveling to the right in a uniform medium.



On the grid below sketch at least one cycle of a periodic wave having twice the amplitude and half the wavelength of wave W.



41. A sound wave is produced by a musical instrument for 0.40 second. If the frequency of the wave is 370 hertz, how many complete waves are produced in that time period?

42. Write an equation that correctly relates the speed v, wavelength λ, and period T of a periodic wave.

43. A wave x meters long passes through a medium at y meters per second. The frequency of the wave could be expressed as (1) $\frac{y}{x}$ Hz (2) $\frac{x}{y}$ Hz (3) xy Hz (4) $(x + y)$ Hz

44. Which is a unit for the amplitude of a transverse wave? (1) m/s (2) s (3) Hz (4) m

45. If the frequency of a sound wave increases, the wavelength of the wave in air will (1) decrease (2) increase (3) remain the same

46. Which phrase best describes the wavelength of a sound wave in air at STP? (1) inversely proportional to its amplitude and inversely proportional to its frequency (2) inversely proportional to its amplitude and directly proportional to its frequency (3) independent of its amplitude and inversely proportional to its frequency (4) independent of its amplitude and directly proportional to its frequency

47. A water wave travels a distance of 10.0 meters in 5.0 seconds. What can be determined from this information? (1) the speed of the wave only (2) the period of the wave only (3) the speed and frequency of the wave (4) the period and frequency of the wave

Periodic Wave Phenomena

By observing two types of mechanical waves, transverse and longitudinal, you can discover some characteristics of waves and the behavior of waves under various conditions. Some of these characteristics and behaviors are discussed below.

Wave Fronts

When water drips from a leaky faucet into a water-filled sink, waves spread, or radiate, in concentric circles along the surface of the water from the point where the drips strike the surface. In a three-dimensional medium such as air, waves radiate in concentric spheres from a vibrating point. All points on a wave that are in phase comprise a wave front. A **wave front** is the locus of all adjacent points on a wave that are in phase. For example, in the waves in the sink, all of the points on one of the crests constitute a wave front. Two successive crests are separated by a distance of one wavelength and, therefore, are in phase.

Doppler Effect

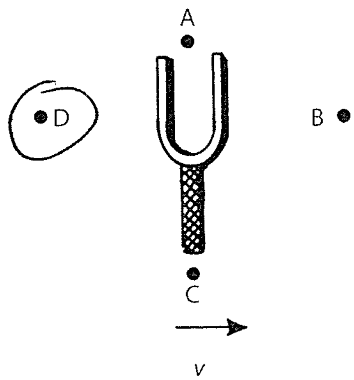
When a source and an observer (receiver) of waves are moving relative to each other, the observed frequency is different from the frequency of the vibrating source. This change in observed or apparent frequency due to relative motion of source and observer is called the **Doppler effect.**

If the source is approaching the observer, or if the observer is approaching the source, the frequency appears to increase. If the source is receding from the observer or the observer is receding

Review Questions

48. What term describes the variations in the observed frequency of a sound wave when there is relative motion between the source and the receiver?

49. The vibrating tuning fork shown in the diagram that follows produces a constant frequency. The tuning fork is being moved to the right at constant speed, and observers are located at points A, B, C, and D. Which observer hears the lowest frequency?



50. The driver of a car hears the siren of an ambulance that is moving away from her. If the actual frequency of the siren is 2000. hertz, the frequency heard by the driver may be (1) 1900. Hz (2) 2000. Hz (3) 2100. Hz (4) 4000. Hz

51. A police officer's stationary radar device indicates that the frequency of the radar wave reflected from an automobile is less than the frequency emitted by the radar device. This indicates that the automobile is (1) moving toward the police officer (2) moving away from the police officer (3) not moving

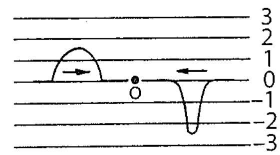
52. A stationary person makes observations of the periodic waves produced by a moving source. When the wave source recedes from the observer, he observes an apparent increase in the wave's (1) speed (2) frequency (3) wavelength (4) amplitude

53. Light from a distant star displays a Doppler red shift. This shift is best explained by assuming the star is (1) decreasing in temperature (2) increasing in temperature (3) moving toward Earth (4) moving away from Earth

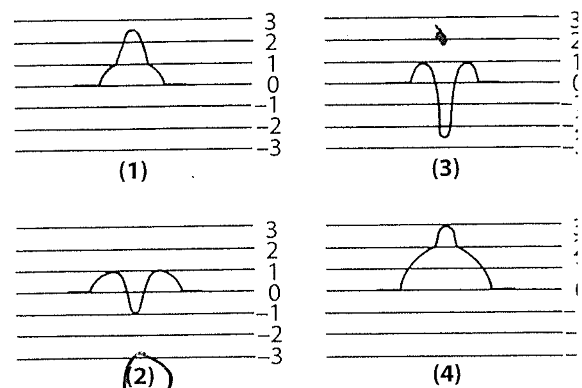
54. Maximum constructive interference occurs when the phase difference between the intersecting wave is (1) 0° (2) 45° (3) 90° (4) 180°

55. By how many degrees should two waves be out of phase to produce maximum destructive interference?

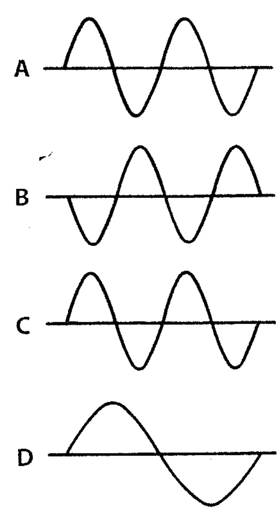
56. The diagram below shows a rope with two pulses moving along it in the directions shown.



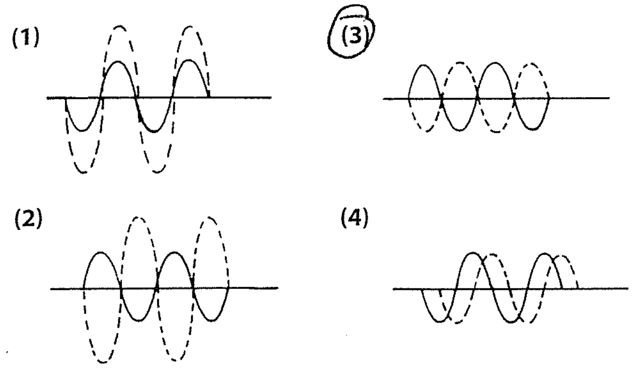
What is the resultant wave pattern at the instant when the maximum displacement of both pulses at point O on the rope?



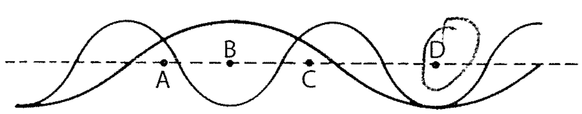
57. The following diagram shows four waves that pass simultaneously through a region. Which two waves will produce maximum constructive interference when they are combined? (1) A and B (2) A and C (3) B and C (4) C and D



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



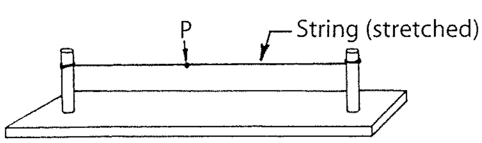
59. The following diagram represents two waves traveling simultaneously in the same medium. At which of the given points will maximum constructive interference occur?



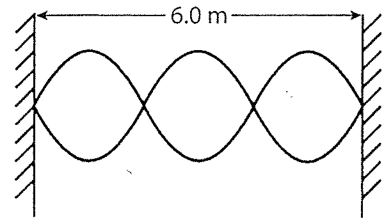
60. Standing waves are produced by two waves traveling in opposite directions in the same medium. The two waves must have (1) the same amplitude and the same frequency (2) the same amplitude and different frequencies (3) different amplitudes and the same frequency (4) different amplitudes and different frequencies

61. In order for standing waves to form in a medium, two waves must (1) have the same frequency (2) have different amplitudes (3) have different wavelengths (4) travel in the same direction

62. When the stretched string of the apparatus represented in the following diagram is made to vibrate, point P does not move. Point P is most probably the location of (1) a node (2) an antinode (3) maximum amplitude (4) maximum pulse



Base your answers to questions 63 and 64 on the following diagram, which shows a standing wave in a rope.

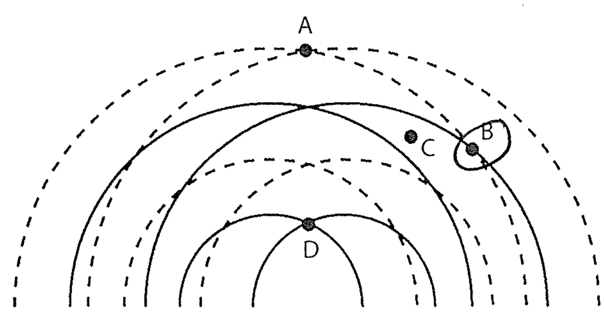


63. How many nodes are represented?

64. If the rope is 6.0 meters long, what is the wavelength of the standing wave?

65. Two waves traveling in the same medium interfere to produce a standing wave. What is the phase difference in degrees between the two waves at a node?

66. Two wave sources operating in phase in the same medium produce the circular wave patterns shown in the diagram that follows. The solid lines represent wave crests and the dashed lines represent wave troughs. Which point is at a position of maximum destructive interference?

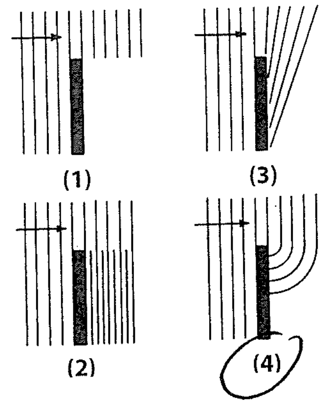


67. An opera singer's voice is able to break a thin crystal glass if a note sung and the glass have the same natural (1) speed (2) frequency (3) amplitude (4) wavelength

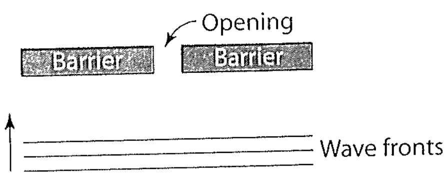
68. When an opera singer hits a high-pitch note, a glass on the opposite side of the opera hall shatters. Which statement best explains this phenomenon? (1) The amplitude of the note increases before it reaches the glass. (2) The singer and the glass are separated by an integral number of wavelengths. (3) The frequency of the note and the natural frequency of the glass are equal. (4) The sound produced by the singer slows down as it travels from the air into the glass.

69. A wave spreads into the region behind a barrier. What is this phenomenon called?

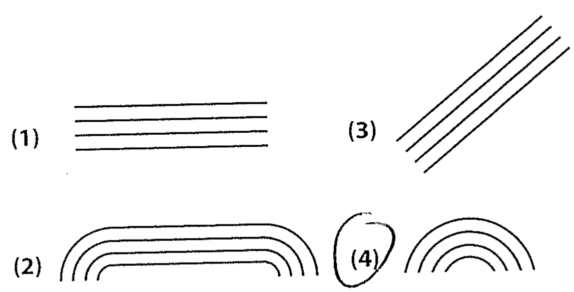
70. Which diagram best illustrates diffraction of waves incident on a barrier?



71. The diagram that follows represents straight wave fronts approaching a narrow opening in a barrier.



Which diagram best represents the shape of the waves after passing through the opening?



Light

The human eye can perceive only an extremely small fraction of the electromagnetic spectrum. That portion of the spectrum, which allows us to see, is called light and covers the range of wavelengths from approximately 3.90×10^{-7} to 7.81×10^{-7} meter. (The electromagnetic spectrum will be discussed in detail later in this topic.) Obviously, these wavelengths are too small to measure with a ruler as you might measure the wavelength of a transverse wave on a rope or a water wave in a shallow tank.

Speed of Light

Measurements of the speed of light to more than two or three significant figures could not be mad until about 100 years ago. To three significant figures, the speed of light in a vacuum or air is 3.00×10^8 meters per second. Measurements of the speed of light are now recorded to nine signif cant figures. This more accurate data reveals tha the speed of light in air is slightly less than it is i a vacuum. The speed of light in a vacuum is repr sented by the symbol c, an important physical constant.

The speed of light in a vacuum is the upper limit for the speed of any material body. No obje can travel faster than c. The speed of light in a material medium is always less than c. The equa tion $v = f\lambda$ applies to light waves. Therefore, $c = f\lambda$, where f is the frequency of a light wave a λ is its wavelength in a vacuum.

Ray Diagrams

Because it is not possible to see individual wave fronts in a light wave, a ray is used to indicate t direction of wave travel. A **ray** is a straight line that is drawn at right angles to a wave front an points in the direction of wave travel. Ray diagrams show only the direction of wave travel, n the actual waves. An **incident ray** is a ray that originates in a medium and is incident on a bou ary or an interface of that medium with anothe medium. A **reflected ray** is a ray that has rebounded from a boundary or interface. A **refracted ray** is a ray that results from an incident ray entering a second medium oblique Figure 5-13 on the following page shows these rays as well as the wave fronts whose motion tl represent.

Incident, reflected, and refracted rays form responding angles measured from a line called normal. The **normal** is a line drawn perpendicu to the barrier or to the interface between two media at the point where the incident ray strik In ray diagrams, all the rays and the normal li a single plane.