Name: _____ ID: _____ ~~Lab~~ (day/time): _____

Physics 202
Final Exam
3/18/2019

Collaboration is not allowed. Allowed on your desk are: up to ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating scientific calculator, 1 page of scratch paper, writing utensils, and the exam. You will have 110 minutes to complete this exam.

Useful constants:

$\rho_{water} = 1000\ \frac{kg}{m^3}$ $\rho_{air} = 1.225\ \frac{kg}{m^3}$ $g = 9.81\ \frac{m}{s^2}$ $0^\circ C = 273.15\ K$

$P_{atm} = 101,325\ Pa$ $v_{sound} = 343\ \frac{m}{s}$ $R = 8.314\ \frac{J}{mol \cdot K}$ $I_0 = 10^{-12}\ \frac{W}{m^2}$

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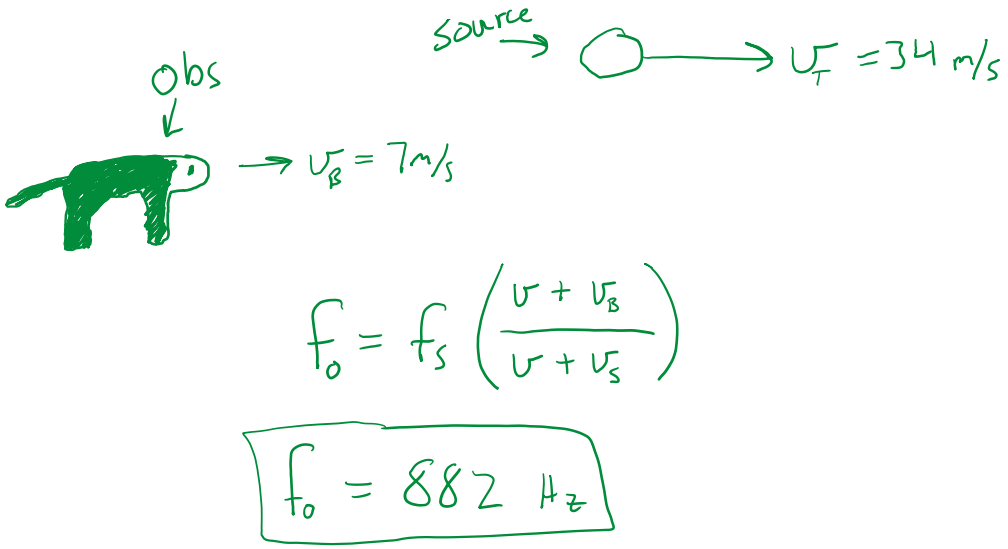
1. (5 points) Brody, The dog, is sitting at your feet like a good boy. You throw a dog toy away from you at a speed of 34 *m/s* (assume constant horizontal velocity). Brody runs after the ball at a constant speed of 7 *m/s*. The toy is designed to make a constant high frequency tone of 950 Hz as it flies through the air.

(a) What frequency does Brody hear as he chases the toy?



$$f_o = f_s \left(\frac{v + v_B}{v + v_s} \right)$$

$$f_o = 882\ Hz$$

For questions 2 through 5 **fill in the square** next to all correct answers, a given problem may have more or less than one correct answer. Each correctly chosen answer will receive two points. There are 7 correct answers in this section and only the first 7 filled in answers will be graded. There is no partial credit.

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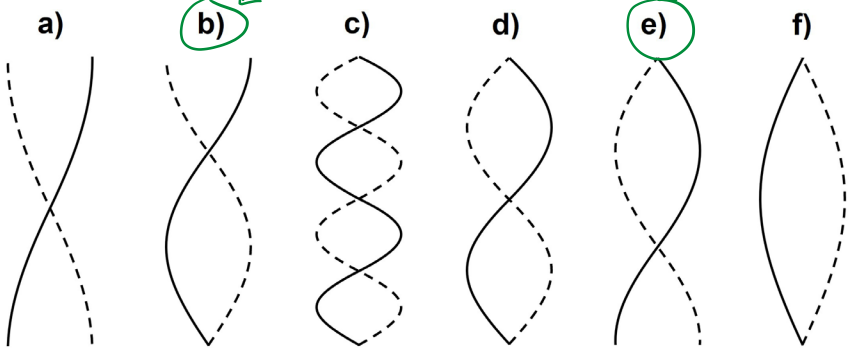
2. Which of the pictured modes of standing wave resonance is/are possible for sound in a coffee thermos (a long, narrow, upright cylinder with the top end open and the bottom end closed)?

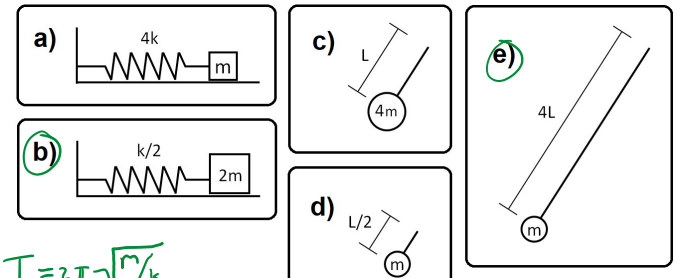
displacement ← b) e) → pressure

a.
b.
c.
d.
e.
f.



3. A pendulum and a spring are undergoing simple harmonic oscillation (pictured to the right), each having the same period of oscillation, T_0. Which of the following similar oscillators has/have a period of $2T_0$?

a.
b.
c.
d.
e.



$T_0 = 2\pi\sqrt{m/k}$

$T_b = 2\pi\sqrt{4m/k} = 2T_0$

$T_0 = 2\pi\sqrt{L/g}$

$T_e = 2\pi\sqrt{4L/g} = 2T_0$

4. A singer is hitting the last note of an opera. If you were to change it/them, which of the following would change the pitch you hear?

a. The temperature of the room. ↑ freq

b. If you both were underwater.

c. How quickly her vocal cords to wiggle back and forth. ⇒ freq

d. How fast she is running at you.

e. The speed of sound in air.

5. Which of the following oscillations has the largest time constant, τ?

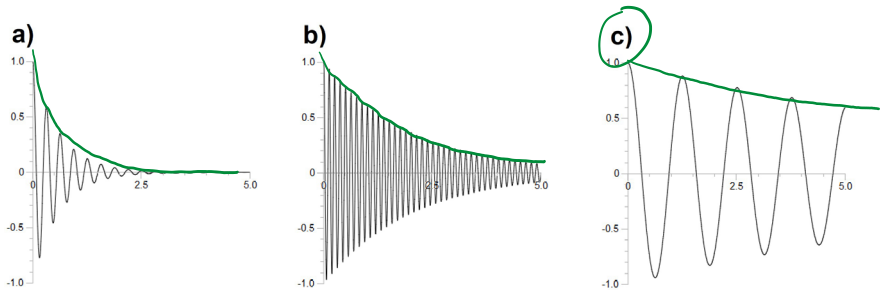
$e^{-t/\tau}$ ⇒ small τ ⇒ quick decay

⇒ large τ ⇒ slow decay

a.

b.

c.



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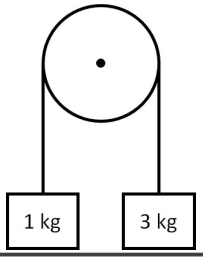
6. (6 points) Two masses are hung from a common string over a 40 cm diameter disk of mass **m** as shown. The disk will rotate with the string without slipping. The system is released from rest at t = 0 In the orientation shown.



(a) Indicate whether each of the following quantities are positive, negative, or zero at t=0.
(After the system has been released, but t = 0)

Angular speed of disk: $\omega = 0$ @ $t=0$

Radial acceleration of a point on the disk edge: $a_r = \frac{v^2}{r} = \omega^2 r = 0$ @ $t=0$
(Positive points outward from pivot)

Torque from 1 kg mass: $\tau \Rightarrow$ CCW $\Rightarrow$ +

(b) If the magnitude of the observed angular acceleration of the disk is 0.002 *rad/sec*, what is the moment of inertia of the disk?

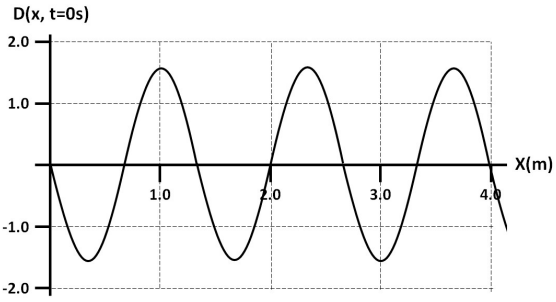
$$\sum \tau = I\alpha$$

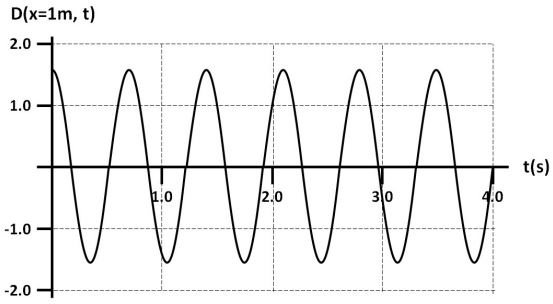
$$\sum \tau = +mgr - m_3 gr = I\alpha$$

$$= (1\,kg)(9.8\,m/s^2)(0.2\,m) - (3\,kg)(9.8\,m/s^2)(0.2\,m) = I\,(-0.002\,rad/sec)$$

$$\Rightarrow \boxed{I = 1960\ kg\,m^2}$$

7. (8 points) Pictured below are a snapshot and history graph of a travelling wave. Find the following quantities.





(a) Period of the wave.

$\left(5\frac{3}{4}\right)T = 4\ \text{sec} \Rightarrow \boxed{T = 0.696\ \text{sec}}$

(b) Wavenumber of the wave.

$k = \frac{2\pi}{\lambda} \qquad 3\lambda = 4\ m \qquad \lambda = \frac{4}{3}\ m \Rightarrow k = \frac{6\pi}{4} = \boxed{\frac{3\pi}{2}\ \frac{\text{rad}}{m} = k}$

(c) Speed of the wave.

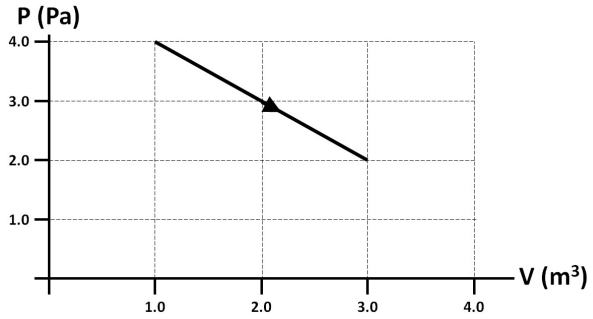
$v = f\lambda = \left(\frac{1}{T}\right)\lambda = \boxed{1.92\ m/s}$

(d) Can you tell if the wave is a transverse or longitudinal wave? Explain.

Displacement given, not direction

$\Rightarrow$ cannot tell what mode

8. (7 points) 20 moles of ideal monatomic gas undergo the process described by the following PV graph.



(a) What is the work done **on the gas** during this process? Include the sign.

|Work done| = area under P-V curve

⇒ 6J

expansion (V↑)
⇒ negative work

$W = -6\,J$

(b) What is the energy change during this process?

$\Delta E = N\left(\frac{3}{2}k_B\Delta T\right) = \frac{3}{2}nR\Delta T$

$PV = nRT \Rightarrow \Delta T = \frac{1}{nR}(P_fV_f - P_iV_i)$

$\Rightarrow \Delta E = \frac{3}{2}(P_fV_f - P_iV_i)$

$= \frac{3}{2}(2P_a\,3m^3 - 4P_a\,1m^3)$

$\Delta E = +3\,J$

(c) Does heat enter or leave the gas? How much?

$\Delta E = W + Q$

$+3J = -6J + Q$

$\Rightarrow Q = +9J \Rightarrow$ heat enters the gas

For the following question, *very little* credit will be given to correct answers with no explanation.

9. (6 points) One bar of gold pressed latinum (a very dense material, valuable in the 24th century) is glued to a large block of styrofoam. Initially they are floating stationary in a tub of water with the latinum on top of the styrofoam.

(a) If the styrofoam and gold pressed latinum flip over so that the gold pressed latinum is under water, what happens to the water level in the tub? Explain.
(Assume the glue holds and the bar is still stuck to the underside of the styrofoam.)

floating ⇒ weight of Styrofoam + latinum equals weight of displaced water

flip ⇒ still floating ⇒ same amount of water is displaced

⇓

water level does not change!

(b) If the glue fails and the gold pressed latinum falls off the styrofoam and sinks to the bottom, what happens to the water level in the tub? Explain.

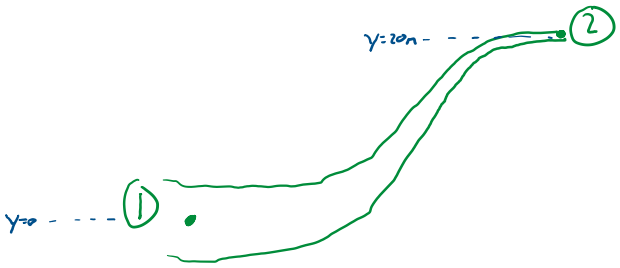
latinum is now only displacing its own volume in water. Formerly was displacing its own weight worth of water. Styrofoam is still floating ⇒ displaces own weight (⇒ no change due to styro)

less water displaced

⇒ water level falls

10. **(6 points)** Water is distributed to homes through a network of city-owned pipes of 0.65 meter radius. When you turn on your friend's 2.0 *cm* diameter kitchen faucet, the water comes out at 3.0 *m/s*. If they live in an apartment and their kitchen faucet is 20.0 meters above the city water pipes:

What is the water pressure in the city pipe?



$$A_1 v_1 = A_2 v_2$$

$$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

$$v_1 = \frac{r_2^2}{r_1^2} v_2$$

$$= \frac{(.01)^2}{(.65)^2}(3) = 0.7 \text{ mm/sec}$$

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$$

(negligible)

$$P_1 = 101{,}325 \text{ Pa} + (1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(20 \text{ m}) + \frac{1}{2}(1000 \text{ kg/m}^3)(3 \text{ m/s})^2$$

$$= 301{,}825 \text{ Pa}$$

$P_1 = 302 \text{ kPa}$

11. (8 points) You ask Alexa (a spherically symmetric speaker) to play your favorite Nickleback song. When you are standing 3.0 meters away, your ears hear an intensity level of 50 decibels.

(a) What is the current power output of the speaker?

$50\,dB = 10\,dB \log \frac{I}{I_0}$

$10^5 = \frac{I}{10^{-12}\ W/m^2}$

$I = 10^{-7}\ \frac{W}{m^2}$

$I = \frac{P}{A}$ ← sphere

$P = I A$

$= I\, 4\pi r^2$

$= \left(10^{-7}\ \frac{W}{m^2}\right)(4\pi)(3\,m)^2$

$P = 1.13 \times 10^{-5}\ W$

(b) Since you cannot hear the song clearly over the conversation next to you, you ask Alexa to increase her power. If you walk to a new location 4 meters from the speaker, by what factor does Alexa need to increase the power output of the speaker to raise the intensity level you hear to 80 decibels at your new location (which will drown out the hipster talking about the band you've never heard of)?

dangerous!

$80\,dB = 10\,dB \log \frac{I}{I_0}$

$10^8 = \frac{I}{10^{-12}\ \frac{W}{m^2}}$

$I = 10^{-4}\ \frac{W}{m^2}$

$P = I A$

$= \left(10^{-4}\ \frac{W}{m^2}\right)(4\pi)(4\,m)^2$

$P = 2.01 \times 10^{-2}\ W$

$\frac{P_f}{P_i} = 1{,}780$