INTRODUCTION TO BIOPHYSICS 2

BPH 112

PROBLEMS-A

PROBLEMS

Note:

The equilibrium density of air at 20°C is $\rho = 1.20\ \text{kg/m}^3$.

The speed of sound in air is $v = 340\ \text{m/s}$.

Pressure variations

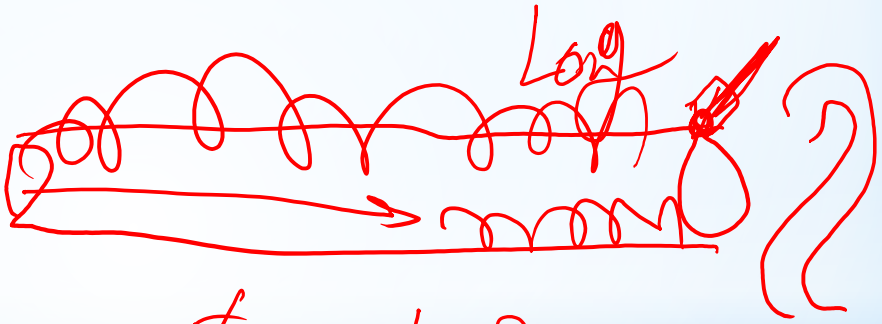
P are measured relative to atmospheric pressure, $1.013 \times 10^5\ \text{N/m}^2$.

1. Suppose that you hear a clap of thunder 25 s after seeing the associated lightning stroke. The speed of sound waves in air is 340 m/s. How far are you from the lightning stroke?

2. When a workman strikes a steel pipeline with a hammer, he generates both longitudinal and transverse waves. The two types of reflected waves return 2.4 s apart.

How far away is the reflection point?

[For steel, v_l = 6.2 km/s, v_t = 3.2 km/s]



$x = vt$

$= 6.2 \times 10^3 \times 1.2$

$= 7.44 \times 10^3$ m $= 7.44$ km

$t_1 = 1.2$

3. A bat can detect very small objects, such as an insect whose length is approximately equal to one wavelength of the sound the bat makes. If a bat emits chirps at a frequency of 60.0 kHz, and if the speed of sound in air is 340 m/s,

what is the smallest insect the bat can detect?

$\ell = \lambda$

$v = \lambda f \quad (\quad \ell = \lambda$

$f = 60 \times 10^3 \text{ Hz}$

$v_s = 340 \text{ m/s}$

$\ell = \lambda = \frac{v}{f} = \frac{340}{60 \times 10^3} = 5{,}7 \times 10^{-3} \text{ m}$

$\simeq 5{,}7 \text{ mm}$

4. A sound wave in air has a pressure amplitude equal to $4.00 \times 10^{-3}\ \text{N/m}^2$. Calculate the displacement amplitude of the wave at a frequency of 10.0 kHz.

Intensity $\quad W/m^2$

$$I = \frac{1}{2}\rho v \gamma^2 \omega^2$$

$$I = \frac{P_0^2}{2Z}$$

Pressure $\quad \frac{N}{m^2}$

$$\gamma^2 = \frac{2I}{\rho v (2\pi f)^2}$$

$$= \frac{2P_0^2}{2Z\rho v (2\pi f)^2}$$

Example sound	Sound Intensity I (W/m^2)	Intensity Ratio (I/I_o)	Intensity Level (dB)
Loud rock concert	1	10^{12}	120
Underground train	10^{-2}	10^{10}	100
Shouting person	10^{-4}	10^{8}	80
Normal conversation	10^{-6}	10^{6}	60
Quiet room	10^{-8}	10^{4}	40
Rustling leaves	10^{-10}	10^{2}	20
Reference level (Io)	10^{-12}	1	0

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

5. The area of a typical eardrum is about $5 \times 10^{-5}\ m^2$. Calculate the sound power incident on an eardrum at:

I = Power/A (W/m^2)

(a) the threshold of hearing (and

(b) the threshold of pain.

Sound intensity **(I)** $= \frac{1}{2} \rho v Y^2 (2\pi f)^2 = \frac{P_o^2}{2Z}$ **(W/m^2)**

P_o is the maximum acoustic pressure= Z Y ω. **(N/m^2)**

I_{th} (hearing) = $10^{-12}\ W/m^2$

I_{th} (pain) = 1 W/m^2

I = Power/A (W/m^2)

Power = I A= (W)

$10^{-12} \times 5 \times 10^{-5} = 50 \times 10^{-18}$ W

$1 \times 5 \times 10^{-5} = 50 \times 10^{-6}$ W

6. Calculate the sound level in decibels of a sound wave that has an intensity of 4.00 W/m^2.

I

$$SL = 10 \log \frac{I}{I_0}$$

$$I_0 = 10^{-12}\ W/m^2$$

7. A vacuum cleaner produces sound with a measured sound level of 70 dB.

(a) What is the intensity of this sound in W/m^2?

(b) What is the pressure amplitude of the sound?

$$SL = 10 \log \frac{I}{I_0}$$

$$70 = 10 \log \frac{I}{10^{-12}}$$

$$\text{antilog } 7 = \frac{I}{10^{-12}} \Rightarrow I = 10^{-12} \text{ antilog } 7$$

$$= 10^{-12} \times 10^{7}$$

$$= 10^{-5} \text{ w/m}^2$$

8. The intensity of a sound wave at a fixed distance from a speaker vibrating at 1.00 kHz is 0.600 W/m^2.

(a) Determine the intensity if the frequency is increased to 2.50 kHz while a constant displacement amplitude is maintained. $\left(\frac{f_2}{f_1}\right)^2 = 6.25$

(b) Calculate the intensity if the frequency is reduced to half and the displacement amplitude is doubled. $\left(\frac{f_2}{f_1}\right)^2 = \frac{1}{4}\left(\frac{Y_2}{Y_1}\right)^2 = 1$ (Result I unchanged)

(c) Calculate the intensity if the frequency is maintained constant and the displacement amplitude is reduced to half . $\left(\frac{Y_2}{Y_1}\right)^2 = \frac{1}{4}$

I Reduced to $\frac{1}{4}$

$$I = \frac{1}{2} \rho v y^2 (2\pi f)^2$$

$$I_1 = \frac{1}{2} \rho v y_1^2 (2\pi f_1)^2$$

$$I_2 = \frac{1}{2} \rho v y_2^2 (2\pi f_2)^2$$

9. If sound waves fall from air to fat tissues, calculate the sound wave relative transmitted intensity (Zair = 430 , Ztissue = 1.33×10^6 kg/m^{2}s).

$$\frac{P_r}{P_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2 \quad \& \quad \frac{P_t}{P_i} = T = \frac{2Z_2}{(Z_2 + Z_1)}$$