PHY130: HW_13 Help

Solution or Explanation

The speed of sound in seawater at 25°C is 1533 m/s. Therefore, the time for the sound to reach the sea floor and return is

$$t = \frac{2d}{v} = \frac{2(205\ \text{m})}{1533\ \text{m/s}} = 0.267\ \text{s}$$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

(a) The intensity level corresponding to an intensity of $6.30 \times 10^{-3}\ \text{W/m}^2$ is the following.

$$\beta_1 = 10 \log\left(\frac{I_1}{I_0}\right) = 10 \log\left(\frac{6.30 \times 10^{-3}\ \text{W/m}^2}{1.00 \times 10^{-12}\ \text{W/m}^2}\right)$$
$$= 98.0\ \text{dB}$$

(b) The ratio of wave intensities on spherical surfaces of different radii is the following.

$$\frac{I_1}{I_2} = \frac{r_2^{\,2}}{r_1^{\,2}}$$

Solve for I_2 and substitute values to find the intensity at a distance of $r_2 = 42.0$ m.

$$I_2 = \frac{r_1^{\,2}}{r_2^{\,2}} I_1 = \frac{(1.25\ \text{m})^2}{(42.0\ \text{m})^2}(6.30 \times 10^{-3}\ \text{W/m}^2)$$
$$= 5.58 \times 10^{-6}\ \text{W/m}^2$$

(c) The intensity level corresponding to an intensity of $5.58 \times 10^{-6}\ \text{W/m}^2$ is the following.

$$\beta_2 = 10 \log\left(\frac{I_2}{I_0}\right) = 10 \log\left(\frac{5.58 \times 10^{-6}\ \text{W/m}^2}{1.00 \times 10^{-12}\ \text{W/m}^2}\right)$$
$$= 67.5\ \text{dB}$$

Solution or Explanation

(a) $I = \dfrac{P}{4\pi r^2} = \dfrac{109\text{ W}}{4\pi(11.4\text{ m})^2} = 0.0667\text{ W/m}^2$

(b) $\beta = 10\log\left(\dfrac{I}{I_0}\right) = 10\log\left(\dfrac{0.0667\text{ W/m}^2}{1.00\times10^{-12}\text{ W/m}^2}\right)$

$= 10\log(6.67\times10^{10}\text{ W/m}^2) = 108\text{ dB}$

(c) At the threshold of pain (β = 120 dB), the intensity is $I = 1.00\text{ W/m}^2$. Thus, from $I = P/4\pi r^2$, the distance from the speaker is

$r = \sqrt{\dfrac{P}{4\pi I}} = \sqrt{\dfrac{109\text{ W}}{4\pi(1.00\text{ W/m}^2)}} = 2.95\text{ m}.$

Two trains on separate tracks move toward each other. Train 1 has a speed of 134 km/h; train 2, a speed of 69.0 km/h. Train 2 blows its horn, emitting a frequency of 500 Hz. What is the frequency heard by the engineer on train 1?

587 Hz

Solution or Explanation

Both source and observer are in motion, so $f_o = f_s\left(\dfrac{v + v_o}{v - v_s}\right)$. Since each train moves *toward* the other, $v_o > 0$ and $v_s > 0$. The speed of the source (train 2) is

$v_s = 69.0\ \dfrac{\text{km}}{\text{h}}\left(\dfrac{1000\text{ m}}{1\text{ km}}\right)\left(\dfrac{1\text{ h}}{3600\text{ s}}\right) = 19.2\text{ m/s},$

and that of the observer (train 1) is v_o = 134 km/h = 37.2 m/s. Thus, the observed frequency is

$f_o = (500\text{ Hz})\left(\dfrac{343\text{ m/s} + 37.2\text{ m/s}}{343\text{ m/s} - 19.2\text{ m/s}}\right) = 587\text{ Hz}.$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

In the fundamental mode of vibration, the wavelength of waves in the wire is

$\lambda = 2L = 2(0.820\text{ m}) = 1.64\text{ m}.$

If the wire is to vibrate at f = 261.6 Hz, the speed of the waves must be

$v = \lambda f = (1.64\text{ m})(261.6\text{ Hz}) = 429\text{ m/s}.$

The mass per unit length of the wire is

$\mu = \dfrac{m}{L} = \dfrac{3.400\times10^{-3}\text{ kg}}{0.820\text{ m}} = 4.146\times10^{-3}\text{ kg/m}$

and the required tension is given by $v = \sqrt{F/\mu}$ as

$F = v^2\mu = (429\text{ m/s})^2(4.146\times10^{-3}\text{ kg/m}) = 763\text{ N}.$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

When the string vibrates in the fourth harmonic (i.e., in four equal segments) at a frequency of f_4 = 730 Hz, we have $L = 4(\lambda_4/2)$, or the wavelength is $\lambda_4 = 2L/4$. The speed of transverse waves in the string is then

$$v = \lambda_4 f_4 = (2L/4)f_4.$$

For the string to vibrate in two segments (i.e., second harmonic), the wavelength must be such that $L = 2(\lambda_2/2)$ or $\lambda_2 = 2L/2$. The new frequency would then be

$$f_2 = \frac{v}{\lambda_2} = \frac{(2L/4)f_4}{2L/2} = \frac{2}{4}f_4 = \frac{2}{4}(730\text{ Hz}) = 365\text{ Hz}.$$

Solution or Explanation

Note: We are displaying rounded intermediate values for practical purposes. However, the calculations are made using the unrounded values.

Assuming an air temperature of T = 36°C = 309 K, the speed of sound inside the pipe is

$$v = (331\text{ m/s})\sqrt{\frac{T_K}{273\text{ K}}} = (331\text{ m/s})\sqrt{\frac{309}{273}} = 352\text{ m/s}.$$

In the fundamental resonant mode, the wavelength of sound waves in a pipe closed at one end is $\lambda = 4L$. Thus, for the whooping crane

$$\lambda = 4(4.9\text{ ft}) = 20\text{ ft}$$

and $f = \dfrac{v}{\lambda} = \dfrac{(352\text{ m/s})}{20\text{ ft}}\left(\dfrac{3.281\text{ ft}}{1\text{ m}}\right) = 58.9\text{ Hz}.$

Solution or Explanation

Hearing would be best at the fundamental resonance, so we have the following.

$$\lambda = 4L = 4(2.7\text{ cm})$$

and

$$f = \frac{v}{\lambda} = \frac{343\text{ m/s}}{4(2.7\text{ cm})}\left(\frac{100\text{ cm}}{1\text{ m}}\right) = 3.18 \times 10^3\text{ Hz} = \underline{3.18\text{ kHz}}$$

Solution or Explanation

The beat frequency is $f_b = |f_2 - f_1|$. With $f_1 = 201$ Hz, solve for f_2 to find the following.

$$f_2 = f_1 - f_b = (201\text{ Hz}) - (6\text{ Hz}) = 195\text{ Hz}$$

and

$$f_2 = f_1 + f_b = (201\text{ Hz}) + (6\text{ Hz}) = 207\text{ Hz}$$

Solution or Explanation

At normal body temperature of $T = 37.0°C$, the speed of sound in air is

$$v = (331\text{ m/s})\sqrt{1 + \frac{T_c}{273}} = (331\text{ m/s})\sqrt{1 + \frac{37.0}{273}}$$

and the wavelength of sound having a frequency of $f = 17{,}000$ Hz is

$$\lambda = \frac{v}{f} = \frac{(331\text{ m/s})}{(17{,}000\text{ Hz})}\sqrt{1 + \frac{37.0}{273}} = 2.07 \times 10^{-2}\text{ m} = 2.07\text{ cm.}$$

Thus, the diameter of the eardrum is 2.07 cm.