Review 10 Waves and Sound

1. A spring stretches by 25 cm when a 0.5–kg mass is suspended from its end.
   a. Determine the spring constant.
   b. How much elastic potential energy is stored in the spring when it is stretched this far?

2. A spring has a spring constant of 135 N/m. How far must it be compressed so that 4.39 J of elastic potential energy is stored in the spring?

3. On a planet where the gravitational acceleration is five times g on Earth, a pendulum swings back and forth with a period of 1.22 s. What is the length of the pendulum?

4. Sonya hears water dripping from the eaves of the house onto a porch roof. She counts 30 drops in 1 min.
   a. What is the frequency of the drops?
   b. What is the period of the drops?

5. Hiroshi is generating waves on a rope by flipping the rope up and down. Each motion up or down lasts 0.2 s. The distance from a crest to a trough is 0.4 m.
   a. What is the amplitude of the wave?
   b. What is the frequency of the waves?

6. A water wave travels a distance of 15 m in 1 min. When this wave passes a point where a cork is floating in the water, it causes the cork to move up and down 12 times in 15 s.
   a. What is the speed of this water wave?
   b. What is the wavelength of this water wave?
   c. What is the period of this water wave?

7. A Lowe wave, one of the four types of waves associated with earthquakes, is a transverse wave in which the surface of Earth moves back and forth as the wave passes. What is the speed of a Love wave that has a period of 150 s and a wavelength of 620 km?

8. A pulse with an amplitude of 0.53 m travels to the right along a rope. Another pulse, with an amplitude of –0.24 m, travels to the left along the same rope. The two pulses approach each other. What is the displacement of the rope at the point where the midpoints of the pulses pass each other?

9. A physics teacher attaches an electric oscillator to one end of a 2–m horizontal spring and attaches the other end of the spring to a stationary hook in the wall. She adjusts the frequency of the oscillator to produce a standing wave in the spring. Students observe that the standing wave has three nodes and two antinodes. She then doubles the frequency of the oscillations and produces another standing wave. How many nodes and antinodes do the students observe in the new standing wave?

10. What magnitude force will compress a spring so that the spring elastic potential increases by 0.24 J? The spring constant is 18 N/cm.

11. Each back–and–forth movement of the bob in a small pendulum clock releases a cog on a wheel. As the cog is released, the wheel undergoes a slight rotation. If the release of three cogs moves the second hand of the clock forward 1 s, what is the length of the pendulum?

12. Calculate the frequency in hertz of each of the following:
    a. a "new" moon (period = 27.3 days)
    b. a day on Earth
    c. a breath (Assume a breathing rate of 8–12 breaths in 60.0 s.)
    d. a heart beat (Assume a heart rate of 1.0–1.6 beats per second.)

13. The distance between four consecutive antinodes of a standing wave in a spring is 42 cm. What is the wavelength of the standing wave?

14. The sound a mosquito makes is produced when it beats its wings at the average frequency of 620 wing beats per second. What is the wavelength of the sound waves produced by the mosquito?

15. You are listening to an outdoor concert on a day when the temperature is 0°C. The sound with a wavelength of 0.49 m is emitted by a flute on the stage 125 m from where you are standing.
    a. What is the time elapsed before you hear the sound emitted from the stage?
    b. What is the frequency of the sound?

16. The pulse–echo technique is used in diagnostic medical imaging. A short ultrasound pulse is emitted from the device, and echoes are produced when the pulse is reflected at a tissue interface. The echo signals are received back at the device and then analyzed to build up an image of the organ. The speed of sound in soft tissue is 1540 m/s. If an echo is received 58.2×10^{-6} s after the pulse was emitted, how far is the tissue interface from the ultrasound device?

17. Hannah places an open, vertical glass tube into a container of water so that the lower end of the tube is submerged. She holds a vibrating tuning fork over the top of the tube while varying the water level in the tube. Hannah notices that the loudest sound is heard when the distance from the water to the top of the tube is 32.7 cm, and again when the distance is 98.2 cm. What is the frequency of the tuning fork?

18. The six strings of a standard guitar are tuned to the following frequencies: 165, 220, 294, 392, 494, and 659 Hz.
    a. Find the lengths of the shortest open–ended organ pipes that would produce the same frequencies.
    b. Sketch the pipes, showing their lengths to scale.

19. The fundamental tone of an open–pipe with a length of 48 cm is the same as the second harmonic tone of a closed–pipe. What is the length of the closed–pipe?

20. A radio station broadcasts their signal with a wavelength of 3.5 μm. Although your radio will translate this signal into audible sound, explain why you cannot hear the radio signal directly.

21. An open tube is filled with water which is slowly drained as a tuning fork of frequency $f = 1000$ Hz is held over the open end. As the water drains, the level of the water is marked as a maximum of sound is heard in the tube. These maxima are detected at distances of 16.7 cm, 33.4 cm and 50.1 cm, measured from the open end of the tube. What is the speed of sound in the air within the tube?

1a.
$$F = kx$$
$$mg = kx$$
$$k = \frac{mg}{x}$$
$$k = \frac{(0.5\text{ kg})g}{0.25\text{ m}}$$
$$k = 19.6\text{ N/m}$$

1b.
$$PE = \tfrac{1}{2}kx^2$$
$$PE = \tfrac{1}{2}(19.6\text{ N/m})(0.25\text{ m})^2$$
$$PE = 0.6125\text{ J}$$

2.
$$PE = \tfrac{1}{2}kx^2$$
$$x = \sqrt{\frac{2PE}{k}}$$
$$x = \sqrt{\frac{2(4.36\text{ J})}{135\text{ N/m}}}$$
$$x = 0.25\text{ m}$$

3.
$$T = 2\pi\sqrt{\frac{\ell}{g}}$$
$$\ell = \frac{gT^2}{4\pi^2}$$
$$\ell = \frac{5(9.8\text{ m/s}^2)(1.22\text{ s})^2}{4\pi^2}$$
$$\ell = 1.85\text{ m}$$

4a.
$$\frac{30\text{ drops}}{60\text{ s}} = 0.5\text{ drops/s}$$
$$= 0.5\text{ Hz}$$

4b.
$$\frac{60\text{ s}}{30\text{ drops}} = 2\text{ s/drop}$$
$$= 2\text{ s}$$

5a.
$$\text{amplitude} = \frac{0.4\text{ m}}{2}$$
$$= 0.2\text{ m}$$

5b.
$$\text{frequency} = \frac{0.5\text{ waves}}{0.4\text{ s}}$$
$$= 1.25\text{ Hz}$$

6a.
$$v = \frac{\Delta d}{\Delta t}$$
$$v = \frac{15\text{ m}}{60\text{ s}}$$
$$v = 0.25\text{ m/s}$$

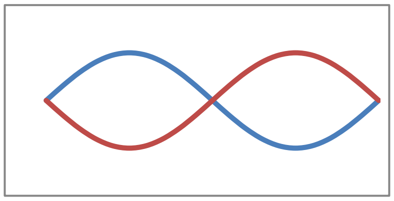
6c.
$$T = \frac{15\text{ s}}{12\text{ waves}}$$
$$T = 1.25\text{ s}$$

6b.
$$v = \frac{\lambda}{T}$$
$$\lambda = vT$$
$$\lambda = (0.25\text{ m/s})(1.25\text{ s})$$
$$\lambda = 0.31\text{ m}$$

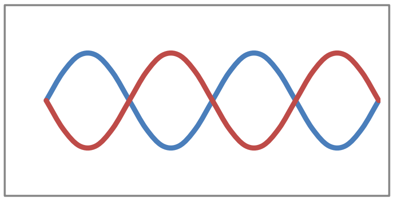
7.
$$v = \frac{\lambda}{T}$$
$$v = \frac{620\text{ km}}{150\text{ s}}$$
$$v = 4.13\text{ km/s}$$

8.
$$\text{displacement} = 0.53\text{ m} + (-0.24\text{ m})$$
$$= 0.29\text{ m}$$

9.



3 nodes



5 nodes

10. $PE = \frac{1}{2}kx^2$

$$x = \sqrt{\frac{2PE}{k}}$$

$$x = \sqrt{\frac{2(0.24\ \text{J})}{1800\ \text{N/m}}}$$

$$x = 0.016\ \text{m}$$

$$F = kx$$

$$F = (1800\ \text{N/m})(0.016\ \text{m})$$

$$F = 29\ \text{N}$$

11. $T = 2\pi\sqrt{\frac{\ell}{g}}$

$$\ell = \frac{gT^2}{4\pi^2}$$

$$\ell = \frac{g(0.33\ \text{s})^2}{4\pi^2}$$

$$\ell = 0.028\ \text{m}$$

12a. $\frac{27.3\ \text{days}}{1} \times \frac{86\,400\ \text{s}}{\text{day}} = 2\,358\,720\ \text{s}$

$$f = \frac{1}{T}$$

$$f = \frac{1}{2\,358\,720\ \text{s}}$$

$$f = 4.24 \times 10^{-7}\ \text{Hz}$$

12b. $f = \frac{1}{T}$

$$f = \frac{1}{86\,400\ \text{s}}$$

$$f = 1.16 \times 10^{-5}\ \text{Hz}$$

12c. $f = \frac{1}{T}$

$$f = \frac{10\ \text{breaths}}{60\ \text{s}}$$

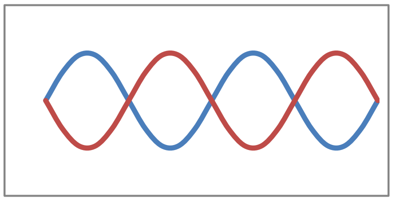
$$f = 0.17\ \text{Hz}$$

12d. $f = \frac{1}{T}$

$$f = \frac{1.3\ \text{beat}}{1\ \text{s}}$$

$$f = 1.3\ \text{Hz}$$

13.



4 consequative antinodes is 1.5 waves

$$1.5\lambda = 42\ \text{cm}$$

$$\lambda = 28\ \text{cm}$$

14. $v = f\lambda$

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{340\ \text{m/s}}{620\ \text{Hz}}$$

$$\lambda = 0.55\ \text{m}$$

15a. $v = \frac{\Delta d}{\Delta t}$

$$\Delta t = \frac{\Delta d}{v}$$

$$\Delta t = \frac{125\ \text{m}}{331\ \text{m/s}}$$

$$\Delta t = 0.378\ \text{s}$$

15b. $v = f\lambda$

$$f = \frac{v}{\lambda}$$

$$f = \frac{331\ \text{m/s}}{0.49\ \text{m}}$$

$$f = 676\ \text{Hz}$$

16. $v = \frac{\Delta d}{\Delta t}$

$$\Delta d = v\Delta t$$

$$\Delta d = (1540\ \text{m/s})\left(\frac{58.2 \times 10^{-6}\ \text{s}}{2}\right)$$

$$\Delta d = 0.0448\ \text{m}$$

17. $v = f\lambda$

$$f = \frac{v}{\lambda}$$

$$f = \frac{340\ \text{m/s}}{2(0.982\ \text{m} - 0.327\ \text{m})}$$

$$f = 260\ \text{Hz}$$

18a.

$$v = f\lambda$$

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{340 \text{ m/s}}{165 \text{ Hz}}$$

$$\lambda = 2.06 \text{ m}$$

$$L_{165} = 1.03 \text{ m}$$

$$L_{220} = 0.77 \text{ m}$$

$$L_{294} = 0.58 \text{ m}$$

$$L_{392} = 0.43 \text{ m}$$

$$L_{494} = 0.34 \text{ m}$$

$$L_{659} = 0.26 \text{ m}$$

18b.

19.

$$f_{1 \text{ open}} = \frac{v}{2L_{\text{open}}}$$

$$f_{2 \text{ closed}} = \frac{3v}{4L_{\text{closed}}}$$

$$\frac{v}{2L_{\text{open}}} = \frac{3v}{4L_{\text{closed}}}$$

$$\frac{L_{\text{open}}}{1} = \frac{2L_{\text{closed}}}{3}$$

$$L_{\text{closed}} = \frac{3L_{\text{open}}}{2}$$

$$L_{\text{closed}} = \frac{3(48 \text{ cm})}{2}$$

$$L_{\text{closed}} = 72 \text{ cm}$$

20.

$$v = f\lambda$$

$$f = \frac{v}{\lambda}$$

$$f = \frac{3 \times 10^8 \text{ m/s}}{3.5 \times 10^{-6} \text{ m}}$$

$$f = 8.6 \times 10^{13} \text{ Hz}$$

Human hearing only goes up to 20 kHz.

21.

$$v = f\lambda$$

$$v = (1000 \text{ Hz})(0.501 \text{ m - } 0.167 \text{ m})$$

$$v = 334 \text{ m/s}$$