SOUND , HEARING , SPEECH

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OVERVIEW

FINAL EXAM

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Cardiovascular System	Electrical Properties of Body	Sound, Hearing, Speech	Light & Vision

INTRODUCTION

Sound is also important in medical diagnostics. Physicians use stethoscopes to listen to sounds in the body and they tap on parts of the body, as one would a drum, as a percussive diagnostic. Another important medical diagnostic using sound is ultrasonic mapping or ultrasonography. It is a nondestructive imaging method that makes use of sound at frequencies (~1–10 MHz), way above our hearing range (20 Hz–20 kHz), that provides images with the very useful spatial resolution of ~1 mm. Waves are sent to an object and reflected, with the delay time between the transmission of the probe beam and the arrival of the reflected acoustic pulses at the detector giving the relative location of the object. For example, in analyzing the heart the use of a scanned single beam gives valuable, yet limited information, such as the wall thickness and chamber diameters (M-mode echocardiography), while the use of multiple beams transmitted through a wide arc provides two-dimensional images of the heart. The shifting of the acoustic frequency when the ultrasound reflects from a moving target is the basis for measuring blood flow direction, turbulence, and speed.

“Music is powerful.
As people listen to it,
they can be affected.
They respond.”

—RAY CHARLES

SAMPLES

SOUND, ULTRASOUND AND INFRASOUND

Infrasounds

- Elephant

Human auditory field

- Elephant
- Cats and Dogs
- Bat and Dolphin

Ultrasounds

- Cats and Dogs
- Bat and Dolphin

0

20

20000

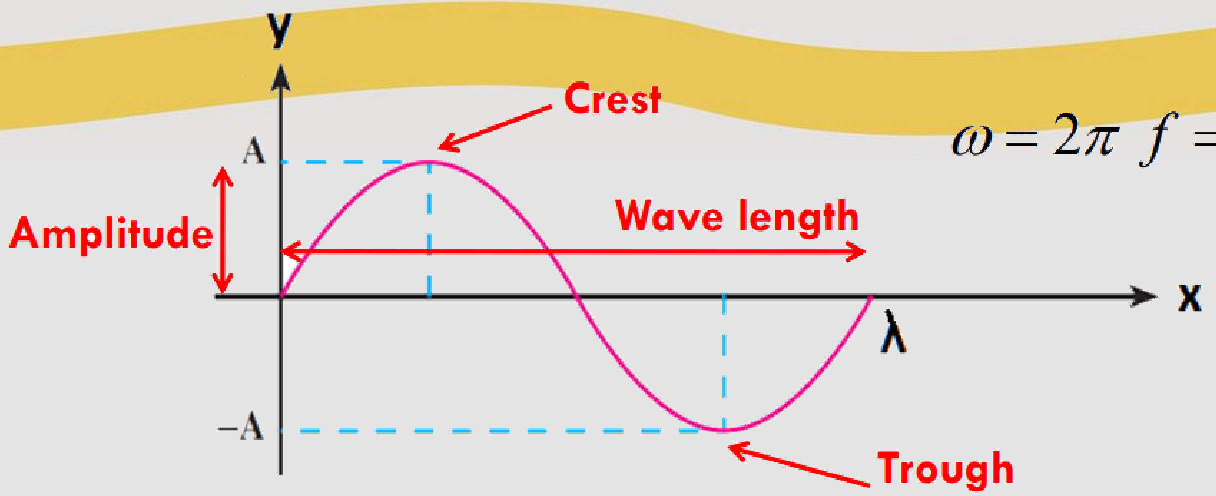
40000

160000

02

GENERALS

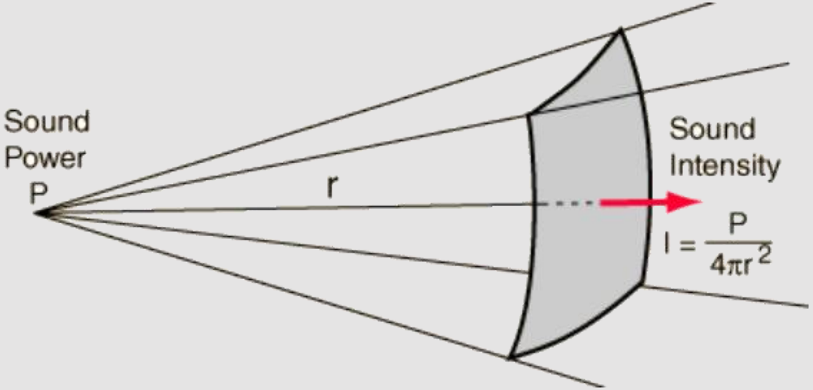
GENERAL PROPERTIES OF MECHANICAL WAVE



$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$v = \lambda \times f \qquad \text{wave velocity} = \text{wave legth} \times \text{frequency}$$

SOUND INTENSITY



SOUND PRESSURE

max gauge pressure $P = A\omega\rho v = A\omega Z = \sqrt{2ZI}$

$$\left(\frac{A_1}{A_2}\right)^2 \qquad \left(\frac{P_1}{P_2}\right)^2$$

$$\frac{I_1}{I_2}$$

$$\left(\frac{f_1}{f_2}\right)^2 \qquad \left(\frac{r_2}{r_1}\right)^2$$

$$\log\frac{I_2}{I_1}=\log\left[\frac{P_2}{P_1}\right]^2 \rightarrow Bell$$

$$10\log\frac{I_2}{I_1}=20\log\frac{P_2}{P_1}\rightarrow dB$$

sound impedance $Z=\rho\, v$

$v=\lambda\times f$ wave velocity = wave legth × frequency

max gauge pressure $P = A\omega\rho v = A\omega Z=\sqrt{2ZI}$

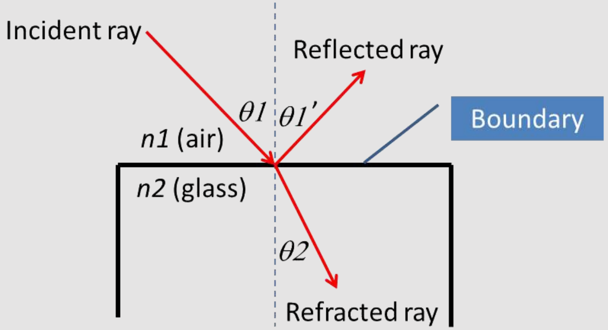
$$A=A_0e^{-\alpha x}\qquad f_{fund}=\frac{v}{4L}=\frac{340}{4\times 0.025}=3400\qquad f_{\text{fund}}=\frac{1}{2L}\sqrt{\frac{\sigma}{\rho}}$$

$$I=I_0e^{-2\alpha x}$$

$$\frac{I}{I_0}=e^{-2\alpha x}=\frac{1}{2}$$

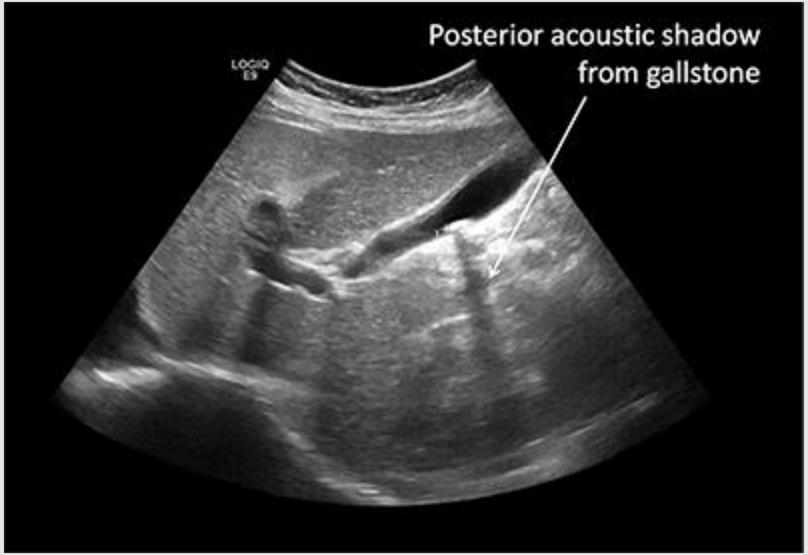
$\rightarrow x=HVT$

$$f_{fund}=\frac{v}{4L}$$

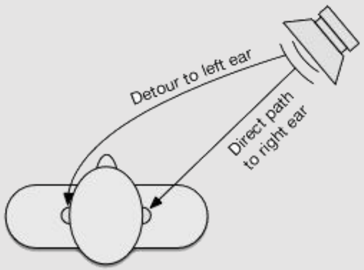


$$\frac{\sin\theta_1}{V_1}=\frac{\sin\theta_2}{V_2}$$

ACOUSTIC SHADOW



SOUND LOCALIZATION



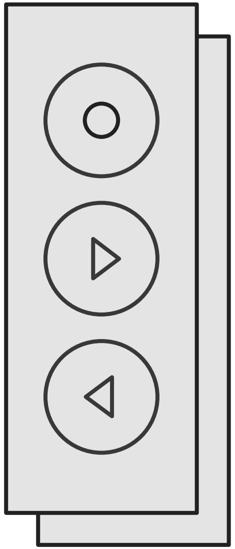
FUN ! !

Fun Fact about Electro Larynx

ELECTRO LARYNX

"MY NAME IS DARTH VADER. I AM AN EXTRATERRESTRIAL FROM THE PLANET VULCAN."

—Lord Darth Vader—



03

EXAMPLES

EXAMPLE 7-1

The density of air is 1.3×10^{-3}. The speed of sound in air is 343.2 meters per second. Obtain the air displacement for 120 dB and a frequency of 4 Hz.

EXAMPLE 7-1

Answer:

$$120 = 10\log\frac{I}{I_o} \rightarrow I = 1$$

$$I = \frac{1}{2}\rho v(Aw)^2 \rightarrow I = \frac{1}{2} \times 1.3 \times 10^{-3} \times 343.2 \times (8\pi A)^2$$

$w = 2\pi f = 2\pi \times 4$

$$A = 11.87\ m^2$$

EXAMPLE 7-2

A sound wave with a level of 120 decibels hits the individual eardrum. What is the input force? $\boldsymbol{Density = 1.2\,\frac{kg}{m^3},\ A = 55 \times 10^{-6} m^2,\ \ v = 340\,\frac{m}{s}}$

EXAMPLE 7-2

Answer:

$$Z = 1.2 \times 340 = 480 \frac{kg}{m^2 s}$$

$$120 = 10 \log \frac{I}{I_o} \rightarrow I = 1$$

$$\frac{f}{A} = P \rightarrow f = P \times A = \sqrt{2ZI} \times A = \sqrt{2 \times 408} \times 55 \times 10^{-6}$$

$$f = 1.571 \times 10^{-3}$$

EXAMPLE 7-3

In the previous example (Example 7-2), if the distance is doubled, how many decibels will the wave intensity decrease?

EXAMPLE 7-3

Answer:

$$\frac{I_2}{I_1} = \left(\frac{r_1}{r_2}\right)^2 \xRightarrow{r_2=2r_1} \frac{I_2}{I_1} = \frac{r_1^2}{4r_1^2} = \frac{1}{4}$$

$$10\log\frac{I}{I_o} = 10\log\frac{1}{4} = -20\log 2 \cong -6.02\ dB$$

EXAMPLE 7-4

Suppose a person is 10 meters deep underwater and the ear canal is completely filled with water.

A. Does the sensitivity of this person's ear change in terms of the frequencies that are better transmitted to the eardrum compared to the person who is outside the water? Compare numerically. Consider the length of the ear canal to be 3 cm.

B. If a sound source outside the water produces a sound wave with a frequency of 15 kHz and a sound level of 120 dB, calculate what force is applied to the eardrum of the said person? Consider the area of the eardrum as 55 mm square and consider the hydrostatic pressure caused by the height of the water.

EXAMPLE 7-4

Answer:

A)

$$f = \frac{V}{4L}\ , \qquad\qquad L = 3\ cm$$

$$\begin{cases} air: v = 343\dfrac{m}{s}\ \rightarrow f = \dfrac{344}{4 \times 0.03}\ \cong 2858\ Hz\ \cong 3kHz \\ water: v = 1482\dfrac{m}{s}\ \rightarrow f = \dfrac{1482}{4 \times 0.03} = 12350\ Hz\ \cong 12\ Hz \end{cases}$$

EXAMPLE 7-4

Answer:

B)

$$Z_{air} = 413 \frac{kg}{m^2 s}, \qquad Z_{water} = 1.48 \times 10^6 \frac{kg}{m^2 s}$$

$$T = \frac{I_t}{I_i} = \frac{4\frac{Z_2}{Z_1}}{(1 + \frac{Z_2}{Z_1})^2}, \qquad \frac{Z_2}{Z_1} = 3583.54$$

$$T = \frac{I_t}{I_i} = 0.0011$$

$$\begin{cases} \frac{I}{I_o} = e^{-2\alpha x} \\ x = 10\ m \\ \alpha_{water} = 5.62 \times 10^{-8} \end{cases} \rightarrow \frac{I}{I_o} = e^{-2\times 5.62\times 10^{-8}\times 10} \cong 1$$

EXAMPLE 7-4

Answer:

B)

$$I_i = 120dB = 10\log\frac{I}{I_{ref}} \to \frac{I}{I_{ref}} = 10^{12} \to I = 10^{12} I_{ref} \to I = 1$$

$$I_{ear} = 0.0011\, I_i = I_{ear} = 0.0011$$

$$I = \frac{P^2}{2Z} \to P = \sqrt{2IZ} = 57.06\, Pa$$

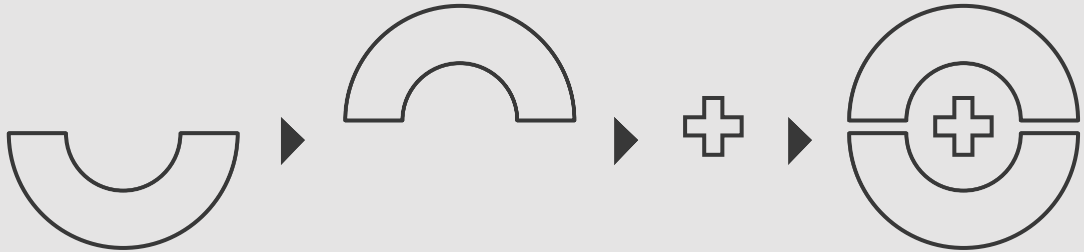
$$F = P \times A = 57.06 \times 55\, mm^2 = 0.0031\, N$$

04

ASSIGNMENT

HWH06

PRACTICAL EXERCISE



HWc06

RESOURCES

DR. MALIKEH NABAEI:

- SLIDES
- CLASSES

FAEZEH JAHANI:

- SLIDES

BIOLOGICAL AND MEDICAL PHYSICS, BIOMEDICAL ENGINEERING

- THE REFERENCE BOOK

THANKS !

Do you have any questions?
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Have a good afternoon