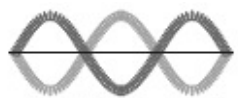
Worksheet
15.2

Musical Instruments

1. You and your group stretch a spring 12 feet across the floor and you produce a standing wave that has a node at each end and one antinode in the center. Sketch this and determine the wavelength of this wave.

2. You now create a standing wave with three nodes and two antinodes on the spring above. Sketch this and determine the wavelength of this wave.

3. Now the standing wave below is produced on the 12-foot spring. If the frequency of the wave is 3 Hz, what is the speed of the wave in ft/sec?



4. How many different standing wave patterns are possible on the spring? Explain your answer.

5. The length of a violin string is 33 cm. When bowed it plays a G3 at 196 Hz.
   a) What is the speed of the wave on this string?
   b) If the length of the string is shortened to 28 cm, what frequency will it produce?

6. The A string of a guitar vibrates at a frequency of 220 Hz when properly tuned. If the speed of the wave in the string is 273 m/s, what is the length of the string?

7. The "high A" note on a xylophone is constructed from an oak bar 14.82 cm long and it is supported at two points 8.17 cm apart. When struck, the bar vibrates at 880 Hz.

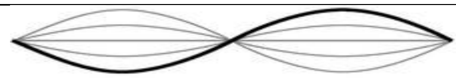
   a) Where are the nodes and antinodes on this bar?
   b) What is the wavelength of this wave?
   c) What is the speed of the wave in this bar?

8. A tube on a wind chime has a length of 45 cm and vibrates at 280 Hz. If you want to create a new tube that vibrates at 340 Hz, what length should it be?

9. A vertical tube with a tap at the base is filled with water, and a tuning fork vibrates over its mouth. As the water level is lowered in the tube, resonance is heard when the water level has dropped to 17 cm, and again at 49 cm. What is the frequency of the tuning fork?

10. The auditory canal leading to the eardrum is a closed pipe that is 3.0 cm long. Find the approximate value (ignoring end correction) of the lowest resonance frequency.

11. If you hold a 1.2–m aluminum rod in the center and hit one end with a hammer, it will oscillate like an open pipe. Antinodes of pressure correspond to nodes of molecular motion, so there is a pressure antinode in the center of the bar. The speed of sound in aluminum is 5150 m/s. What would be the bar's lowest frequency of oscillation?
12. A flute acts as an open pipe. If a flute sounds a note with a 370–Hz pitch, what are the frequencies of the second, third, and fourth harmonics of this pitch?
13. A clarinet sounds the same note, with a pitch of 370 Hz, as in the previous problem. The clarinet, however, acts as a closed pipe. What are the frequencies of the lowest three harmonics produced by this instrument?
14. A guitar string is 65 cm long and is tuned to produce a lowest frequency of 196 Hz.
    a. What is the speed of the wave on the string?
    b. What are the next two higher resonant frequencies for this string?
15. The lowest note on an organ is 16.4 Hz.
    a. What is the shortest open organ pipe that will resonate at this frequency?
    b. What is the pitch if the same organ pipe is closed?
16. A flexible, corrugated, plastic tube is 0.85 m long. When it is swung around, it creates a tone that is the lowest pitch for an open pipe of this length. What is the frequency?
17. The tube from the previous problem is swung faster, producing a higher pitch. What is the new frequency?
18. If you drop a stone into a well that is 122.5 m deep how soon after you drop the stone will you hear it hit the bottom of the well?
19. When a wet finger is rubbed around the rim of a glass, a loud tone of frequency 2100 Hz is produced. If the glass has a diameter of 6.2 cm and the vibration contains one wavelength around its rim, what is the speed of the wave in the glass?

<table>
<tr><td>1.</td><td> The wavelength is 24 ft.</td></tr>
<tr><td>2.</td><td> The wavelength is 12 ft.</td></tr>
<tr><td>3.</td><td>λ = 8 ft.; f = 3 Hz
$v = f\lambda$
$v = (3\text{ Hz})(8\text{ ft})$
$v = \boxed{24\text{ ft/s}}$</td></tr>
<tr><td>4.</td><td>There are an infinite number of possible standing waves. There can be 1, 2, 3, … possible antinodes.</td></tr>
<tr><td>5a.</td><td>L = 33 cm, λ = 66 cm = 0.66 m; v = 196 Hz
$v = f\lambda$
$v = (196\text{ Hz})(0.66\text{ m})$
$v = \boxed{129\text{ m/s}}$</td></tr>
<tr><td>5b.</td><td>L = 28 cm, λ = 56 cm = 0.56 m; v = 129 m/s
$f = \frac{v}{\lambda}$
$f = \frac{129\text{ m/s}}{0.56\text{ m}}$
$f = \boxed{231\text{ Hz}}$</td></tr>
<tr><td>6.</td><td>$v = f\lambda$
$\lambda = \frac{v}{f}$
$\lambda = \frac{273\text{ m/s}}{220\text{ Hz}}$
$\lambda = 1.24\text{ m}$
$L = \frac{\lambda}{2}$
$L = \frac{1.24\text{ m}}{2}$
$\boxed{L = 0.62\text{ m}}$</td></tr>
<tr><td>7a.</td><td>The nodes are at the support points, an antinode exists at the center.</td></tr>
</table>

7b.	The length is double the distance between the antinodes, which is double the distance between the supports. $\lambda = 2(8.17\text{ cm})$ $\boxed{\lambda = 16.34\text{ cm}}$
7c.	$v = f\lambda$ $v = (880\text{ Hz})(0.1634\text{ m})$ $\boxed{v = 144\text{ m/s}}$
8.	$v = f\lambda$ Assume the speed of the wave remaind constatnt from one tube to the next. Also assume the wavelength is proportional to the length of the tube. $f_1\lambda_1 = f_2\lambda_2$ $f_1L_1 = f_2L_2$ $L_1 = \frac{f_2L_2}{f_1}$ $L_1 = \frac{(280\text{ Hz})(45\text{ cm})}{340\text{ Hz}}$ $\boxed{L_1 = 37\text{ cm}}$
9.	49 cm – 17 cm = 32 cm This is the distance from one antinode to the next. $0.32\text{ m} = \frac{\lambda}{2}$ $\lambda = 0.64\text{ m}$ $v = f\lambda$ $f = \frac{v}{\lambda}$ $f = \frac{340\text{ m/s}}{0.64\text{ m}}$ $f = 530\text{ Hz}$
10.	Treat the auditory canal as a closed tube. $0.030\text{ m} = \frac{\lambda}{4}$ $\lambda = 0.120\text{ m}$ $v = f\lambda$ $f = \frac{v}{\lambda}$ $f = \frac{340\text{ m/s}}{0.120\text{ m}}$ $f = 2800\text{ Hz}$

11.	$1.2\text{ m} = \frac{\lambda}{2}$ $\lambda = 2.4\text{ m}$ $v = f\lambda$ $f = \frac{v}{\lambda}$ $f = \frac{5150\text{ m/s}}{2.4\text{ m}}$ $f = 2100\text{ Hz}$
12.	$f_n = nf_1 \left(n = 1, 2, 3, \ldots\right)$ $f_2 = (2)(370\text{ Hz})$ $f_2 = 740\text{ Hz}$ $f_3 = (3)(370\text{ Hz})$ $f_3 = 1110\text{ Hz}$ $f_4 = (4)(370\text{ Hz})$ $f_4 = 1480\text{ Hz}$
13.	$f_n = mf_1 \left(m = 1, 3, 5, \ldots\right)$ $f_2 = (3)(370\text{ Hz})$ $f_2 = 1110\text{ Hz}$ $f_3 = (5)(370\text{ Hz})$ $f_3 = 1850\text{ Hz}$ $f_4 = (7)(370\text{ Hz})$ $f_4 = 2590\text{ Hz}$
14a.	$0.65\text{ m} = \frac{\lambda}{2}$ $\lambda = 1.3\text{ m}$ $v = f\lambda$ $v = (196\text{ Hz})(1.3\text{ m})$ $v = 255\text{ Hz}$
14b.	$f_n = nf_1 \left(n = 1, 2, 3, \ldots\right)$ $f_2 = (2)(196\text{ Hz})$ $f_2 = 392\text{ Hz}$ $f_3 = (3)(196\text{ Hz})$ $f_3 = 588\text{ Hz}$

15a.	$v = f\lambda$ $\lambda = \frac{v}{f}$ $\lambda = \frac{340\text{ m/s}}{16.4\text{ Hz}}$ $\lambda = 20.7\text{ m}$ $L = \frac{\lambda}{2}$ $L = \frac{20.7\text{ m}}{2}$ $L = 10.3\text{ m}$
15b.	$10.3\text{ m} = \frac{\lambda}{4}$ $\lambda = 41.5\text{ m}$ $v = f\lambda$ $f = \frac{v}{\lambda}$ $f = \frac{340\text{ m/s}}{41.5\text{ m}}$ $f = 8.2\text{ Hz}$
16.	$0.85\text{ m} = \frac{\lambda}{2}$ $\lambda = 1.7\text{ m}$ $v = f\lambda$ $f = \frac{v}{\lambda}$ $f = \frac{340\text{ m/s}}{1.7\text{ m}}$ $f = 200\text{ Hz}$
17.	$f_n = nf_1 \left(n = 1, 2, 3, \ldots\right)$ $f_2 = (2)(200\text{ Hz})$ $f_2 = 400\text{ Hz}$

18.	Time for the stone to fall to the bottom of the well. $t = \sqrt{\frac{2h}{g}}$ $t = \sqrt{\frac{2(122.5 \text{ m})}{9.8 \text{ m/s}^2}}$ $t = 5.00 \text{ s}$ Time for sound to return to the top of the well. $d = vt$ $t = \frac{d}{v}$ $t = \frac{122.5 \text{ m}}{340 \text{ m/s}}$ $t = 0.36 \text{ s}$ Total time = 5.00 s + 0.36 s = 5.36 s
19.	$C = \pi d$ $C = \pi(0.062 \text{ m})$ $C = 0.195 \text{ m} = \lambda$ $v = f\lambda$ $v = (2100 \text{ Hz})(0.195 \text{ m})$ $v = 409 \text{ m/s}$