me: ____________________

Period: ____________________

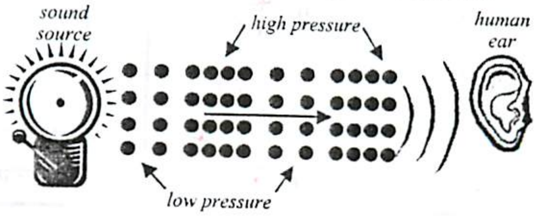
Due today!

Sound

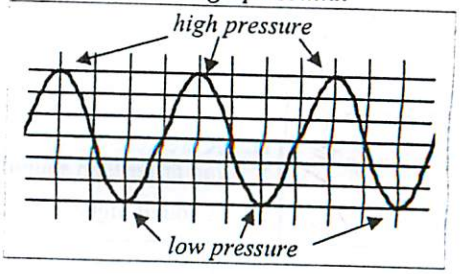
What is Sound?

Sound is the movement of compression waves (longitudinal waves) hitting our ears. These compression waves are alternating high and low pressure areas. The air molecules vibrate back and forth, but don't move.

Sound Wave Moving Through Air Molecules

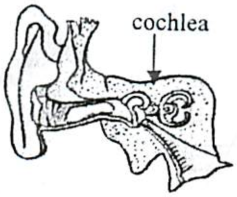


How we graph sound:



Speakers imitate sounds by pushing air and causing vibrations.

Tiny hairs inside the ***cochlea*** (inner ear) translate air pressure into electrical impulses that can be read by the brain.



Sound needs a *medium* to travel through. Sound cannot travel through the vacuum of space. ***Space is silent*** (no matter what you hear in the movies).

Frequency = Pitch

We hear the frequency of sound as ***pitch***. A higher frequency we hear as a higher pitch. A lower frequency we hear as a lower pitch.

Higher Frequency = Higher Pitch

Frequency (f)	Wavelength (λ)	Source
20 Hz	17 m	rumble of thunder
100 Hz	3.4 m	bass guitar
2,000 Hz	17 cm	fire truck siren
5,000 Hz	7 cm	highest note of piano
10,000 Hz	3.4 cm	whine of a jet turbine

Humans can hear frequencies that are between 20 Hz and 20,000 Hz!

Elephants and submarines use ***infrasonic*** sound (too low to hear) to communicate over long distances. Very low frequencies (very bass) travel for very long distances and can penetrate through water (just like thru cars).

Dog whistles use ***ultrasonic*** frequencies — frequencies above human hearing, but perfect for dog ears!

Amplitude = Loudness

We hear pressure (the amplitude) of sound as ***loudness***. It takes more energy to create a louder sound. Too loud of a sound can cause ***deafness***.

Loudness is measured in decibels (dB)

10 - 15 dB	A quiet whisper, 3 feet away
30 dB	A house in the country
65 dB	Ordinary conversation, 3 feet away
70 dB	City traffic
90 dB	A jackhammer, 10 feet away
120 dB	The threshold of physical pain from loudness

A +10 dB change we hear as twice as loud.

A 30 dB sound is twice as loud as a 20 dB sound.

A -10 dB change we hear as half as loud.

A 30 dB sound is half as loud as a 40 dB sound.

Speed of Sound (v_s)

The speed of sound changes. Hotter (faster) molecules conduct sound faster. Also, just as heat travels faster in solids, so does sound.

Material	V_s (m/sec)
Air	340
Helium	965
Water	1530
Wood	2000
Gold	3240
Steel	5940

The speed of sound in air is about 340 m/sec (660 mph).

You can use $v_s = f\lambda$. to find frequency or wavelength. AND use S = D/T to find distance or time (using v_s for S).

Ex. Find the wavelength of a 200 Hz sound.	
$v_s = 340$ m/s $f = 200$ Hz $\lambda = ?$	$v = f\lambda$ so $\lambda = v/f$ $\lambda = (340\ \text{m/s}) \div (200\ \text{Hz})$ $\lambda = 1.7$ m

Ex. If you hear a sound 3 seconds after you see the motion. How far away is it?	
$V_s = 340$ m/s $T = 3$ sec $D = ?$	$v_s = D/T$ so $D = v_s T$ $D = (340\ \text{m/s})\ X\ (3\ \text{sec})$ $D = 1020$ m

Motion faster than sound is called ***supersonic***. Supersonic planes give their speed in multiples of ***Mach*** (1 X the speed of sound).

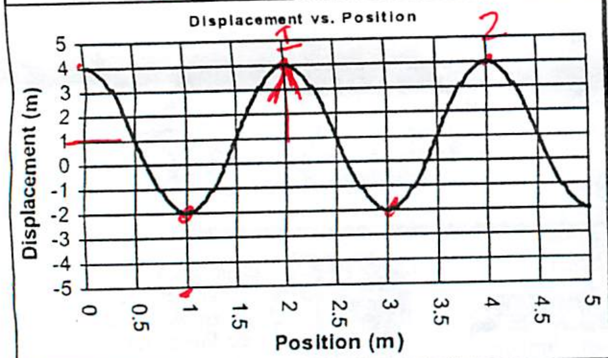
Mach 1 = 340 m/s (660mph)
Mach 2 = 680 m/s (1320 mph)

A ***sonic boom*** is caused by an object breaking through the sound barrier. Supersonic planes, bullets, and bullwhips all make sonic booms.

Name: ____________________

Period: ____________________

1. Sound B	A. Faster than the speed of sound.	1. Pitch B	A. Where there is no sound because of its vacuum.
2. Sonic boom D	B. A wave caused by alternating high and low pressure.	2. dB D	B. How we hear changes of frequency of sound.
3. Supersonic A	C. The organ that detects sound waves.	3. Space A	C. 340 m/s in air.
4. Ultrasonic E	D. A pressure wave caused by an object going faster than sound.	4. Loudness E	D. How we measure loudness.
5. Cochlea C	E. A sound higher than humans can hear.	5. v_s C	E. The amplitude or strength of a sound.



Use the graph to answer these questions: λ = 2m

1 cycle is from 1 m to 3 m; 1/2 cycle is from 0 m to 1m.

Amplitude (A) = 3 m Total cycles: 2½;

It is a sound wave; find frequency: $v = \lambda f$

$340\,m/s = (2m)\,f$ $f = 170\,Hz$

Is this frequency audible to humans (can we hear it)?

yes b/cω 20 & 20000 HZ.

A wave's velocity is 90 m/sec with a frequency of 6 Hz. What is it's wavelength?

$v = f\lambda$ $\lambda = \frac{v}{f} = \frac{90\,m/s}{6\,Hz} = \boxed{15\,m}$

Why is space silent? space is a vacuum. Sound needs a medium.

If I increase the energy I give a sound wave what changes:

Increase Amplitude

A sound wave has a wavelength of 20 m. Find its frequency.

$v = \lambda f$

$f = v/\lambda = \frac{340\,m/s}{20\,m} = \boxed{17\,Hz}$

If a wave's fourth harmonic has a frequency of 40 Hz, what is its natural frequency and what is the frequency of H_6?

$f_4 = 4f_f$ $40\,Hz/4 = f_f$ $\boxed{10\,Hz = f_f}$

$10\,Hz \times 6 = \boxed{60\,Hz = H_6}$

If a sound wave's frequency is 100 Hz. What is its period?

$T = \frac{1}{100\,Hz} = \boxed{0.01\,s}$

What is the above wave's wavelength?

$\lambda = \frac{v}{f} = \frac{340\,m/s}{100\,Hz} = \boxed{3.4\,m}$

If a wave's fundamental is 6 Hz, what harmonic has a frequency of 48 Hz?

$\frac{48\,Hz}{6\,Hz} = 8$ So its the $\boxed{8^{th}\ \text{Harmonic}}$

A railroad crew is repairing a rail. You hear the hammer 0.5 seconds after it is swung. How far away is the crew?

$v = \frac{d}{t}$ $(340\,m/s)(.5\,s) = d$

$\boxed{170\,m = d}$

You hear a plane 4 seconds after you see it. Find the distance to the plane.

$d = vt = (340\,m/s)(4\,s)$

$= \boxed{1360\,m}$

Find its period: 1/80Hz = 0.0125 s

What harmonic is this? 4

Could a human hear this frequency? yes

Mark the nodes and anti-nodes.

How many wavelengths is it? 2

Find the fundamental frequency:

$80\,Hz/4 = \boxed{20\,Hz}$

5th harmonic frequency:

$5 \times 20\,Hz = \boxed{100\,Hz}$

80 Hz

If a sound is 40 dB loud. Answer how many dB these would be:

1) A sound twice as loud: 50 dB

2) A sound half as loud: 30 dB

Compared to a 50 dB sound, you would hear a 60 dB as:

twice as loud.

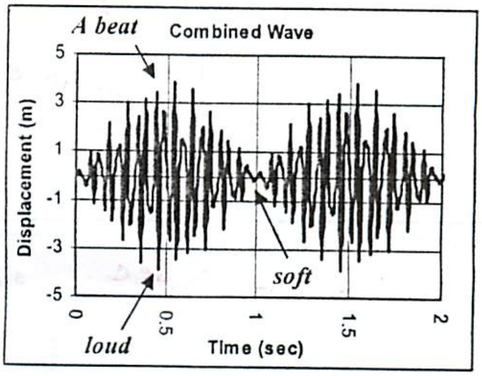
Ancillary Sound Topics

Beats

When two notes of sound are very close together we hear them fight with an alternating loud and soft pattern, called **beats** (sounds like a fast "wah, wah, wah").

Beats come from interference. When two waves of close frequencies interact they interfere, causing alternating constructive and destructive interference. The constructive interference is the loud part and the destructive, the soft part of the pattern. The closer the frequencies of the two notes, the slower the beats.

On the graph there is one beat per second.
Frequency 1 = 680 Hz
Frequency 2 = 681 Hz OR 679 Hz.



# of beats = difference of two frequencies.

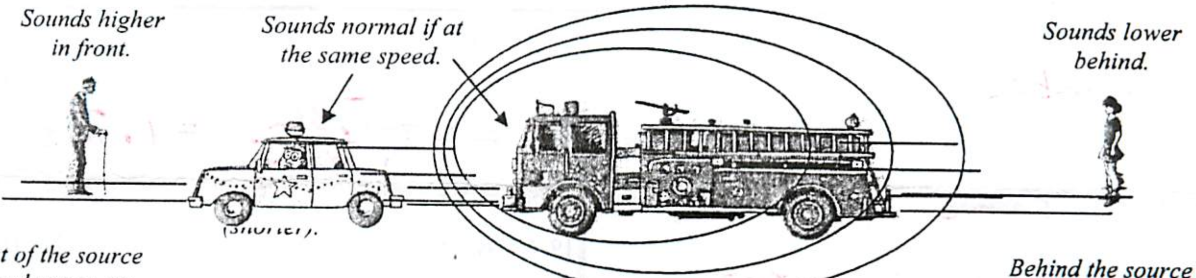
Ex 1: $f_1 = 345$ Hz; $f_2 = 342$ Hz
beats = 3
There will be three beats per second.

Ex 2: $f_1 = 805$ Hz; $f_2 = 810$ Hz
beats = 5

Doppler Effect

When a train or ambulance passes you the pitch drops. This raising and lowering of the pitch is due to the movement of the sound source and is called the **Doppler effect.**

The Doppler effect occurs only when an object is moving towards you or away from you (relative to you). Since the speed of sound cannot change (medium hasn't changed), the wavelength and frequency must. Note: The notes only changes as the object moves past you, but stays constant while moving toward you. For a person moving the same speed as the sound source (police car) there is no change of pitch, because there is no relative motion (they are moving together).



Sounds higher in front.

Sounds normal if at the same speed.

Sounds lower behind.

In front of the source the sound waves are compressed (shorter λ), raising the frequency (pitch).

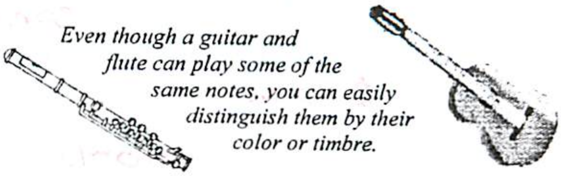
Anything moving at the same speed as the source will experience no change in frequency.

Behind the source the sound waves are stretched (longer λ), dropping the frequency (pitch).

Timbre

A flute and a clarinet can play the same note (frequency) but they sound very different. This quantity of sound coloration is called **timbre** *(pronounced "tamber").*

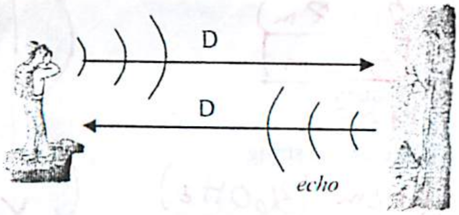
A person can sing the vowels "oo" and "ee" on the same notes. The "oo" sounds very dark, while the "ee" sounds very bright. The frequency of the note is that of the fundamental. The color of the note (bright, dark, dull, warm) is due to harmonics. The "oo" has mostly low harmonics, while the "ee" has a lot of high harmonics.



Even though a guitar and flute can play some of the same notes, you can easily distinguish them by their color or timbre.

Echoes

Echoes are sounds that are reflected back by a hard boundary.



An echo travels a distance of 2D: there and back!.

For echo problems:

$$V = \frac{2D}{T}$$

Many animals use ***echolocation*** to see through dark water or at night! Animals use sound echoes to locate an object or prey.

Humans use echolocation, too, in ***sonar*** (sound thru water), ***radar*** (light waves thru air), and ***sonograms*** (sound waves thru the human body).

1. Timbre B
2. Beats C
3. Echo E
4. Echo-location A
5. Doppler Effect D

A. Using reflected waves to "see".
B. How two sounds can have the same frequency, but different sounds.
C. Created by two frequencies that are very close to each other.
D. Changing of pitch because of a moving object.
E. A reflected sound.

6. In front (F), behind (B), or on the ambulance (O)?

A. B Pitch is lower?
B. F Pitch is higher?
C. B λ is longer?
D. F λ shorter?
E. Same everywhere Speed of sound is greater?
F. O Pitch is the same (unchanged)?

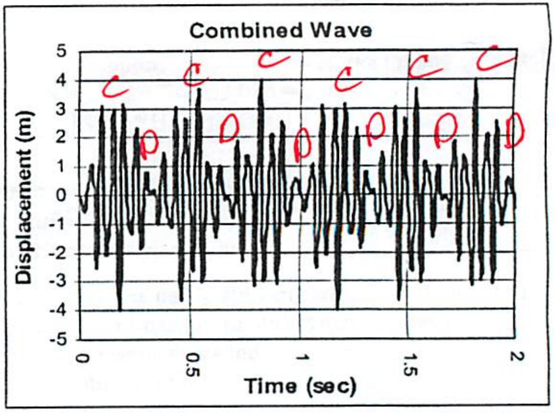
7. What happens as it passes you? Pitch goes from high to low

8. Note 1 has a frequency of 185 Hz. Note 2 has a frequency of 189 Hz. How many beats do you hear? 4 beats per sec

9. f_1 = 366 Hz. There are 3 beats per second.
f_2 = 363 or 369 Hz

10. If you heard 4 beats before and now you hear 2 beats, are the notes more [✓ in-tune] or out-of-tune?

11. Use the graph at the right to answer the following.
A. Mark constructive interference (C) and destructive interference (D).
B. How many beats are shown per second? 3 beats/s
C. If f_1 = 592 Hz and f_2 is higher, what is f_2?
595 Hz



12. What helps us distinguish between two different instruments?
Timbre

13. A clarinet and an oboe play the same note.
A. How do the fundamental frequencies of the two notes compare? same
B. What is different between the two notes?
presence of different harmonics

14. Which has higher harmonics: [✓ a bright note] or a dark note?

15. A boat using sound to map the bottom of a deep lake. The instrument reads 115 m deep.
A. What kind of echolocation is being used? Sonar
B. How far do the sound waves travel to get back to the boat?
230 m

16. A person yelling into a canyon hears the echo in 1.4 seconds.
A. What is the speed of the yell? 340 m/s
B. How deep is the canyon?

$d = v \cdot t = (340 m/s)(1.4 s) = 476 m$

$d/2 = 238 m$

17. A person claps their hands, the echo is heard 1.5 seconds later after it reflects off of a wall 254 m away. How fast is the speed of sound for that temperature, and pressure?

$$V = \frac{d}{t} = \frac{(254 m) \times 2}{1.5 s} = \boxed{339 m/s}$$

REVIEW:

18. Find the period of a pendulum with a length of 35 cm.

$$T = 2\pi\sqrt{\frac{.35m}{9.8 m/s^2}} = 1.2 s$$

19. A mass of 600 g is placed on a spring. It stretches 18 cm. Find the spring constant of the spring.

$F = kx$

$mg = kx$

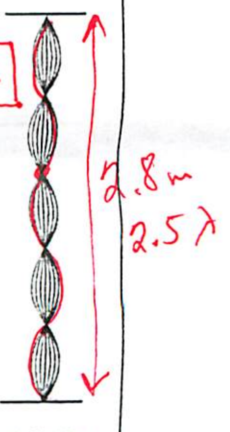
$(.6 kg)(9.8 m/s^2) = k(.18 m)$

$\boxed{K = 32.7 N/m}$

20. A sound has a frequency of 550 Hz in air. Find wavelength.

$$\lambda = \frac{V}{f} = \frac{340 m/s}{550 Hz} = \boxed{0.62 m}$$

21. Use the picture at the right to answer the following:



360 Hz

A. If the string length is 2.8 meters, find the wavelength of this harmonic.

$$\frac{2.8 m}{2.5} = \frac{2.5\lambda}{2.5}, \boxed{\lambda_5 = 1.12 m}$$

B. What is the wavelength of the fundamental?

$$\lambda_f = 2L = 2(2.8 m) = \boxed{5.6 m}$$

C. Can we hear this frequency? yes

D. Find the wave speed of this string.

$$V = \lambda_5 f_5 = (1.12 m)(360 Hz) = \boxed{403.2 m/s}$$