Chapter 17 End-of-Chapter Problems

Halliday & Resnick, 10th Edition

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Hit me where it Matters

Where needed in the problems, use
speed of sound in air = 343 m/s
and
density of air = 1.21 kg/m^3
unless otherwise specified.

1 Problem 1

Two spectators at a soccer game see, and a moment later hear, the ball being kicked on the playing field. The time delay for spectator A is 0.23 s, and for spectator B it is 0.12 s. Sight lines from the two spectators to the player kicking the ball meet at an angle of 90°. How far are (a) spectator A and (b) spectator B from the player? (c) How far are the spectators from each other?

1.1 Solution (a)

This is a simple question to answer. The distance traveled to A would be equal to the speed of sound times the time taken to travel the distance.

$$x = vt = (343\,\mathrm{m/s})(0.23\,\mathrm{s}) = \boxed{78.89\,\mathrm{m}} \tag{1}$$

1.2 Solution (b)

The is calculatable the same way.

$$y = vt = (343\,\mathrm{m/s})(0.12\,\mathrm{s}) = \boxed{41.16\,\mathrm{m}} \tag{2}$$

1.3 Solution (c)

The 90 degree angle of their sight lines makes the triange of the two spectators and the ball a right triangle, so we can use the Pythagorean theorem to find the distance between the spectators.

$$h = \sqrt{x^2 + y^2} = \sqrt{(78.89\,\mathrm{m})^2 + (41.16\,\mathrm{m})^2} = \boxed{88.98\,\mathrm{m}} \tag{3}$$

2 Problem 3

When the door of the Chapel of the Mausoleum in Hamilton, Scotland, is slammed shut, the last echo heard by someone standing just inside the door reportedly comes 15 s later. (a) If that echo were due to a single reflection off a wall opposite the door, how far from the door is the wall? (b) If, instead, the wall is 25.7 m away, how many reflections (back and forth) occur?

2.1 Solution (a)

Use the speed and the time taken to calculate the distance covered.

$$\Delta s = vt = (343\,\mathrm{m/s})(15\,\mathrm{s}) = 5145\,\mathrm{m} \tag{4}$$

This is twice the length of the church, so if we divide this by two, we will get the length of the church.

$$L = \frac{\Delta s}{2} = \frac{5145\,\mathrm{m}}{2} = \boxed{2572.5\,\mathrm{m}} \tag{5}$$

2.2 Solution (b)

We can divide the total distance covered by the length of the church to fnd the number of reflections.

$$n = \frac{5145\,\mathrm{m}}{25.7\,\mathrm{m}} = 200.19 \tag{6}$$

$$\lfloor n \rfloor = \boxed{200} \tag{7}$$

3 Problem 5

Earthquakes generate sound waves inside Earth. Unlike a gas, Earth can experience both transverse (S) and longitudinal (P) sound waves. Typically, the speed of S waves is about 4.5 km/s, and that of P waves 8.0 km/s. A seismograph records P and S waves from an earthquake. The first P waves arrive 3.0 min before the first S waves. If the waves travel in a straight line, how far away did the earthquake occur?

3.1 Solution

3.0 minutes is equivalent to 180 seconds. If the time it takes the longitudinal wave to reach the scale is t, the time it takes the transverse wave would be $t + 180\,\mathrm{s}$. We can use this in an equation for distance from velocity.

$$\Delta x = vt \tag{8}$$
$$x = (8.0\,\mathrm{km/s})t \tag{9}$$
$$x = (4.5\,\mathrm{km/s})(t + 180\,\mathrm{s}) \tag{10}$$

Use the transistive property and solve for the time.

$$(8.0\,\mathrm{km/s})t = (4.5\,\mathrm{km/s})(t + 180\,\mathrm{s}) \tag{11}$$
$$(3.5\,\mathrm{km/s})t = 810\,\mathrm{km} = \frac{810}{3.5}\,\mathrm{s} \tag{12}$$

Substitute this into the first equation for the distance covered.

$$x = (8.0\,\mathrm{km/s})(\frac{810}{3.5}\,\mathrm{s}) = \boxed{1851\,\mathrm{km}} \tag{13}$$

4 Problem 7

A stone is dropped into a well. The splash is heard 3.00 s later. What is the depth of the well?

4.1 Solution

The time taken of 3.00 s is the time taken for the stone to drop plus the time taken for the sound to return up the well. We can create formulas for each of these, using a gravitational constant of $9.81\,\mathrm{m/s^2}$.

$$h = \frac{1}{2}gt_1^2 = \frac{(9.81\,\mathrm{m/s^2})}{2}t_1^2 \tag{14}$$

$$h = vt_2 = (343\,\mathrm{m/s})t_2 \tag{15}$$

$$t_1 + t_2 = 3.00\,\mathrm{s} \rightarrow t_2 = 3.00\,\mathrm{s} - t_1 \tag{16}$$

We can substitute our value of t_2 into the equation for the distance traveled by the sound and solve that for t_1.

$$h = (343\,\mathrm{m/s})(3.00\,\mathrm{s} - t_1) \tag{17}$$

$$3.00\,\mathrm{s} - t_1 = \frac{h}{343\,\mathrm{m/s}} \tag{18}$$

$$t_1 = 3.00\,\mathrm{s} - \frac{h}{343\,\mathrm{m/s}} \tag{19}$$

This in turn can be substituted into our other equation for the depth of the well.

$$h = \frac{(9.81\,\mathrm{m/s^2})}{2}t_1^2 = \frac{(9.81\,\mathrm{m/s^2})}{2}\left(3.00\,\mathrm{s} - \frac{h}{343\,\mathrm{m/s}}\right)^2 \tag{20}$$

$$2(343\,\mathrm{m/s})^2 h = 9.81\,\mathrm{m/s^2}\left((1029\,\mathrm{m})^2 - (2058\,\mathrm{m})h + h^2\right) \tag{21}$$

This gives us a polynomial. Solving that polynomial gives us a value of $\boxed{h = 40.72\,\mathrm{m}}$.

5 Problem 11

Diagnostic ultrasound of frequency 4.50 MHz is used to examine tumors in soft tissue. (a) What is the wavelength in air of such a sound wave? (b) If the speed of sound in tissue is 1500 m/s, what is the wavelength of this wave in tissue?

5.1 Solution (a)

We have an equation for frequency and wavelength and an accepted speed of sound in air.

$$v = \lambda f \tag{22}$$
$$v = 343\,\mathrm{m/s} \tag{23}$$

We can use these to get the wavelength.

$$\lambda = \frac{v}{f} = \frac{343\,\mathrm{m/s}}{4,50 \times 10^6\,\mathrm{Hz}} = \boxed{7,62 \times 10^{-5}\,\mathrm{m}} \tag{24}$$

5.2 Solution (b)

Let's do the same thing.

$$v = \lambda f \tag{25}$$
$$v = 1500\,\mathrm{m/s} \tag{26}$$

We can use these to get the wavelength.

$$\lambda = \frac{v}{f} = \frac{1500\,\mathrm{m/s}}{4,50 \times 10^6\,\mathrm{Hz}} = \boxed{3,3 \times 10^{-4}\mathrm{m}} \tag{27}$$

6 Problem 15

A handclap on stage in an amphitheater sends out sound waves that scatter from terraces of width $w = 0.75$ m (Fig. 17-33). The sound returns to the stage as a periodic series of pulses, one from each terrace; the parade of pulses sounds like a played note. (a) Assuming that all the rays in Fig. 17-33 are horizontal, find the frequency at which the pulses return (that is, the frequency of the perceived note). (b) If the width w of the terraces were smaller, would the frequency be higher or lower?

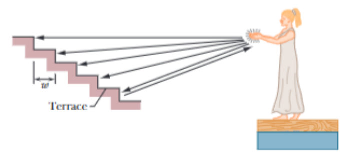

Figure 17-33 Problem 15.

6.1 Solution (a)

With each step, the sound would have to travel an additional distance of $2w$. If we divide the speed of all these sounds by the extra distance to travel, we would get the frequency of the return of the pulse rays.

$$f = \frac{v}{\Delta x} = \frac{343\,\mathrm{m/s}}{2(0.75\,\mathrm{m})} = \boxed{228.67\,\mathrm{Hz}} \tag{28}$$

6.2 Solution (b)

The frequency would be higher.

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7.1 Solution

8 Problem 19

8.1 Solution

9 Problem 20

9.1 Solution

10 Problem 25

10.1 Solution

11 Problem 27

11.1 Solution

12 Problem 29

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22 Problem 61

22.1 Solution

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