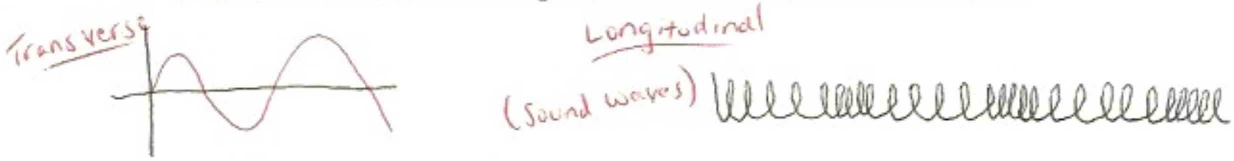
Honors Physics: Sound Problem Set

Conceptual Questions:

1. Sketch a transverse and a longitudinal wave. Which is a sound wave?



2. Amplitude controls what part of a sound? What does frequency control?

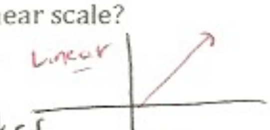
   Volume — Pitch or the note

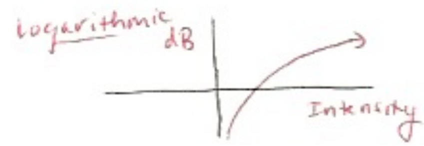
3. Why can't we hear sounds in outer space?

   There is nothing to vibrate

4. How are decibels calculated – is it a linear scale?

   no - it's a logarithmic scale meaning that the decibels change quickly at first - but later it takes a lot of change in intensity to increase dB.





5. What factors can affect the speed of sound?

   ① Temperature: Colder = slower
   ② Particle Density: Denser = Faster
   ③ Material Elasticity: Rigid = Faster Rubbery = Slower

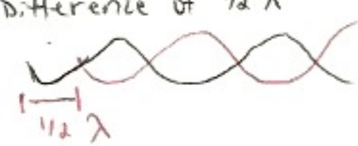
6. How does movement affect the frequency and wavelength of a sound?

   Doppler Effect
   - As you move or a sound source comes towards you - you hear a higher frequency
   - As you move or a sound source moves away - you hear a lower frequency.

7. What is the difference between constructive and destructive interference?

   Constructive = larger amplitude, louder sound. Difference of whole λ

   Destructive = smaller amplitude, softer, Difference of 1/2 λ



8. What is beat frequency? What does it tell you?

   This is a throbbing sound created by two sounds that are close in frequency but not the same. 'Beats' tell you how far apart in Hertz the two sounds are.

9. How does the tension and thickness of a string affect its velocity and therefore its frequency?

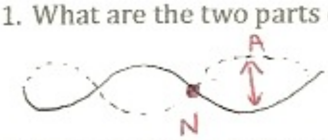
   If you increase the tension - the velocity + frequency increase

   $v = \sqrt{\frac{F_T}{m/L}}$ If you increase the thickness - the velocity + frequency decrease.

10. What makes a musical instrument different from a tuning fork?

    Tuning forks play only one frequency (Pure tone). But instruments produce a fundamental frequency and harmonics - this gives an instrument its voice or timbre.

11. What are the two parts of a standing wave? Which part can create the most sound?



    N = Node = little to no movement
    A = Anti-node = max movement (most sound)

12. What is the limitation of pipes only open at one end?

    The can only produce audible ODD harmonics

13. A person standing a certain distance from an airplane with four equally noisy engines experiences a sound level close to the threshold of the pain, 120 dB. How many decibels of sound can be produced by one engine? Assume the sound is spreading uniformly in all directions.

4 engines = 120 dB

[E] [E] [E] [E]
each w/ its own intensity = 4·I

* Decibels are not linear - can't just divide by 4.
* Find the intensity of one.

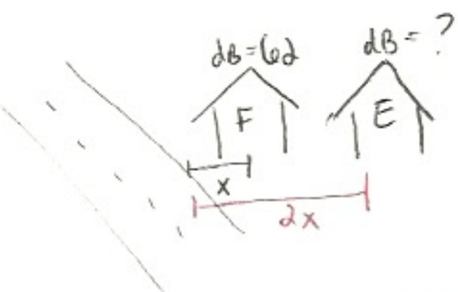
$$dB = 10 \cdot \log_{10}\left(\frac{I}{I_0}\right)$$
$$120 = 10 \cdot \log_{10}\left(\frac{4 \cdot I}{1.0\times10^{-12}}\right)$$
$$12 = \log_{10}\left(\frac{4 \cdot I}{1.0\times10^{-12}}\right)$$
$$10^{\wedge 12} = \frac{4 \cdot I}{1.0\times10^{-12}}$$
$$1.0\times10^{12} = \frac{4 \cdot I}{1.0\times10^{-12}}$$
$$(1.0\times10^{12})(1.0\times10^{-12}) = 4 \cdot I$$
$$1 = 4 \cdot I$$
$$I = 0.25\ W/m^2$$

So now - how many decibels is 0.25 W/m²?

$$dB = 10 \cdot \log_{10}\left(\frac{I}{I_0}\right)$$
$$dB = 10 \cdot \log_{10}\left(\frac{0.25}{1.0\times10^{-12}}\right)$$
$$dB = 10 \cdot \log_{10}(2.5\times10^{11})$$
$$dB = 10 \cdot 11.3979$$
$$dB = 113.979$$
$$\boxed{dB \approx 114}$$

14. A highway was built near Mr. Fredericksen's home. On an average day, Mr. Fredericksen would hear about 62 dB of sound coming from this highway. Mr. Fredericksen's friend, Mr. Edericksen, has a house twice as far away from the highway. What are the decibels of noise heard at Mr. Edericksen's house? Assume the sound is spreading uniformly in all directions.

*Recall that the decibel scale is not linear



Again - Decibels are not linear so again - let's find the intensity of sound produced at Mr. F's house

$$dB = 10 \cdot \log_{10}\left(\frac{I}{I_0}\right)$$
$$62 = 10 \cdot \log_{10}\left(\frac{I}{1.0\times10^{-12}}\right)$$
$$6.2 = \log_{10}\left(\frac{I}{1.0\times10^{-12}}\right)$$
$$10^{\wedge 6.2} = \frac{I}{1.0\times10^{-12}}$$
$$1.58\times10^{6} = \frac{I}{1.0\times10^{-12}}$$
$$I = (1.58\times10^{6})(1.0\times10^{-12})$$
$$I = 1.58\times10^{-6}\ W/m^2$$

Ok - So now if Mr. E's house is twice as far back - he will only hear 1/4 of the intensity Mr. F's house gets.

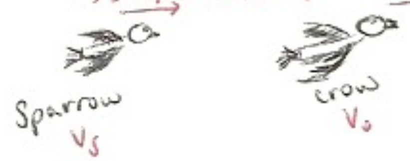
$$\frac{I}{4} = \frac{1.58\times10^{-6}}{4} = 3.95\times10^{-7}\ W/m^2$$

Now turn this into decibels

$$dB = 10 \cdot \log_{10}\left(\frac{I}{I_0}\right)$$
$$dB = 10 \cdot \log_{10}\left(\frac{3.95\times10^{-7}}{1.0\times10^{-12}}\right)$$
$$dB = 10 \cdot \log_{10}(3.95\times10^{5})$$
$$dB = 10 \cdot 5.5966$$
$$dB = 55.966$$
$$\boxed{dB \approx 56.0}$$

15. A sparrow chases a crow with a speed of 55 miles per hour, while chirping at a frequency of 850.0 Hz. What frequency of sound does the crow hear as he flies away from the sparrow with a speed of 45 miles per hour? (1 mile ≈ 1609 m)

55 mph = 24.6 m/s → 45 mph = 20.1 m/s →



$$\frac{55 \text{ miles}}{\text{hour}} \left| \frac{1609 \text{ m}}{1 \text{ mile}} \right| \frac{1 \text{ h}}{3600 \text{ s}} = 24.6 \text{ m/s}$$

$$\frac{45 \text{ miles}}{\text{hour}} \left| \frac{1609 \text{ m}}{1 \text{ mile}} \right| \frac{1 \text{ h}}{3600 \text{ s}} = 20.1 \text{ m/s}$$

* Source is moving towards the observer
* observer is moving away from the source

$$f_o = f_s \left(\frac{v +/- v_o}{v +/- v_s} \right)$$

$$f_o = (850.0) \left(\frac{343 - 20.1}{343 - 24.6} \right)$$

$$f_o = (850.0)(1.01413)$$

$$\boxed{f_o = 862 \text{ Hz}}$$

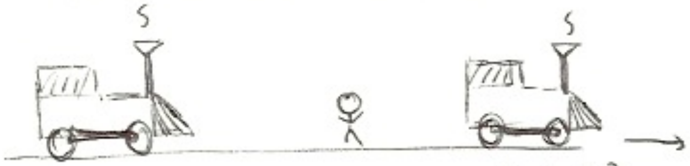
16. A musician is tuning a string on a harp. When she plays her string with a 196 Hz tuning fork, she hears a beat frequency of 2 Hz. When she plays her string with a 206 Hz tuning fork, she hears 8 beats. What is the frequency of the string?

196 Hz (2 Beats) → 194 Hz, 198 Hz

206 Hz (8 Beats) → 198 Hz, 214 Hz

$\boxed{198 \text{ Hz}}$

17. Two trains emit whistles of the same frequency (277 Hz). If one train is at rest and the other is moving at 40.0 km/h away from an observer at rest, what is the beat frequency heard between the two whistles.



$$\frac{40\text{ km}}{1\text{ h}}\left|\frac{1000\text{ m}}{1\text{ km}}\right|\frac{1\text{ h}}{3600\text{ s}} = 11.1\text{ m/s}$$

Train #1
At rest
277 Hz

Train #2
Moving Away
40 km/h
268 Hz

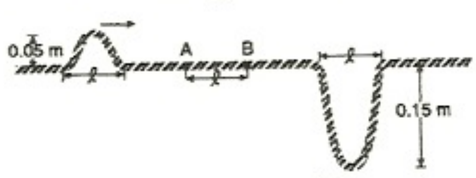
$$f_o = f_s\left(\frac{v +/- v_o}{v +/- v_s}\right)$$

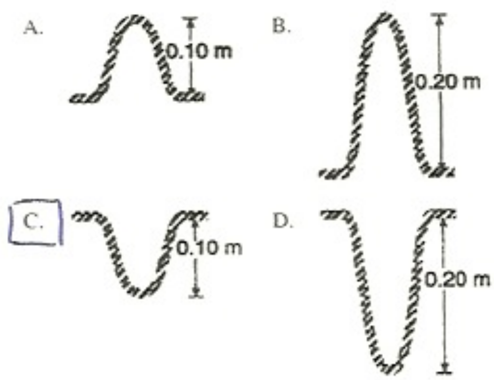
$$f_o = 277\left(\frac{343 +/- 0}{343 + 11.1}\right)$$

$$f_o = 268\text{ Hz}$$

Beat freq. = 277 - 268
= 9 Beats

18. The diagram to the below shows two pulses of equal width traveling towards each other at equal speeds in a rope. Which choice from the options to the right best represents the shape of the rope when both pulses are in region AB?





19. In a demonstration, Paul Hewitt attaches a piece of steel wire (L = 1.23 m) to a piece of equipment called a *mechanical oscillator* using 132 N of tension. He then tunes the oscillator to a frequency of 588 Hz. The wire begins vibrating in the sixth harmonic wave pattern.

A. What is the velocity of the wave within the wire?
B. What is the mass of the wire being used?
C. What is the fundamental frequency at which the wire will vibrate?

$L = 1.23\ m$

$F_T = 132\ N$

$f_6 = 588\ Hz$

A.) $v = \sqrt{\frac{F_T}{m/L}}$

*missing mass

$f_n = n\left(\frac{v}{2 \cdot L}\right)$

$f_6 = 6\left(\frac{v}{2(1.23)}\right)$

$588 \cdot 2 \cdot 1.23 = 6 \cdot v$

$1446.48 = 6 \cdot v$

$\boxed{v = 241\ m/s}$

B.) $v = \sqrt{\frac{F_T}{m/L}}$

$v^2 = \frac{F_T \cdot L}{m}$

$v^2 \cdot m = F_T \cdot L$

$m = \frac{F_T \cdot L}{v^2}$

$m = \frac{(132)(1.23)}{(241)^2}$

$\boxed{m = 2.80 \times 10^{-3}\ kg}$

C.) $f_6 = 588\ Hz$

$f_6 = 6 \cdot f_1$

$588 = 6 \cdot f_1$

$f_1 = \frac{588}{6}$

$\boxed{f_1 = 98\ Hz}$

20. A particular organ pipe can resonate at 264 Hz, 440 Hz, and 616 Hz, but not at any other frequencies between 264 and 616 Hz.

A. Is this a pipe open at both ends or only one end?
B. What is the fundamental frequency of the pipe?

3rd	5th	7th
264 Hz	440 Hz	616 Hz

176 Hz   176 Hz

$\frac{264}{176} = 1.5$ $\frac{440}{176} = 2.5$ $\frac{616}{176} = 3.5$

* 176 Hz can't be the fundamental - it doesn't divide evenly. these must be all ODD harmonics

$\frac{176}{2} = 88\ Hz$

$\frac{264}{88} = 3$ $\frac{440}{88} = 5$ $\frac{616}{88} = 7$

Pipe open at one end.

B.) fundamental = 88 Hz

21. An organ pipe is open at both ends. It is producing a sound where its seventh harmonic is a frequency of 427 Hz.
   A. What is the fundamental frequency?
   B. What is the length of the pipe?

$f_7 = 427\ Hz$

A.) $f_7 = 7 \cdot f_1$

$427 = 7 \cdot f_1$

$f_1 = \frac{427}{7}$

$f_1 = 61\ Hz$

B.) $f_1 = 1 \cdot \left(\frac{v}{2 \cdot L}\right)$

$61 = 1\left(\frac{343}{2 \cdot L}\right)$

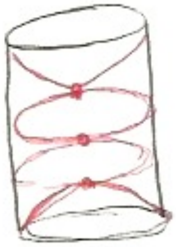
$61 \cdot 2L = 343$

$L = 2.81\ m$

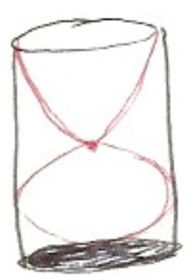
22. Sketch the third harmonic for the following situations:
   A. A vibrating string
   B. A pipe open at both ends
   C. A pipe only open at one end

3rd

A.) 

B.) 

3rd

C.) 

3rd