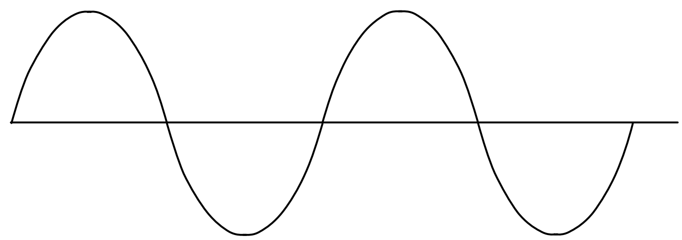
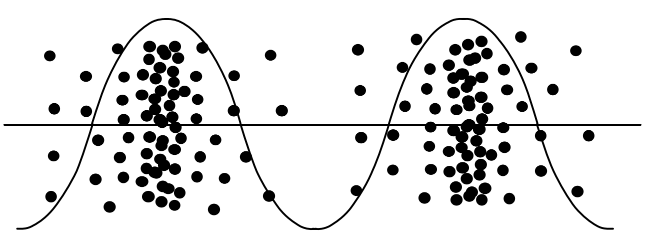
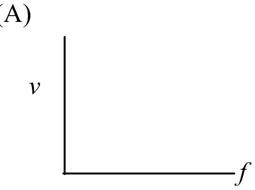
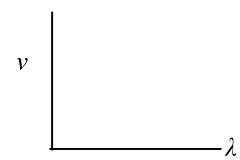
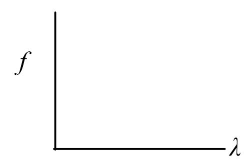
42 TRAVELING WAVES

1. **Wave progagation** (A) **Source** (B) **Disturbance** (C) **Medium** (D) **Speed** (E) **Traveling waves** (F) **Mechanical waves** (G) **Electromagnetic waves**	(A) (B) (C) (D) (E) (F) (G)
2. **Transverse Waves** have the classic sinusoidal appearance. Therefore, it will be easiest to label key terms associated with measuring wave characteristics using the transverse wave. (A) On the top diagram label the following: i. **Equilibrium** (0) ii. **Amplitude** (A) iii. Several **wavelengths** (λ) (B) How does the direction of the vibration compare to the direction that the wave travels? (C) What is the best example of a transverse wave?	(A)  (B) (C)
3. **Longitudinal Waves** are difficult to draw and visualize. Even though they do not have the classic sinusodal appearance they do graph sinusoidally. (A) On the bottom diagram label the following: i. **Compression** ii. **Rarefaction** iii. The direction of the vibration. (B) How does the direction of the vibration compare to the direction that the wave? (C) What is the best example of a longitudinal wave? (D) What are some other names for this type of wave?	(A)  (B) (C) (D)
4. **Wave Pulse**: Sketch a wave pulse traveling along a string, with an arrow indicating the direction of motion. Label the leading and trailing edges of the pulse.	

5. What is necessary in order for mechanical waves to transmit?		
6. What aspect of wave propagation does the medium control?		
7. Waves on a string (the medium is the string) depends on string's linear density and tension. (A) How does linear density influence wave speed? (B) How does string tension influence wave speed?	$\mu = \frac{m}{L}$ $v = \sqrt{\frac{T}{\mu}}$	μ Linear density (kg/m) m Mass (kg) L Length (m) v Wave speed (m/s) T Tension (N)
	(A)	
	(B)	
8. Sound waves (A) In general what physical property of matter controls the speed of sound waves? (B) How does the speed of sound compare between gases, liquids, and solids? The speed of sound in gases is important to us, as we live in a gaseous environment. The equation for the speed of sound in a gas is shown at the right. (C) Most values in the equation are constant. Which factor varies and how does it affect the speed of sound in gases?	(A)	
	(B) where γ and k_B are constants,	
	$v_{sound} = \sqrt{\frac{\gamma k_B T}{M}}$	γ A constant that depends on the gas ($\gamma = 1.40$ for O_2 and N_2) k_B Boltzman constant = 1.38×10^{-23} (J/K) T Temperature in Kelvin (K) M Molar mass of the gas molecules
	(C)	
9. **Period** and **Frequency** $\boxed{T = \frac{2\pi}{\omega} = \frac{1}{f}}$	T Period: time of one complete cycle (seconds, s)	
	f Frequency: number of cycles in one second (1/s , s^{-1} , Hertz, Hz)	
10. The key in cyclic behaviors is always one cycle. In one cycle there are…	____ periods	____ wavelengths ____ amplitudes
11. **Wave speed** $v = \frac{d}{t}$, $v = \frac{\lambda}{T}$, $\boxed{v = f\lambda}$	v wave speed in the medium it is moving through (meters per second, m/s)	
	f Frequency: number of cycles in one second (1/s , s^{-1} , Hertz, Hz)	
	λ Wavelength (meters, m)	

<table>
<tr><td>12. An object vibrates 60 times in 3 min. The wavelength is measured as 30 cm. Determine wave speed.</td><td colspan="3"></td></tr>
<tr><td>13. A wave traveling at 28 m/s has a wavelength of 16 cm. Determine the period of the vibration.</td><td colspan="3"></td></tr>
<tr><td rowspan="2">14. A sound wave traveling in a air has a wavelength of 1.34 m.
(A) Determine the frequency.
(B) The sound is heard as an echo 3.0 seconds after it is emitted. How far away is the barrier that reflected the sound wave back to the source?</td><td colspan="3">A)</td></tr>
<tr><td colspan="3">B)</td></tr>
<tr><td>15. You see the flash of lightening and then hear the sound of thunder 2.0 seconds later. How far away is the lightening strike?</td><td colspan="3"></td></tr>
<tr><td rowspan="3">16. Sketch the graphs showing the relationships between wave speed, frequency, and wavelength for the following conditions. Describe the mathematical relationship between the independent and dependent variables in each graph, and note if the slope of each graph has any significance.
(A) Constant Medium
(B) Changing Medium, while frequency is held constant
(C) Changing Medium, while wavelength is held constant</td><td>(A)

</td><td>
</td><td>
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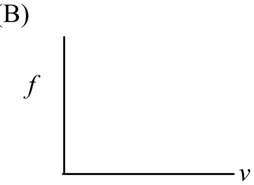
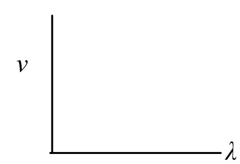
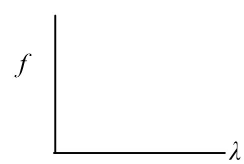

</td><td>
</td><td>
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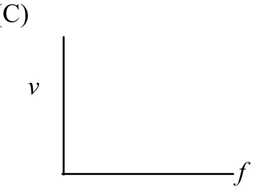
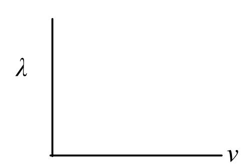
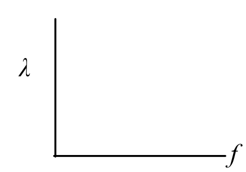
<tr><td>(C)

</td><td>
</td><td>
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43 ENERGY, POWER, AND INTENSITY

17. What type of wave are sound waves?	
18. What is pitch?	
19. What is loudness?	
20. Range of human hearing?	
21. What is (A) Infrasound (B) Audible sound (C) Ultrasound	(A)
	(B)
	(C)

22. For the wave types listed below sketch **wave front** diagrams that help to visualize invisible waves such as sound. On each diagram label one wavelength. (A) Plane waves (B) Circular waves (C) Spherical waves	(A)	(B)	(C)
23. **Waves transmit energy**. List the three ways to alter the energy of a wave.			

		v	$=$ f	$\times$ λ	E
24. Wave speed depends on the medium. Therefore, there are three possible types of problems. (A) **<u>Constant medium</u>**: State the relationships between speed, frequency, wavelength, and energy if the medium is constant while other variables change. (B) **<u>Changing medium, while keeping frequency constant</u>**: State the relationships for this scenario. (C) **<u>Changing medium, while keeping wavelength constant</u>**: State the relationships for this scenario.	(A) Constant Medium				
	(B) Changing Medium (frequency held constant)				
	(C) Changing Medium (wavelength held constant)				

25. The rate that waves transmit energy is…	

26. **Intensity** (A) What properties of sound and light are related to the intensity of each of these phenomena? (B) Intensity depends on the power of the sound waves and the area receiving the sound waves (C) Sound waves move outward in all directions creating spherical wave fronts. The surface area of a sphere is $4\pi r^2$, and this can be substituted into the intensity formula.	(A) Sound Light	
	(B) $I = \frac{P}{A}$	I Intensity (W/m^2) P Power (W) A Area (m^2)
	(C) $I = \frac{P}{4\pi r^2}$	Where r is both the radius of the sphere and the distance from the source in meters.
27. How is intensity perceived as you move farther from a source emitting (A) plane waves? (B) spherical waves?	(A) (B)	
28. A spherical sound wave is emitted by a source with a power of 20 W. What is the intensity of the sound wave when it has traveled 20 m?		
29. When the intensity of sound is increased by 10 times, how many times is the perceived loudness of sound increased?		
30. Threshold of hearing, I_0 , has an intensity of $I_0 = 1.0 \times 10^{-12}$ W/m^2 . What does this represent?		

31. Decibel Scale is a scale of loudness reflecting the logarithmic nature of perceived intensity. $\beta = (10\,\text{dB})\log_{10}\left(\frac{I}{I_0}\right)$

This scale sets the threshold of hearing as zero dB. As intensity increases by a fractor of 10, the decibal scale increases by 10 dB, and the perceived intensity increases by a factor of 2.

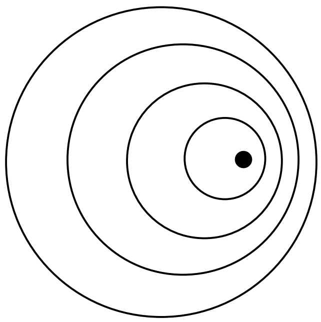
Example: A whisper has an intensity of 1.0×10^{-10} W/m^2 and loudness of 20 dB.

Normal conversation has an intensity of 1.0×10^{-6} W/m^2 and loudness of 60 dB.

A normal converation has a perceived loudness that is 4 times louder than a whisper.

32. An observer standing 1.0 m from a source of spherical sound waves moves to a location that is 10 m from the source. (A) By what factor does the intensity of sound change? (B) By what factor does the perceived volume change?	(A) (B)

44 DOPPLER EFFECT

33. **Doppler Effect** (A) What is the Doppler Effect? (B) What is the direction of motion of the object shown below? (C) If you are standing to the right of the diagram how will the sound of the approaching object be altered? (D) How about on to the left of the diagram 	A) B) C) D)

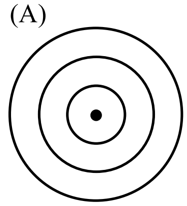
34. Doppler Effect Equations $f_O = \left(\frac{v \pm v_S}{v \mp v_O}\right) f_S$	f_O	Frequency heard by the observer (1/s , s^{-1} , Hertz, Hz)
	f_S	Frequency emitted by the source (1/s , s^{-1} , Hertz, Hz)
	v	Speed of sound (m/s)
	v_S	Speed of the source (m/s)
	v_O	Speed of the observer (m/s)

35. Whether the source or the observer is moving how is frequency perceived if the distance between them is (A) Decreasing (B) Increasing	(A)	(B)

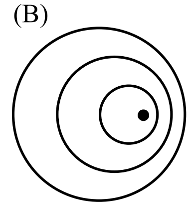
36. How do you decide which signs to select in the equation for the Doppler effect above?	
37. A sound source is emitting a tone with a frequency of 256 Hz. The source has a speed of 50 m/s toward the observer. Determine the frequency heard by the observer.	
38. A sound source is emitting a tone with a frequency of 256 Hz. The observer is moving away from the source at 50 m/s Determine the frequency heard by the observer.	

39. What is the motion of the sound source relative to the speed of sound in the diagrams at the right?

(A)



(B)



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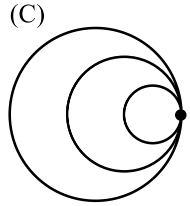
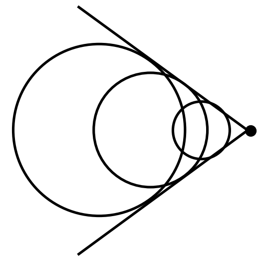


(D)



40. In diagram (C) of the previous question, what is the region where the waves are superimposing known as?

41. In diagram (D) of the previous question
  (A) What is the wake of sound trailing the source known as?
  (B) What do you hear as it passes by?

(A)

(B)

45 SUPERPOSITION, INTERFERENCE, AND STANDING WAVES

42. **Phase**
  (A) When waves are "**in phase**" they…
  (B) "**Out of phase**" means that waves…
  (C) What is significant about being "**180^o out of phase**?"

(A)

(B)

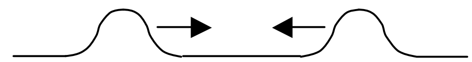
(C)

43. What is wave **superposition**?

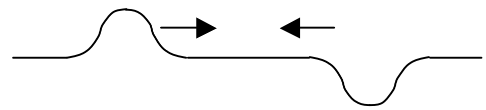
44. What is wave **interference**?

45. The following wave pulses are moving toward each other. Add them at the instant that they meet and interfere. Draw the result of this interference.
    (A) **Constructive interference**
    (B) **Destructive interference**

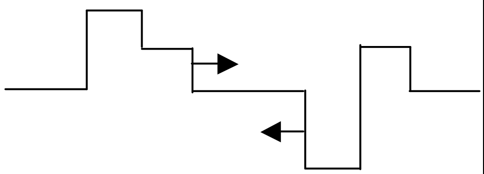
(A)



(B)



46. Diagram the wave form at the instant that the two waves shown superimpose on each other.



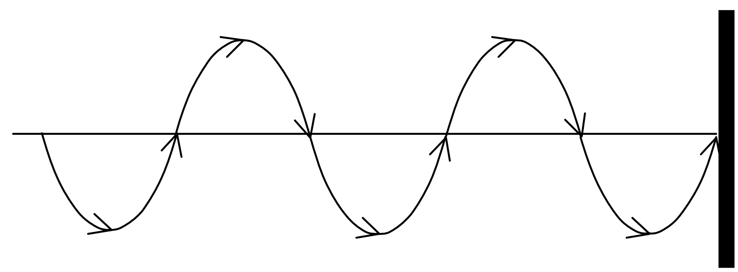
47. Discuss and draw the following wave reflections.
    (A) How do waves in a string reflect if the end of the string is tied down?
    (B) How do they reflect if the end of the string is tied to a ring that is free to slide along a rod?
    (C) How do waves reflect when they strike a **discontinuity** (a change in the property of the medium) and it causes wave speed to increase?
    (D) How do waves reflect when they strike a **discontinuity** (a change in the property of the medium) and it causes wave speed to decrease?

(A)

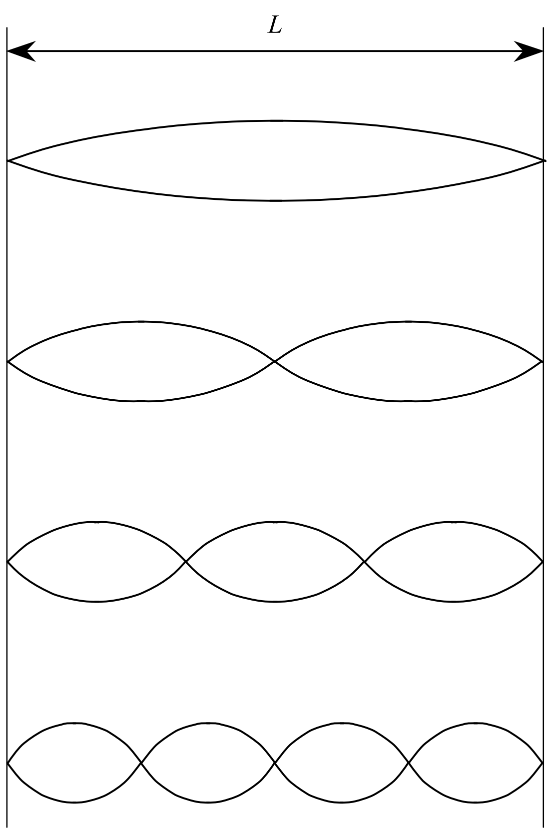
(B)

(C)

(D)

48. What is a **standing wave**, and give a common example?	
49. At the right waves move along a string. They originate from a point vibrating the string, at the left, and travel along the string until they strike barrier that the string is tied top, at the right. (A) Draw the reflected waves bouncing off of the barrier at ther right. (B) Label the **nodes** and **antinodes**. (C) How many wavelengths are shown in the diagram? (D) How many antinodes are in one complete wavelength?	(A) and (B)  (C) | (D)

50. The diagram below shows various standing waves that occur in a vibrating string of length L that is held in place at both ends.
Mode Number (n): a value assigned to identify each wave form. The simpliest wave form is assigned a mode number, $n = 1$, and subsequent waveforms are number sequentially. For a vibrating string the mode number is equal to the number of antinodes.



For a vibrating string that is anchored at both ends, standing waves that are multiples of half wavelengths are the only possible waveforms that can exist.

$L = \frac{1}{2}\lambda$	$\lambda = \frac{2}{1}L$	$\lambda = \frac{2L}{n}$ where $n = 1$	**1**st Harmonic (Fundamental) contains **1 half λ**
$L = \frac{2}{2}\lambda$	$\lambda = \frac{2}{2}L$	$\lambda = \frac{2L}{n}$ where $n = 2$	**2**nd Harmonic (1st Overtone) contains **2 half λ's**
$L = \frac{3}{2}\lambda$	$\lambda = \frac{2}{3}L$	$\lambda = \frac{2L}{n}$ where $n = 3$	**3**nd Harmonic (2st Overtone) contains **3 half λ's**
$L = \frac{4}{2}\lambda$	$\lambda = \frac{2}{4}L$	$\lambda = \frac{2L}{n}$ where $n = 4$	**4**nd Harmonic (3st Overtone) contains **4 half λ's**

51. Equation for a vibrating string

$\lambda = \frac{2L}{n}$ $n = 1, 2, 3, 4,\ldots$ = number of ½ wavelengths = Harmonic #

$v = f\lambda$ $v = f\left(\frac{2L}{n}\right)$ or rearranged for frequency $f = n\left(\frac{v}{2L}\right)$

52. Wave speed in a string depends on tension, T, and linear density, μ.

$$v = \sqrt{\frac{T}{\mu}}$$

Wave speed is also related to resonant mode.

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

Combine the equations to solve for frequency.

53. An amplified wave generator set at a specific frequency generates the standing wave pattern seen in the diagram at the right. A mass M attached to the other end of the string is draped over a pulley. The string has a mass m and a length L. Determine the following in terms of M, m, L, and known constants.

(A) the wavelength

(B) the wave speed in the string

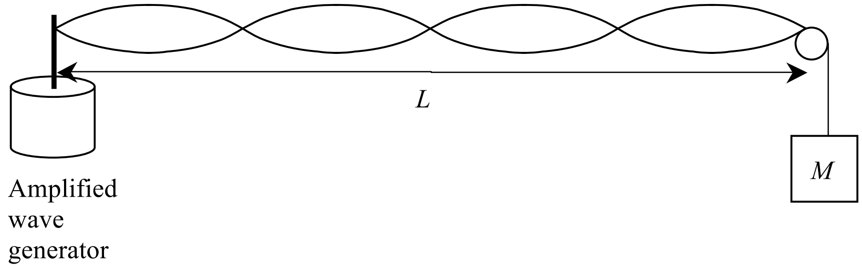
(C) the frequency

If the hanging mass it increased, how are the following variables affected?

(D) the frequency

(E) the wave speed in the string

(F) the wavelength



(A)

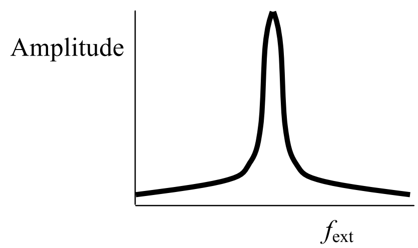
(B)

(C)

(D)

(E)

(F)

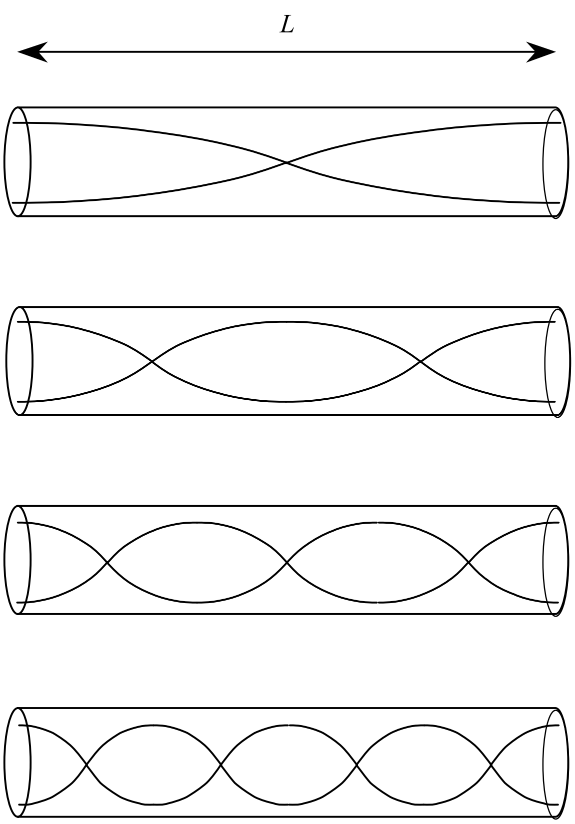
46 RESONANCE	
54. **Drivien oscillation**	
55. **Natural frequency** (f_0)	
56. **Driving frequency** (f_{ext})	
57. **Response Curve:** What is causing the extreme peak in the response curve shown below? 	
58. **Resonance**	
59. **Resonant frequency**	
60. For the vibrating string in the previous section the possible standing waves correspond to the possible **resonant modes** (**resonances**) of the vibrating sting. (A) What is the simplest resonance (corresponding to m = 1) known as, and how is its frequency annotated? (B) What is the next resonance (correspoonding to m = 2) known as, and how is its frequency annotated? (C) What is the third resonance (correspoonding to m = 3) known as, and how is its frequency annotated?	(A) (B) (C)

61. Standing sound waves in tubes (wind instruments) are similar to those in strings (string instruments), but there are some key differnces. (A) What is the medium in a tube instrument compared to the medium in a string instrument? (B) When the wave reaches the end of a string it encounters a _______, while a wave reaching the end of a tube encounters a _______.	(A) (B)

62. There are two ways to diagram standing sound waves in a tube. The diagrams below represent the displacement of the air molecules as they vibrate. The vibration is actually left to right, but the diagrams represent the graphed sine wave of the vibration. However, some textbooks may instead diagram the pressure variation of the air molecules. When this alternate method is used the diagrams will look exactly like the previous diagrams of vibrating springs.

63. For the displacement method diagrams shown below (A) what part of the standing wave occurs at an open end of a tube? (B) what part of the standing wave occurs at a closed end of a tube?	(A) (B)

64. The diagram below shows various standing waves that occur in a tube that is **OPEN AT BOTH ENDS**.



For a tube **OPEN AT BOTH ENDS**, standing waves that are **multiples of half wavelengths** are the only possible waveforms.

$L=\frac{1}{2}\lambda$	$\lambda=\frac{2}{1}L$	$\lambda=\frac{2L}{n}$ where $n=1$	**1**st Harmonic (Fundamental) contains **1 half λ**
$L=\frac{2}{2}\lambda$	$\lambda=\frac{2}{2}L$	$\lambda=\frac{2L}{n}$ where $n=2$	**2**nd Harmonic (1st Overtone) contains **2 half λ's**
$L=\frac{3}{2}\lambda$	$\lambda=\frac{2}{3}L$	$\lambda=\frac{2L}{n}$ where $n=3$	**3**nd Harmonic (2st Overtone) contains **3 half λ's**
$L=\frac{4}{2}\lambda$	$\lambda=\frac{2}{4}L$	$\lambda=\frac{2L}{n}$ where $n=4$	**4**nd Harmonic (3st Overtone) contains **4 half λ's**

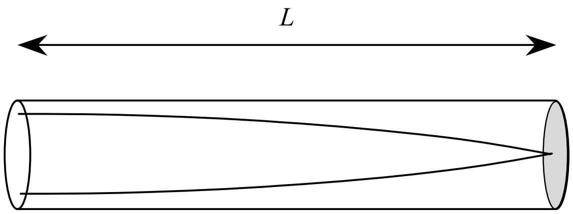
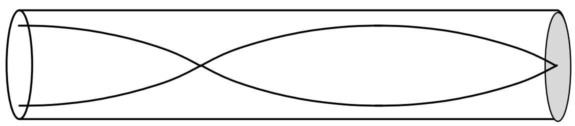
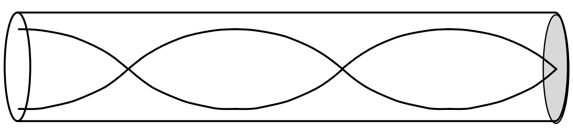
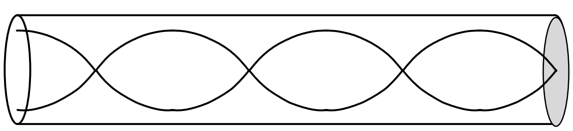
65. Equation for a tube **OPEN AT BOTH ENDS**.

$\lambda=\frac{2L}{n}$ n = 1, 2, 3, 4,… = number of ½ wavelengths = Harmonic #

$v=f\lambda$ $v=f\left(\frac{2L}{n}\right)$ or rearranged for frequency $f=n\left(\frac{v}{2L}\right)$

66. The diagram below shows various standing waves that occur in a tube that is **CLOSED AT ONE END**.

For a tube **CLOSED AT ONE END**, standing waves that are **multiples of the ODD QUARTER wavelengths** are the only possible waveforms.

Diagram				
	$L = \frac{1}{4}\lambda$	$\lambda = \frac{4}{1}L$	$\lambda = \frac{4L}{n}$ where $n = 1$	**1**st Harmonic (Fundamental) contains **1 quarter λ**
	$L = \frac{3}{4}\lambda$	$\lambda = \frac{4}{3}L$	$\lambda = \frac{4L}{n}$ where $n = 3$	**2**nd Harmonic (1st Overtone) contains **3 quarter λ's**
	$L = \frac{5}{4}\lambda$	$\lambda = \frac{4}{5}L$	$\lambda = \frac{4L}{n}$ where $n = 5$	**3**nd Harmonic (2st Overtone) contains **5 quarter λ's**
	$L = \frac{7}{4}\lambda$	$\lambda = \frac{4}{7}L$	$\lambda = \frac{4L}{n}$ where $n = 7$	**4**nd Harmonic (3st Overtone) contains **7 quarter λ's**

67. Equation for a tube **CLOSED AT ONE END**.

$\lambda = \frac{4L}{n}$ n = 1, 2, 3, 4,… = number of **ODD** ¼ wavelengths

$v = f\lambda$ $v = f\left(\frac{4L}{n}\right)$ or rearranged for frequency $f = n\left(\frac{v}{4L}\right)$

68. A string tied between two points is vibrating at its fundamental frequency. The speed of the waves in the string is 750 m/s and its frequency is 500 Hz. Determine the length of the string.

69. An open tube is resonating at a fundamental frequency of 512 Hz. Determine the length of the tube.

70. A 0.80 m long closed tube is resonating at its fundamental frequency. Determine the fundamental frequency of vibration.

71. Draw a diagram of a sonometer and describe how it functions?	
72. Beats: How do beats occur?	
73. How is beat frequency determined?	