Chapter 17.

1. An experimenter wishes to generate in air a sound wave that has a displacement amplitude of 5.50×10^{-6} m. The pressure amplitude is to be limited to 0.840 Pa. What is the minimum wavelength the sound wave can have?

   Ans:

   We use $\Delta P_{\max} = \rho \upsilon \omega s_{\max} = \rho \upsilon \left(\dfrac{2\pi \upsilon}{\lambda} \right) s_{\max}$:

$$\lambda_{\min} = \frac{2\pi \rho \upsilon^2 s_{\max}}{\Delta P_{\max}} = \frac{2\pi \left(1.20\,\mathrm{kg/m^3}\right)\left(343\,\mathrm{m/s}\right)^2 \left(5.50\times 10^{-6}\,\mathrm{m}\right)}{0.840\,\mathrm{Pa}} = \boxed{5.81\,\mathrm{m}}$$

2. A sound wave in air has a pressure amplitude equal to 4.00×10^{-3} Pa. Calculate the displacement amplitude of the wave at a frequency of 10.0 kHz.

   Ans:

$$\Delta \mathrm{P}_{\max} = \rho \upsilon \omega s_{max}$$

$$s_{\max} = \frac{\Delta P_{\max}}{\rho \upsilon \omega} = \frac{4.00\times 10^{-3}\ \mathrm{N/m^2}}{\left(1.20\,\mathrm{kg/m^3}\right)\left(343\,\mathrm{m/s}\right)\left(2\pi\right)\left(10.0\times 10^{3}\ s^{-1}\right)}$$

$$= \boxed{1.55\times 10^{-10}\ \mathrm{m}}$$

3. The sound intensity at a distance of 16 m from a noisy generator is measured to be 0.25 W/m^2. What is the sound intensity at a distance of 28 m from the generator?

   Ans:

   The intensity is given by $I = \dfrac{P_{\text{avg}}}{4\pi r^2}$.

   The power is not given, but the intensity at a known distance is $I = \dfrac{P_{\text{avg}}}{4\pi r^2}$

   which gives

$$P_{\text{avg}} = I(r) 4\pi r^2 = 4\pi (0.25\ \mathrm{W/m^2})(16\mathrm{m})^2 = 804.2\ \mathrm{W}$$

   which can then be substituted back into the same equation:

$$I = \frac{P_{\text{avg}}}{4\pi r^2} = \frac{804.2\,\mathrm{W}}{4\pi \left(28\,\mathrm{m}\right)^2} = \boxed{0.082\,\mathrm{W/m^2}}$$

4. Calculate the sound level (in decibels) of a sound wave that has an intensity of 4.00 μW/m^2.

   Ans:

$$\beta = \left(10\,\mathrm{dB}\right)\log\left(\frac{I}{I_0}\right) = \left(10\,\mathrm{dB}\right)\log\left(\frac{4.00\times 10^{-6}\ \mathrm{W/m^2}}{1.00\times 10^{-12}\ \mathrm{W/m^2}}\right)$$

$$= \boxed{66.0\,\mathrm{dB}}$$

5. Two small speakers emit sound waves of different frequencies equally in all directions. Speaker *A* has an output of 1.00 mW, and speaker *B* has an output of 1.50 mW. Determine the sound level (in decibels) at point *C* in Figure P17.32 assuming (a) only speaker *A* emits sound, (b) only speaker *B* emits sound, and (c) both speakers emit sound.

Ans:

The speakers broadcast equally in all directions, so the intensity of sound is inversely proportional to the square of the distance from its source.

$$r_{AC} = \sqrt{3.00^2 + 4.00^2}\ \text{m} = 5.00\,\text{m}$$

(a)

$$I = \frac{P}{4\pi r^2} = \frac{1.00\times 10^{-3}\,\text{W}}{4\pi (5.00\,\text{m})^2} = 3.18\times 10^{-6}\ \text{W/m}^2$$

$$\beta = (10\,\text{dB})\log\left(\frac{3.18\times 10^{-6}\ \text{W/m}^2}{10^{-12}\ \text{W/m}^2}\right)$$

$$\beta = (10\,\text{dB})\ 6.50 = \boxed{65.0\,\text{dB}}$$

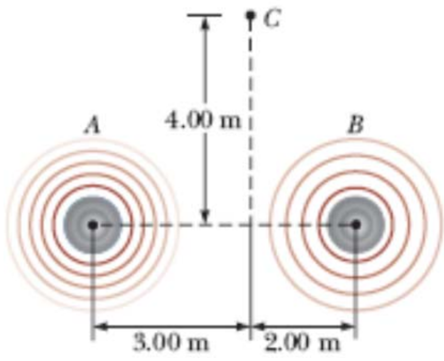

Figure P17.32

(b) $r_{BC} = 4.47$ m

$$I = \frac{1.50\times 10^{-3}\ \text{W}}{4\pi (4.47\,\text{m})^2} = 5.97\times 10^{-6}\ \text{W/m}^2$$

$$\beta = (10\,\text{dB})\log\left(\frac{5.97\times 10^{-6}\ \text{W/m}^2}{10^{-12}\ \text{W/m}^2}\right)$$

$$\beta = \boxed{67.8\,\text{dB}}$$

(c) $I = 3.18\ \mu\text{W/m}^2 + 5.97\ \mu\text{W/m}^2$

$$\beta = (10\,\text{dB})\log\left(\frac{9.15\times 10^{-6}\ \text{W/m}^2}{10^{-12}\ \text{W/m}^2}\right) = \boxed{69.6\,\text{dB}}$$