When two waves pass through the same region of space at the same time, they **interfere**. The resultant displacement at any point and time is the sum of their separate displacements; this can result in **constructive interference, destructive interference**, or something in between, depending on the amplitudes and relative phases of the waves.

Waves traveling on a string of fixed length interfere with waves that have reflected off the end and are traveling back in the opposite direction. At certain frequencies, **standing waves** can be produced in which the waves seem to be standing still rather than traveling. The string (or other medium) is vibrating as a whole. This is a resonance phenomenon, and the frequencies at which standing waves occur are called **resonant frequencies**. Points of destructive interference (no vibration) are called **nodes**. Points of constructive interference (maximum amplitude of vibration) are called **antinodes**.

[*Waves change direction, or **refract**, when traveling from one medium into a second medium where their speed is different. Waves spread, or **diffract**, as they travel and encounter obstacles. A rough guide to the amount of diffraction is $\theta \approx \lambda/L$, where λ is the wavelength and L the width of an opening or obstacle. There is a significant "shadow region" only if the wavelength λ is smaller than the size of the obstacle.]

[*A traveling wave can be represented mathematically as $y = A\sin\{(2\pi/\lambda)(x - vt)\}$.]

Questions

1. Give some examples of everyday vibrating objects. Which exhibit SHM, at least approximately?

2. Is the acceleration of a simple harmonic oscillator ever zero? If so, where?

3. Explain why the motion of a piston in an automobile engine is approximately simple harmonic.

4. Real springs have mass. Will the true period and frequency be larger or smaller than given by the equations for a mass oscillating on the end of an idealized massless spring? Explain.

5. How could you double the maximum speed of a simple harmonic oscillator (SHO)?

6. A 5.0-kg trout is attached to the hook of a vertical spring scale, and then is released. Describe the scale reading as a function of time.

7. If a pendulum clock is accurate at sea level, will it gain or lose time when taken to high altitude? Why?

8. A tire swing hanging from a branch reaches nearly to the ground (Fig. 11–48). How could you estimate the height of the branch using only a stopwatch?

FIGURE 11–48 Question 8.

9. Why can you make water slosh back and forth in a pan only if you shake the pan at a certain frequency?

10. Give several everyday examples of resonance.

11. Is a rattle in a car ever a resonance phenomenon? Explain.

12. Is the frequency of a simple periodic wave equal to the frequency of its source? Why or why not?

13. Explain the difference between the speed of a transverse wave traveling down a cord and the speed of a tiny piece of the cord.

14. Why do the strings used for the lowest-frequency notes on a piano normally have wire wrapped around them?

15. What kind of waves do you think will travel down a horizontal metal rod if you strike its end (*a*) vertically from above and (*b*) horizontally parallel to its length?

* **16.** Since the density of air decreases with an increase in temperature, but the bulk modulus B is nearly independent of temperature, how would you expect the speed of sound waves in air to vary with temperature?

17. Give two reasons why circular water waves decrease in amplitude as they travel away from the source.

* **18.** Two linear waves have the same amplitude and speed, and otherwise are identical, except one has half the wavelength of the other. Which transmits more energy? By what factor?

19. When a sinusoidal wave crosses the boundary between two sections of cord as in Fig. 11–33, the frequency does not change (although the wavelength and velocity do change). Explain why.

20. If a string is vibrating in three segments, are there any places you could touch it with a knife blade without disturbing the motion?

21. When a standing wave exists on a string, the vibrations of incident and reflected waves cancel at the nodes. Does this mean that energy was destroyed? Explain.

* **22.** If we knew that energy was being transmitted from one place to another, how might we determine whether the energy was being carried by particles (material bodies) or by waves?