ChemPhys 173 Quiz (2/6/2013)/Form A

Name: KEY

Physics of Music Quiz

22+25 = 47 Pts

Directions: Yes! You may write on this quiz. Begin by putting your name on it and on the GradeMaster form. Answer the first 11 questions on the GradeMaster form. Show your work on all problems.

Multiple Choice:

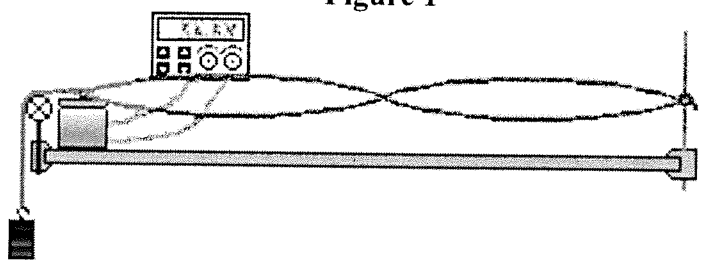
1. The form of this quiz is form _____. (See top of page.)

Read the following passage and use it to answer **Questions #2-#8.**

Standing Waves in a Rope

A group of students are conducting experiments to determine the effect of various factors on the speed of a wave. The apparatus, shown in **Figure 1,** includes a rope extending from a metal pole on one end to a pulley on the other. The rope wraps around the pulley and is pulled tight by a hanging mass. A *mechanical oscillator* vibrates the rope. The frequency of vibrations can be controlled by the students. Frequencies are chosen that cause the rope to vibrate as a **standing wave** with fixed points of no vibration called **nodes.**

Figure 1



Experiment 1

In Experiment 1, students hang a 1.0 kilogram mass on the end of the rope. They vary the frequency at which the rope vibrates in order to create standing wave patterns with varying number of nodes. For each frequency, they measure the wavelength and calculate the speed of the wave. Their data is shown in **Table 1.**

Table 1

Trial	# of Nodes	Frequency (Hz)	Wavelength (m)	Speed (m/s)
1	2	62.2	2.25	141
2	3	93.3	1.50	139
3	4	124.4	1.13	140
4	5	155.6	0.90	141

Experiment 2

In Experiment 2, students vary the amount of mass that hangs on the end of the rope. Increasing the mass causes the tightness (tension) of the rope to increase. In each case, they chose frequencies that vibrate the rope with the same standing wave pattern. The measured frequency and wavelengths and the calculated speeds are shown in **Table 2.**

Table 2

Trial	Mass (kg)	Frequency (Hz)	Wavelength (m)	Speed (m/s)
5	0.5	65.9	1.50	99
6	1	93.6	1.50	140
7	1.5	114.4	1.50	172
8	2	131.9	1.50	198

Experiment 3

In Experiment 3, students vary the rope that is being vibrated. They keep the tension the same from trial to trial and vibrate the rope with the same standing wave pattern. For each rope, they measure the *linear density* (the mass per unit length of the rope). The measured frequency and wavelengths and the calculated speeds are shown in **Table 3.**

Table 3

Trial	Lin. Dens. (kg/m)	Frequency (Hz)	Wavelength (m)	Speed (m/s)
9	0.000345	112	1.50	168
10	0.000492	94.3	1.50	142
11	0.000695	79.1	1.50	119

Questions:

2. Which one of the following statements summarizes the purpose of this collection of three experiments?
   a. To calculate the speed of waves under various conditions.
   b. To experiment with ropes that have different linear densities.
   c. To produce a variety of different standing wave patterns in a rope.
   d. To determine what factors affect the speed at which waves travel through a rope.

D

3. Which statement regarding the frequency-wavelength-speed relationship is consistent with the data in **Table 1**?
   a. As the frequency is doubled, both the wavelength and the speed are doubled.
   b. As the frequency is doubled, the wavelength is halved but the speed remains constant.
   c. As the frequency is doubled, the speed is doubled but the wavelength remains constant.
   d. Neither the speed of a wave nor the wavelength is affected by a doubling of frequency.

B

4. Suppose that the students conduct a trial in **Experiment 1** in which they formed a standing wave with 6 nodes. What approximate frequency, wavelength and speed could be expected for such a trial?
   a. Frequency = 187 Hz, Wavelength = 0.75 m, Speed = 140 m/s
   b. Frequency = 218 Hz, Wavelength = 0.64 m, Speed = 140 m/s
   c. Frequency = 218 Hz, Wavelength = 1.35 m, Speed = 280 m/s
   d. Frequency = 249 Hz, Wavelength = 0.56 m, Speed = 140 m/s

A

5. When the amount of mass hanging on the left end of the rope is doubled, the tension is doubled. In **Experiment 2**, how does the tension have to be changed in order to cause the speed to increase by a factor of two?
   a. The tension must be doubled.
   b. The tension must be increased by a factor of two.
   c. The tension must be increased by a factor of four.
   d. No matter how the tension is changed, the speed will never double.

C

6. Which quantities is/are the control variable(s) or constant quantities in **Experiment 3**?
   a. The tension in the rope.
   b. ~~The linear density of the rope.~~
   c. ~~The frequency at which the rope is vibrated.~~
   d. ~~The speed at which waves travel through the rope.~~

A

7. The data in **Table 2** were collected with a constant linear density value. Use the data in **Table 3** to estimate a value of the linear density that was used in **Experiment 2**.
   a. Approximately 0.000345 kg/m
   b. Approximately 0.000492 kg/m
   c. Approximately 0.000695 kg/m
   d. Approximately 0.000986 kg/m

B

8. Which statement summarizes the results of all three experiments and would serve as an effective Conclusion statement?
   a. Waves with longer wavelengths are always observed to have greater speeds.
   b. Standing waves produce neat patterns that demonstrate mathematical relationships.
   c. The frequency and the wavelength of a wave must be known to calculate the speed.
   d. Tension and linear density are the only factors affecting the speed of waves in the rope.

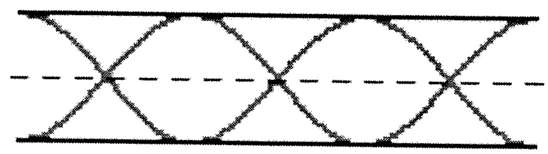
D

9. A pop bottle filled with water can be approximated to be a closed end air column. It is found to resonate in its first harmonic with frequency of 240 Hz. The next highest frequency with which it can resonate is ______ Hz.

AC

a. 120 b. 239 c. 241 d. 360
e. 440 ab. 480 ac. 720 ad. none of these

For Questions#10-#11: A standing wave pattern is established in an open-end air column as it vibrates with the pattern shown. The air column has a length of 90 cm.



10. This pattern represents the ___ harmonic.

C

a. 1^{st} b. 2^{nd} c. 3^{rd}
d. 4^{th} e. 5^{th} ab. 6^{th} ac. 7^{th} ad. 9^{th}

11. The wavelength of the waves creating this pattern is ____ cm.

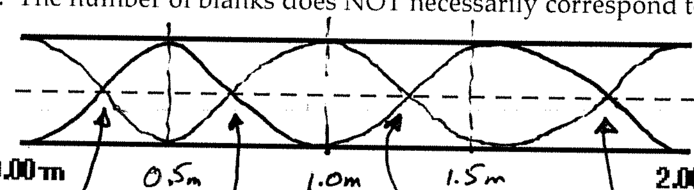
D

a. 22.5 b. 30 c. 45 d. 60
e. 67.5 ab. 72 ac. 90 ad. 120
ae. 135 bc. 180 bd. 270 be. 360

Problem-Solving:

$v = f \cdot \lambda$ $v = \frac{d}{t}$ $v = 331 \text{ m/s} + (0.6 \text{ m/s/C}) \cdot T$ $v = \text{SQRT(Tension/(m/L))}$

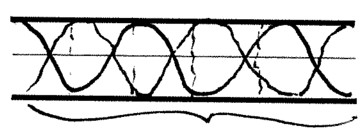
12. Suppose that the air column below is exactly 2.00-meter in length and is vibrating in its fourth harmonic. Determine the numerical positions of all the nodes along the air column. Assume the left end to have the coordinate of 0.00 m and the right end to have the coordinate of 2.00 m. Clearly write your answers in the blanks below the diagram. The number of blanks does NOT necessarily correspond to the number of nodes.



4/4

Nodal Positions → 0.25m 0.75m 1.25 m 1.75m

13. At a temperature of 21°C, an open-end air column produces a fifth harmonic frequency of 686 Hz.
a. Draw the standing wave pattern on the diagram.
b. Determine the length of the air column. PSYW



+1

$T = 21°C \Rightarrow v = 331 \frac{m}{s} + 0.6 * (21°C)$

$v = 343.6 \text{ m/s}$ +1

5/5

$f_5 = 686 \text{ Hz}$

$\lambda_5 = \frac{v}{f_5} = \frac{343.6 \text{ m/s}}{686 \text{ Hz}} = 0.500874... \text{ m}$ +1

$L = \frac{5}{2}\lambda = \frac{5}{2}(\quad) = \boxed{1.25 \text{ m}}$ +2

$(1.2521865... \text{ m})$

3\

14. The vibrating length of a wire is 48.5-cm long. It has a tension of 301 N. The fundamental frequency of the wire is 332 Hz. Determine the mass per length of the wire. **PSYW**

+2

$L = 48.5\,cm = 0.485\,m \Rightarrow$  $\Rightarrow \lambda = 2L = 0.970\,m$

Tension = 301 N

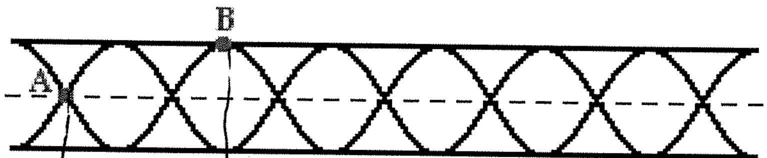
$f_1 = 332\,Hz$ $\longrightarrow v = f \cdot \lambda = (332\,Hz)(.970\,m) = 322.04\,m/s$ +1

6

$v = \sqrt{\frac{Tension}{m/L}} \Rightarrow \frac{m}{L} = \frac{Tension}{v^2} = \frac{301\,N}{(322.04\frac{m}{s})^2} = \boxed{0.00290\,\frac{kg}{m}}$ +1

$2.9023.. \times 10^{-3}\,\frac{kg}{m}$ +2

15. Consider the air column below and the standing wave pattern produced within it. The horizontal distance between points A and B is 52.6 cm. The speed of sound through the air column is 345 m/s. Determine the frequency (in Hz) of this standing wave pattern. **PSYW**



4

$v = 345\,\frac{m}{s}$ $d_{AB} = 52.6\,cm = \frac{3}{4}\lambda \Rightarrow \lambda = \frac{4}{3}(52.6\,cm) = 70.1\bar{3}\,cm$

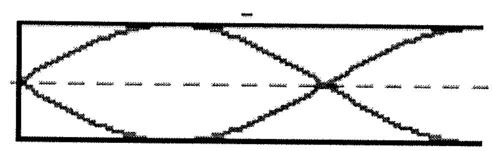
$\lambda = .70133...\,m$

+2

$f = \frac{v}{\lambda} = \frac{345\,m/s}{.70133...\,m} = \boxed{492\,Hz}$ +2

$(491.92015...\,Hz)$

16. Consider the standing wave pattern at the right. The frequency associated with the air column is 314 Hz. Determine the 7th harmonic frequency of a closed-end air column that is 2.2 times longer than the one shown. Assume an identical temperature. **PSYW**



$f_3 = 314\,Hz \xrightarrow[\times\, 7/3]{\text{Same length}} f_7 = 732.666...\,Hz$

$\div 2.2$ since f and L are inversely proportional

4

$\boxed{f_7 = 333\,Hz}$

$(333.0303...\,Hz)$

14

ChemPhys 173 Quiz (2/6/2013)/Form B

Name: Henderson / Kay

Physics of Music Quiz

22 + 23 = 45

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Multiple Choice:

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Read the following passage and use it to answer **Questions #2-#8.**

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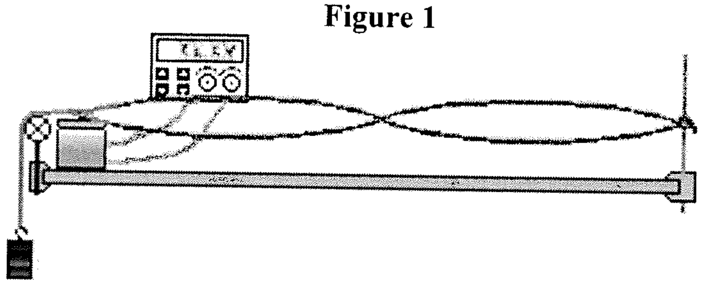
A group of students are conducting experiments to determine the effect of various factors on the speed of a wave. The apparatus, shown in **Figure 1**, includes a rope extending from a metal pole on one end to a pulley on the other. The rope wraps around the pulley and is pulled tight by a hanging mass. A *mechanical oscillator* vibrates the rope. The frequency of vibrations can be controlled by the students. Frequencies are chosen that cause the rope to vibrate as a **standing wave** with fixed points of no vibration called **nodes**.

Figure 1



Experiment 1

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Experiment 2

In Experiment 2, students vary the amount of mass that hangs on the end of the rope. Increasing the mass causes the tightness (tension) of the rope to increase. In each case, they chose frequencies that vibrate the rope with the same standing wave pattern. The measured frequency and wavelengths and the calculated speeds are shown in **Table 2**.

Table 2

Trial	Mass (kg)	Frequency (Hz)	Wavelength (m)	Speed (m/s)
5	0.5	65.9	1.50	99
6	1	93.6	1.50	140
7	1.5	114.4	1.50	172
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Experiment 3

In Experiment 3, students vary the rope that is being vibrated. They keep the tension the same from trial to trial and vibrate the rope with the same standing wave pattern. For each rope, they measure the *linear density* (the mass per unit length of the rope). The measured frequency and wavelengths and the calculated speeds are shown in **Table 3**.

Table 3

Trial	Lin. Dens. (kg/m)	Frequency (Hz)	Wavelength (m)	Speed (m/s)
9	0.000345	112	1.50	168
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   d. Frequency = 249 Hz, Wavelength = 0.56 m, Speed = 140 m/s

5. When the amount of mass hanging on the left end of the rope is doubled, the tension is doubled. In **Experiment 2**, how does the tension have to be changed in order to cause the speed to increase by a factor of two?
   a. The tension must be doubled.
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6. Which quantities is/are the control variable(s) or constant quantities in **Experiment 3**?
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   d. The speed at which waves travel through the rope.

7. The data in **Table 2** were collected with a constant linear density value. Use the data in **Table 3** to estimate a value of the linear density that was used in **Experiment 2**.
   a. Approximately 0.000345 kg/m
   b. Approximately 0.000695 kg/m
   c. Approximately 0.000492 kg/m
   d. Approximately 0.000986 kg/m

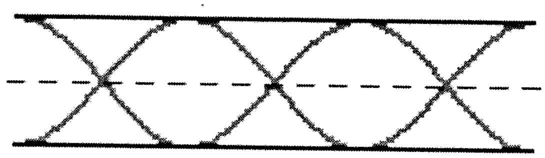
8. Which statement summarizes the results of all three experiments and would serve as an effective Conclusion statement?
   a. Waves with longer wavelengths are always observed to have greater speeds.
   b. The frequency and the wavelength of a wave must be known to calculate the speed.
   c. Standing waves produce neat patterns that demonstrate mathematical relationships.
   d. Tension and linear density are the only factors affecting the speed of waves in the rope.

End of Passage ... More Multiple Choice on Next Page.

9. A pop bottle filled with water can be approximated to be a closed end air column. It is found to resonate in its first harmonic with frequency of 240 Hz. The next highest frequency with which it can resonate is ______ Hz.

a. 120	b. 239	c. 241	d. 360
e. 440	ab. 480	ac. 720	ad. none of these

For Questions#10-#11: A standing wave pattern is established in an open-end air column as it vibrates with the pattern shown. The air column has a length of 90 cm.



10. This pattern represents the ___ harmonic.

a. 1st	b. 2nd	c. 3rd		
d. 4th	e. 5th	ab. 6th	ac. 7th	ad. 9th

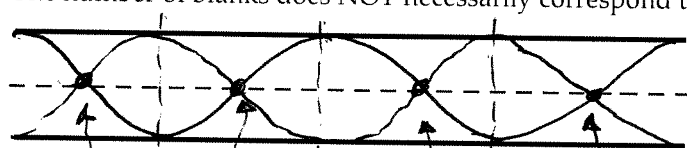
11. The wavelength of the waves creating this pattern is ____ cm.

a. 22.5	b. 30	c. 45	d. 60
e. 67.5	ab. 72	ac. 90	ad. 120
ae. 135	bc. 180	bd. 270	be. 360

Problem-Solving:

$v = f \cdot \lambda$ $\qquad v = \frac{d}{t}$ $\qquad v = 331\ \text{m/s} + (0.6\ \text{m/s/C}) \cdot T$ $\qquad v = \text{SQRT(Tension/(m/L))}$

12. Suppose that the air column below is exactly 2.00-meter in length and is vibrating in its fourth harmonic. Determine the numerical positions of all the nodes along the air column. Assume the left end to have the coordinate of 0.00 m and the right end to have the coordinate of 2.00 m. Clearly write your answers in the blanks below the diagram. The number of blanks does NOT necessarily correspond to the number of nodes.



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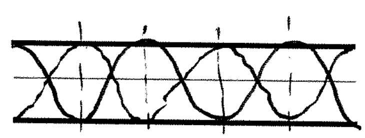
0.00 m — 2.00 m

Nodal Positions ⇒ 0.25 m 0.75 m 1.25 m 1.75 m

13. At a temperature of 28°C, an open-end air column produces a fifth harmonic frequency of 721 Hz.
a. Draw the standing wave pattern on the diagram.
b. Determine the length of the air column. **PSYW**



+1

$T = 28°C \Rightarrow v = 331\,\frac{m}{s} + 28(0.6)$

$v = 347.8\ m/s$ +1

5

$f_5 = 721\ Hz$

$\lambda_5 = \frac{v}{f_5} = \frac{347.8\ m/s}{721\ Hz} = 0.482385....m$ +1

$L = \frac{5}{2}\lambda = \frac{5}{2}(0.482385...m) = \boxed{1.21\,m}$ +2 $(1.20596...m)$

9

14. The vibrating length of a wire is 76.2-cm long. It has a tension of 312 N. The fundamental frequency of the wire is 284 Hz. Determine the mass per length of the wire. **PSYW**

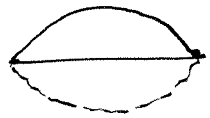
$f_1 = 284\,Hz$

$L = 0.762\,m$

$Tension = 312\,N$

Find $\frac{m}{L}$

6



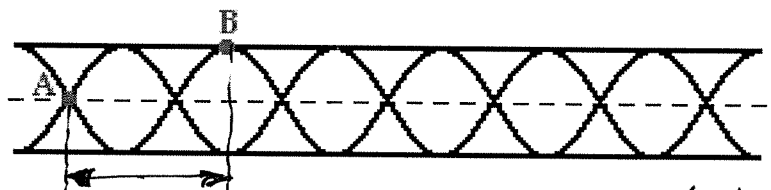
$\lambda = 2 \cdot L = 2(.762\,m) = 1.524\,m$ +2

$v = f \cdot \lambda = (284\,Hz)(1.524\,m) = 432.816\,m/s$ +1

From $v = \sqrt{\frac{Tension}{m/L}} \Rightarrow \frac{m}{L} = \frac{Tension}{v^2} = \frac{312\,N}{(432.816\,\frac{m}{s})^2} = \boxed{0.00167\,m}$ +1 +2

$1.6655 \times 10^{-3}\,m$

15. Consider the air column below and the standing wave pattern produced within it. The horizontal distance between points A and B is 66.1 cm. The speed of sound through the air column is 340 m/s. Determine the frequency (in Hz) of this standing wave pattern. **PSYW**



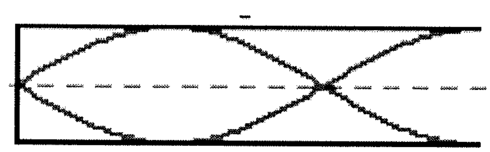
4

$d_{AB} = 66.1\,cm = \frac{3}{4}\lambda \Rightarrow \lambda = \frac{4}{3}(66.1\,cm) = 88.133\ldots\,cm$

$\lambda = 0.881333\ldots\,m$ +2

$f = \frac{v}{\lambda} = \frac{340\,m/s}{.881333\ldots\,m} = \boxed{386\,Hz}$ +2 $(385.77912\ldots\,Hz)$

16. Consider the standing wave pattern at the right. The frequency associated with the air column is 448 Hz. Determine the 7th harmonic frequency of a closed-end air column that is 2.4 times longer than the one shown. Assume an identical temperature. **PSYW**



$f_3 = 448\,Hz \xrightarrow[\div 3 * 7]{\text{Same length}} f_7 = 1045.333\,Hz$

4

$\div 2.4$ since f and L are inversely proportional

$\boxed{f_7 = 436\,Hz}$

$(435.555\ldots\,Hz)$

14