Module 3 · Lesson

Sound Waves

PH11-10

ORIENTATION

Lesson goal: connect sound-wave properties to pitch, loudness, intensity, resonance, and standing-wave behaviour.

The main writing discipline is to keep physical quantities separate from human perception. Pitch is not loudness, and intensity is not frequency.

CORE CONTENT

Sound in air is a longitudinal pressure wave. Air particles oscillate parallel to the direction of energy transfer, producing compressions and rarefactions.

PERCEPTION OR QUANTITY	PHYSICAL DRIVER	UNIT OR MEASURE	COMMON ERROR
Pitch	frequency	Hz	saying amplitude controls pitch
Loudness	intensity/amplitude	W m^-2 or dB	treating dB as linear
Timbre	harmonic content	spectrum shape	saying only frequency matters
Resonance	frequency match	natural frequency	saying resonance is just "louder"

Key equations:

$$v = f\lambda$$

$$I = \frac{P}{A}$$

$$\beta = 10 \log_{10}\left(\frac{I}{I_0}\right)$$

For a point source spreading sound uniformly:

$$I = \frac{P}{4\pi r^2}$$

CONCEPT CHECK

1. Sound in air is mainly:

   - A. transverse displacement of air upward and downward
   - B. longitudinal pressure variation
   - C. electromagnetic radiation
   - D. static charge transfer

   Answer: B.

2. Pitch is mainly determined by:

   - A. intensity
   - B. frequency
   - C. distance only
   - D. air pressure only

   Answer: B.

3. Increasing sound intensity by a factor of 10 changes sound level by:

   - A. 1 dB
   - B. 3 dB
   - C. 10 dB
   - D. 100 dB

   Answer: C.

4. Short response: explain why increasing amplitude does not necessarily change pitch.

APPLIED PRACTICE

Worked Example

A speaker emits sound power $2.4\ \text{W}$ uniformly. Find the intensity $3.0\ \text{m}$ from the source.

1. Use the point-source model:

$$I = \frac{P}{4\pi r^2}$$

2. Substitute:

$$I = \frac{2.4}{4\pi (3.0)^2}$$

3. Calculate:

$$I = 2.12 \times 10^{-2}\ \mathrm{W\ m^{-2}}$$

Final answer: $I = 2.1 \times 10^{-2}\ \mathrm{W\ m^{-2}}$. The answer assumes uniform spreading and ignores room reflections.

Practice Problem

A source emits $1.0\ \mathrm{W}$ of sound power uniformly. Calculate the intensity at $2.0\ \mathrm{m}$ and state one limitation of the model in a classroom.

DEEP PRACTICE AND WRITING

Prompt: explain resonance in an air column. Your answer must identify the driving frequency, natural frequency, and standing-wave pattern.

Strong response pattern:

1. identify the system,
2. state that the driving frequency matches a natural frequency,
3. relate the frequency match to large-amplitude standing waves,
4. connect the claim to nodes/antinodes or pipe length if data are supplied.

MAINTENANCE LOOP

Short retrieval:

1. Pitch corresponds mainly to _____.
2. Loudness relates to _____.
3. A 10-times intensity increase corresponds to _____ dB.
4. Resonance occurs when a driving frequency matches a _____ frequency.

STUDENT WORKING