Environmental Science

Problems Chapter 2

2.1.1 Calculate the speed of a wave on a string that is set between two supports. The string has a mass of 0.35 kg and a length of 2.1 m. The force on the string keeping it between the two points is 72N.

Solution

Applying the formula

$$v = \sqrt{\frac{F}{\mu}}$$

we obtain with F = 72N, μ = 0.35/2.1 kg/m the following velocity

$$v = \sqrt{\frac{72}{0.35/2.1}} = 21 m/s$$

Answer: 21 m/s

2.1.2 The string above is set to vibrate at a frequency of 470 Hz and with an amplitude of 0.12 cm. Calculate the mean power of the wave that is transported along the string.

Solution

Applying the formula for the wave mean power

$$P_{ave} = \frac{1}{2}\sqrt{\mu F}\,\omega^2 A^2$$

we obtain the following result

$$P_{ave} = \frac{1}{2}\sqrt{\frac{0.35}{2.1} \times 72}\,(2\pi \times 470)^2 0.00012^2\, W = 22 W$$

Answer: 22 W

2.2.1 A gas has pressure modulus B = 1.42×10^5 Pa at room temperature. The wave velocity in the gas is 344 m/s. Calculate the gas density.

Solution

Applying the formula for the gas velocity

$$v = \sqrt{\frac{B}{\rho}}$$

gives the following value for the gas density $\rho = B/v^2 = 1.42 \times 10^5/344^2 = 1.20$ kg/m^3, which fits well with the density of air.

Answer: 1.20 kg/m^3

2.2.2 One measures the wave velocity of sound in air at a temperature *T* to be 359 m/s. Calculate the temperature *T*.

Solution

Applying the expression for the wave velocity as a function of temperature, $v = 331.4+0.606 \cdot T$, we obtain: $359 = 331.4+0.606 \cdot T$, resulting in the following temperature $T = (359-331.4)/0.606$ °C = 45.5 °C.

Answer: 45.5 °C.

2.3.1 The so called threshold for hearing is $I_0 = 10^{-12}$ W/m^2. Determine the pressure amplitude p_{max} at the threshold for hearing in air.

Solution

Applying the expression

$$I_{av} = \frac{p_{\max}^2}{2\sqrt{\rho B}}$$

We rewrite the expression an get

$$p_{\max} = \sqrt{2I_{av}\sqrt{\rho B}} = \sqrt{2\times 10^{-12}\sqrt{1.2\times 1.42\times 10^{5}}}\ \text{Pa} = 2.9\times 10^{-5}\ \text{Pa}$$

Answer: 2.9x10^{-5} Pa.

2.4.1 A sound has intensity at the threshold of hearing, or at the Sound level 0 dB. Calculate how much the sound level will rise if the intensity is twice the intensity at the threshold of hearing.

Solution

The sound level at the threshold is $\beta_1 = 0$ dB and $\beta 2 = 10\log(2I_1/I_0) = 10\log 2 + 10\log(I_1/I_0) = 10\log 2 + 0$ dB = 3.01 dB = 3.0 dB

Answer: 3.0 dB.

2.4.2 A sound has intensity at the threshold of hearing, or at the Sound level 0 dB. Calculate how much the sound level will rise if the intensity is 10 times the intensity at the threshold of hearing.

Solution

The sound level at the threshold is $\beta_1 = 0$ dB and $\beta 2 = 10\log(10I_1/I_0) = 10\log 10 + 10\log(I_1/I_0) = 10\log 10 + 0$ dB = 10x1 dB = 10 dB

Answer: 10 dB.

2.5.1 A meteorite is entering the atmosphere. A sensitive microphone detects a sound with frequency 3.7 Hz. Calculate the wavelength of the generated sound.

Solution

Applying the simple formula $v = f\lambda$ we obtain the wavelength $\lambda = v/f = 340/3.7$ m = 91.9 m = 92 m

Answer: 92 m.

2.5.1 A whale gives a sound with frequency 4.5 Hz. Two microphones immersed in the water are placed 315 m from each other, so that the microphones and the whale are on the same straight line. The microphones observe maxima simultaneously. What is the speed of the wave?

Solution

The distance between the microphones equals 1 wavelength, why λ = 315 m. Applying the formula $v = f\lambda$ we obtain the speed of the wave $v = f\,\lambda = 4.5 \times 315$ m/s = 1418 m/s = 1.4 km/s, which agrees well with the speed of sound in water.

Answer: 1.4 km/s.