

The Nature of Sound Waves

Read from Lesson 1 of the Sound and Music chapter at The Physics Classroom:

- <http://www.physicsclassroom.com/Class/sound/u1111a.html>
- <http://www.physicsclassroom.com/Class/sound/u1111b.html>
- <http://www.physicsclassroom.com/Class/sound/u1111c.html>

MOP Connection: Sound and Music: sublevel 1

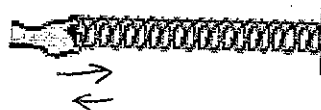
TRUE or FALSE: Identify the following statements as being either true (T) or false (F).

- | | |
|----------|---|
| T or F? | |
| <u>T</u> | 1. Sound waves are longitudinal waves. |
| <u>F</u> | 2. As the teacher talks, students hear the voice because particles of air move from the mouth of the teacher to the ear of the student. |
| <u>T</u> | 3. Sound waves are mechanical waves. |
| <u>T</u> | 4. All sound waves are produced by a vibrating object. |
| <u>F</u> | 5. A sound wave does not consist of crests and troughs. |

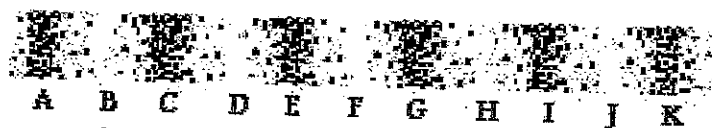
6. Mac is talking to Kate. The dot at A represents a particle of air. Describe the motion that this particle must undergo in order for Kate to hear Mac. Then show the motion by placing arrows on the diagram.



7. Tosh is holding one end of a slinky; the opposite end is attached to a wall. Tosh wishes to produce a longitudinal wave in the slinky. Describe how Tosh must move his hand in order to produce a longitudinal wave. Then place arrows on the diagram to show the way in which Tosh must move his hand.



8. A sound wave is moving through air. The diagram below represents a snapshot of the air particles at a given instant in time. Several regions are labeled with a letter. Use the letters to identify the compressions and rarefactions.



Compressions: A, C, E, G, I, K Rarefactions: B, D, F, H, J

9. A science fiction film depicts inhabitants of one spaceship (in outer space) hear the sound of a nearby spaceship as it zooms past at high speeds. Critique the physics of this film.

No medium, No Sound

Properties of Sound Waves

Read from Lesson 2 of the Sound and Music chapter at The Physics Classroom:

<http://www.physicsclassroom.com/Class/sound/u1112a.html>
<http://www.physicsclassroom.com/Class/sound/u1112b.html>
<http://www.physicsclassroom.com/Class/sound/u1112c.html>

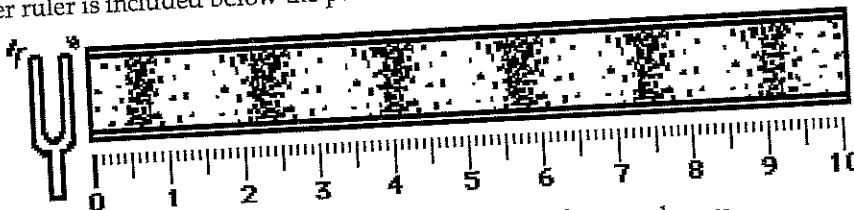
MOP Connection: Sound and Music: sublevel 2

Review:

Match the following wave quantities to the *mini-definition*. Place the letter in the blank.

- A. Frequency B. Period C. Speed D. Wavelength E. Amplitude
- C 1. How fast the wave moves through the medium.
 - D 2. How long the wave is.
 - A 3. How often the particles vibrate about their fixed position. *Cycles/sec*
 - B 4. How much time it takes the particles to complete a vibrational cycle.
 - D 5. How far the particles vibrate away from their resting position.

6. A sound wave with its characteristic pattern of compressions and rarefactions is shown below. A centimeter ruler is included below the pattern. The wavelength of this sound wave is _____ cm.



7. The pitch of a sound is directly related to the _____ of the sound wave.
 - a. frequency
 - b. wavelength
 - c. speed
 - d. amplitude
8. High pitched sounds have relatively large _____ and small _____.
 - a. period, wavelength
 - b. speed, period
 - c. frequency, wavelength
 - d. period, frequency
 - e. amplitude, wavelength
 - f. amplitude, speed
9. As the frequency of a sound increases, the wavelength _____ and the period _____.
 - a. increases, decreases
 - b. decreases, increases
 - c. increases, increases
 - d. decreases, decreases
10. A sound wave is described as being 384 waves/s. This quantity describes the wave's _____.
 - a. frequency
 - b. period
 - c. speed
 - d. wavelength
11. The speed of a sound wave depends upon the _____.
 - a. frequency of the wave
 - b. wavelength of the wave
 - c. amplitude of the wave
 - d. properties of the medium through which it moves
12. If a person yells (as opposed to whispering), then it will cause _____.
 - a. air molecules to vibrate more frequently
 - b. the sound wave to travel faster
 - c. air molecules to vibrate with greater amplitude
13. If a person yells (as opposed to whispering), then it will cause _____.
 - a. the pitch of the sound to be higher
 - b. the speed of the sound to be faster
 - c. the loudness of the sound to be louder

The Speed of Sound

Read from Lesson 2 of the Sound and Music chapter at The Physics Classroom:
<http://www.physicsclassroom.com/Class/sound/u1112c.html>

- When the C4 key on a piano keyboard is pressed, a string inside the piano is struck by a hammer and begins vibrating back and forth at approximately 260 cycles per second.
 - What is the frequency in Hertz of the sound wave?

$$260 \text{ Hz}$$

- Assuming the sound wave moves with a velocity of 345 m/s, what is the wavelength of the wave? PSYW

$$v = f \cdot \lambda \quad \frac{v}{f} = \lambda \quad \frac{345 \text{ m/s}}{260} = 1.3 \text{ m}$$

- An automatic focus camera is able to focus on objects by use of an ultrasonic sound wave. The camera sends out sound waves that reflect off distant objects and return to the camera. A sensor detects the time it takes for the waves to return and then determines the distance an object is from the camera. If a sound wave (speed = 345 m/s) returns to the camera 0.115 seconds after leaving the camera, how far away is the object? PSYW

time to get to object

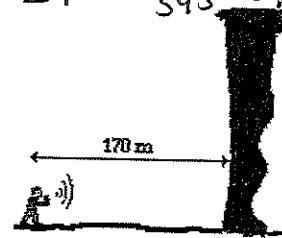
$$0.115 / 2 = 0.0575 \text{ sec.} \quad \text{Speed} = \frac{\Delta d}{\Delta t} \quad \text{Speed} \cdot \Delta t = \Delta d$$

$$345 \cdot 0.0575 = 19.8 \text{ m}$$

- Miles Tugo is camping in Glacier National Park. In the midst of a glacier canyon, he makes a loud holler. The sound ($v = 345 \text{ m/s}$) bounces off the nearest canyon wall (which is located 170 meters away from Miles) and returns to Miles. Determine the time elapsed between when Miles makes the holler and the echo is heard. PSYW

$$170 \times 2 = 340 \text{ m}$$

$$\text{speed} = \frac{\Delta d}{\Delta t} \quad \frac{\text{speed}}{\Delta d} = \Delta t \quad \frac{345}{340} = 1.01 \text{ sec}$$



- Suppose that sound travels at a speed of 345 m/s on the evening of a thunderstorm. There is a lightning strike some distance from your home. The light reaches you nearly immediately. Yet the thunder is heard 3.5 seconds later. How many miles from your home did the lightning strike? (1609 meters = 1 mile) PSYW

$$\text{speed} \cdot \Delta t = d$$

$$345 \cdot 3.5 = 1207 \text{ m} \cdot \frac{1609 \text{ meters}}{1 \text{ mile}} = 0.75 \text{ miles}$$

- A male vocalist with a bass voice can sing as low as 85 Hz. Given that the speed of sound is 345 m/s, what is the wavelength of the sound waves? PSYW

$$v = f \cdot \lambda \quad \frac{v}{f} = \lambda \quad \frac{345}{85} = 4.05 \text{ meters}$$

- A female vocalist with a soprano voice can sing as high as 1000 Hz. Given that the speed of sound is 345 m/s, what is the wavelength of the sound waves? PSYW

$$\frac{v}{f} = \lambda \quad \frac{345}{1000} = 0.345 \text{ m}$$



Sound Intensity and the Decibel System

Read from Lesson 2 of the Sound and Music chapter at The Physics Classroom:
<http://www.physicsclassroom.com/Class/sound/u1112b.html>

MOP Connection: Sound and Music: sublevel 3

- The decibel system is a system used to express the intensity of a sound. It is based on the powers of 10. A decibel is 1/10-th of a Bel. The sound level in Bels describes the power on 10 by which that sound is more intense than the so-called *threshold of hearing* (TOH). A 1-Bel sound is 10^1 times more intense than the TOH; it is a 10-decibel sound. A 2-Bel sound is 10^2 times more intense than the TOH; it is a 20-decibel sound. Use your understanding of the powers of 10 to complete the following table. (NOTE: different literature sources cite different intensity levels.)

Description of Sound	Intensity (W/m ²)	Sound Level (Bels)	Sound Level (decibels)
Threshold of Hearing	1×10^{-12}	0	0
Broadcasting Studio	1×10^{-10}	2	20
Mosquito Buzzing	1×10^{-8}	4	40
Normal Conversation	1×10^{-6}	6	60
Vacuum Cleaner	1×10^{-5}	7	70
Busy Traffic	1×10^{-4}	8	80
Power Mower or Thunder	1×10^{-2}	10	100
Twisted Sister Rock Band (Mr. H's favorite)	1×10^{-1}	11	110
Threshold of Pain	1	12	120
Jackhammer or Nearby Plane (18')	1×10^1	13	130
Explosions	1×10^2	14	140

Handwritten notes and calculations:

$1 = A$

$10 = 10 \log_{10}(10)$

$20 = 10 \log_{10}(100)$

$30 = 10 \log_{10}(1000)$

$20 = 10 \log_{10} \left(\frac{1.0 \times 10^{-11}}{1.0 \times 10^{-12}} \right)$

$30 = 10 \log_{10} \left(\frac{1.0 \times 10^{-9}}{1.0 \times 10^{-12}} \right)$

$100 = 10 \log_{10} \left(\frac{I}{I_0} \right)$

$30 = 10 \log_{10} \left(\frac{I}{I_0} \right)$

$1000 = \frac{I}{I_0}$

Compare the decibel level of the following sounds.

- If Sound B is 10 times the intensity of Sound A, then its decibel level is 10 higher.
- If Sound C is 100 times the intensity of Sound A, then its decibel level is 20 higher.
- If Sound D is 1000 times the intensity of Sound A, then its decibel level is 30 higher.
- If Sound E is 10000 times the intensity of Sound A, then its decibel level is 40 higher.

Handwritten notes for problem 1:

$10 \rightarrow 20 \rightarrow 30 \rightarrow 40$

$\times 2$

- How many times more intense is a ...
 - ... a 30 dB sound than a 20 dB sound?
 - ... a 40 dB sound than a 20 dB sound?
 - ... an 80 dB sound than a 20 dB sound?
 - ... an 80 dB sound than a 50 dB sound?
 - ... a 92 dB sound than a 62 dB sound?

Handwritten solutions for problem 2:

a. 10^x where $x = 1$ or 10

b. 10^x where $x = 2$ or 100

c. 10^x where $x = 6$ or 1,000,000

d. 10^x where $x = 3$ or 1000

e. 10^x where $x = 3$ or 1,000

The Doppler Effect

Read from Lesson 3 of the Sound and Music chapter at The Physics Classroom:

<http://www.physicsclassroom.com/Class/sound/u1113b.html>

MOP Connection: Sound and Music: sublevel 4

1. TRUE or FALSE:

Ken Fused is standing on a corner when a police car passes by with its siren on. Ken hears a different pitch when the police car is approaching him than when it is past him. This is because the siren on the front of the car is set to a higher pitch than the siren on the back of the car.

2. Describe the real reason Ken Fused observes what he does.

more waves/time ↑ frequency

3. TRUE or FALSE:

The Doppler shift is a phenomenon that is observed only of sound waves.

Explain your answer:

light too?

4. TRUE or FALSE:

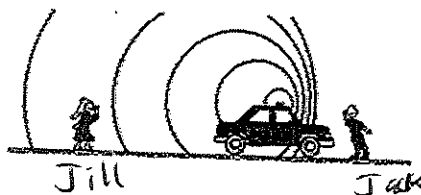
As the source of a sound approaches an observer, the loudness of the sound increases. This is an example of the Doppler Shift.

Explain your answer:

↑ wave fronts

An automobile is traveling away from Jill and towards Jack. The horn is honking, producing a sound wave consisting of the familiar pattern of alternating compressions and rarefactions which travel from their origin through the surrounding medium.

The circles on the diagram at the right represent wave fronts; you can think of the wave fronts as the compressions. Observe that the compressions are closer together in front of the car compared to behind the car.



5. Towards which person do the sound waves travel the fastest?

- a. Jack b. Jill or c. Both the same.

6. Who will hear the highest frequency?

- a. Jack b. Jill c. Both the same.

7. The Doppler effect can be described as the difference between the frequency at which sound waves are produced and the frequency at which they are observed by the hearer. It occurs when the distance between the source of a sound and the observer is changing. As the source approaches an observer, the observer hears the pitch (or frequency) to be _____ (higher, lower). As the source moves away from an observer, the observer hears the pitch (or frequency) to be _____ (higher, lower).



Doppler Effect

$$f_{\text{new}} = f_{\text{old}} \left(\frac{v_{\text{wave}} \pm v_{\text{object}}}{v_{\text{wave}} \mp v_{\text{source}}} \right)$$

top = toward
 bottom = away

1. A car is making an odd noise at 440Hz as it drives away at 30 meter/second.

a. What is the frequency of the sound?

$$440 \text{ Hz} \left(\frac{345}{345 + 30} \right) = 404 \text{ Hz}$$

b. What is the frequency of the sound if it were traveling toward the observer?

$$440 \left(\frac{345}{315} \right) = 481$$

2. Two trains are blowing their whistles at 900 Hz. Train A is moving toward the west at 20 m/s and train B is traveling east at 5m/s.

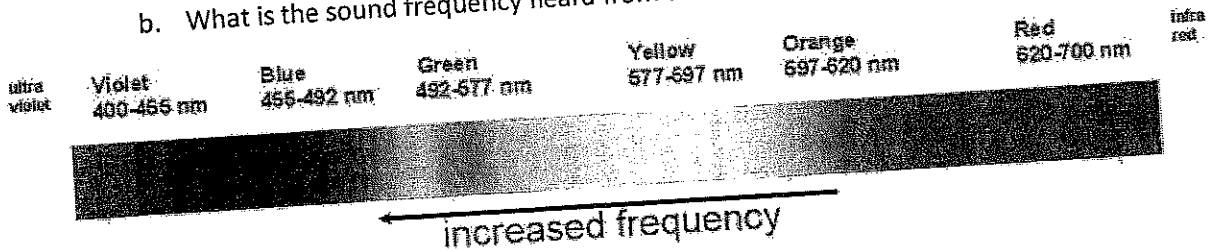
a. Do the trains hear the same sound?

No



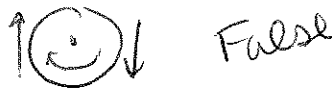
b. What is the sound frequency heard from train B?

$$900 \left(\frac{345 + 20}{345 - 5} \right) \frac{365}{340} = 966$$



3. A green planet is spinning on its axis left to right and it is moving in its orbit coming toward you.

Student A Hypothesis: The entire green planet would be most likely to look violet? Justify or nullify with reasoning?



Student B Hypothesis: The planet will be multiple colors, not all one color. Justify or nullify?

True

as it spins
one side move
toward you other
moves away

Preliminary Quiz 1
Sound Intensity

$$D_b = 10 \log\left(\frac{I}{I_0}\right)$$

Same

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

A single bee is emitting a 15dB sound at 0.6m.

1. What is the power output of this Bee?

~~15 dB = 10 log(x / 1.0E-12)~~

$$15 \text{ dB} = 10 \log\left(\frac{x}{1.0 \times 10^{-12}}\right)$$

$$x = 3.16 \times 10^{-11} \frac{\text{watts}}{\text{m}^2}$$

$$3.16 \times 10^{-11} = \frac{P}{4\pi (0.6)^2}$$

$$P = 1.43 \times 10^{-10} \text{ watts}$$

2. If the bee buzzed all day (8 hours), how much energy would it require?

$$P = \frac{E}{\text{time}}$$

(Energy)

$$P \cdot T = E$$

$$8 \text{ hr} \cdot 3600 \text{ sec} = 28800 \text{ sec}$$

$$1.43 \times 10^{-10} \cdot 28800 = 4.1 \times 10^{-6} \text{ J}$$

3. If the bee flew away, at what distance would you no longer be able to hear the bee?

1.0E-12 W/m² = No longer Hear
dB = 0

Solve for $r = \sqrt{\frac{P}{4\pi I}}$

$$r = \sqrt{\frac{1.43 \times 10^{-10}}{4\pi \cdot 3.16 \times 10^{-11}}} = 0.36 \text{ meters}$$

4. If a bee hive contained 1000 bees how loud (dB) would the hive be at 2 meters?

Can Not x the db.

$$P = 1.43 \times 10^{-10} \times 1000 = 1.43 \times 10^{-7} \text{ Power-output 1000 Bees}$$

$$I = \frac{1.43 \times 10^{-7}}{4\pi (2)^2} = 2.8 \times 10^{-9}$$

$$db = 10 \log\left(\frac{2.8 \times 10^{-9}}{1.0 \times 10^{-12}}\right) = 34 \text{ dB}$$

If a bee buzzed your head at 10 cm away, how loud (dB) would the bee be?

$$I = \frac{P}{4\pi (0.1)^2} = \frac{1.43 \times 10^{-10}}{4\pi (0.1)^2} = 1.1 \times 10^{-9} \text{ W/m}^2$$

6. A fly expends 1/3 of the energy producing noise while flying compared to a single bee. How close to a fly would you need to be to have the same loudness as the bee at 0.6m?

$$\frac{1.43 \times 10^{-10}}{3} = 4.76 \times 10^{-11}$$

$$15 = 10 \log\left(\frac{I}{1.0 \times 10^{-12}}\right)$$

$$I = 3.16 \times 10^{-11} \frac{\text{W}}{\text{m}^2}$$

Some loudness

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

$$3.16 \times 10^{-11} = \frac{4.76 \times 10^{-11}}{4\pi r^2}$$

$$r = 1.9 \times 10^{-6} \text{ m}$$

DO

Stop If you understand

stop

Resonance

Read from Lesson 4 of the Sound and Music chapter at The Physics Classroom:
<http://www.physicsclassroom.com/Class/sound/u1114a.html>
<http://www.physicsclassroom.com/Class/sound/u1114b.html>
<http://www.physicsclassroom.com/Class/sound/u1114c.html>
<http://www.physicsclassroom.com/Class/sound/u1114d.html>

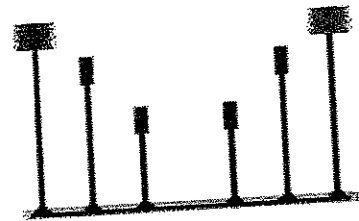
MOP Connection: Sound and Music: sublevel 5

1. Define or describe the significance of the following terms:

- a. Natural frequency:
- b. Forced vibration:
- c. Resonance:



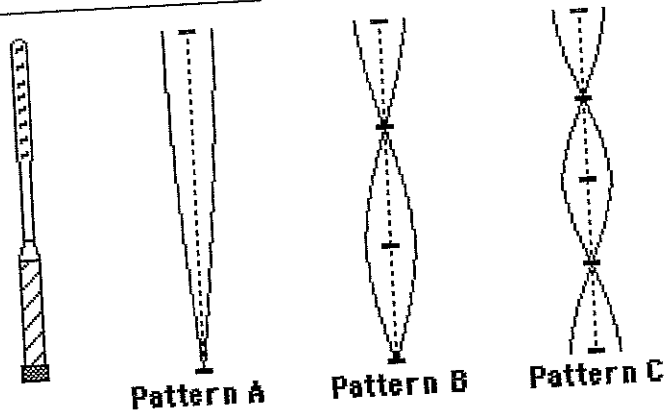
2. Three pairs of wooden dowel rods are mounted on a wooden platform. Small plastic cylinders are attached to their ends; the cylinders are colored red, green and blue. Each pair of dowel rods has a different length. One of the red cylinders is pulled back and let go of, causing it to begin vibrating back and forth with one complete cycle every two seconds. The natural frequency of this dowel rod is _____ Hz.



a. 0.25 b. 0.50 c. 1.0 d. 2.0

As the red cylinder vibrates, it forces the other red cylinder to vibrate. This occurs because the two cylinders have the same _____ (color, composition, natural frequency). When two objects vibrate together like this _____ is occurring.

3. When a tennis racket strikes a tennis ball, the racket begins to vibrate. There is a set of selected frequencies at which the racket will tend to vibrate. Each frequency in the set is characterized by a particular standing wave pattern. The diagrams below show the three of the more common standing wave patterns for the vibrations of a tennis racket. In each diagram, hash marks are placed at the positions of all nodes and antinodes; label these nodes (N) and antinodes (AN).



Compare the wavelength of pattern A to the wavelength of pattern B. Make your comparison both qualitative and quantitative. Repeat for pattern C.

$$\lambda_A \text{ _____ } \lambda_B (<, >, =)$$

$$\lambda_A \text{ _____ } \lambda_C (<, >, =)$$

$$\lambda_A = \text{ _____ } \cdot \lambda_B (2, 3, 4, \text{ etc.})$$

$$\lambda_A = \text{ _____ } \cdot \lambda_C (2, 3, 4, \text{ etc.})$$

When the racket vibrates as in pattern A, its frequency of vibration is approximately 30 Hz. Determine the frequency of vibration of the racket when it vibrates as in pattern B and pattern C.

$$f_B = \text{ _____ } \text{ Hz}$$

$$f_C = \text{ _____ } \text{ Hz}$$