Name:______________________________ ID:______________________________

Physics 202

Final Exam

3/21/2018

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/graphing scientific calculator, 1 page of scratch paper, writing utensils, and the exam. You will have 110 minutes to complete this exam.

Constants and Conversions

k_B = 1.38x10^{-23} J/K, R = 8.31 J/mol·K, p_{atm} = 101,300 Pa, 1 cal = 4.19 J, 1 liter = 1x10^{-3} m^3, c_{water} = 4190 J/kg·K, c_{ice} = 2090 J/kg·K, c_{copper} = 385 J/kg·K, $c_{aluminum}$ = 900 J/kg·K, $L_{f,water}$ = 3.33x10^5 J/kg, $L_{v,water}$ = 22.6x10^5 J/kg, k_{copper} = 400 W/m·K, $k_{aluminum}$ = 157 W/m·K, σ = 5.67x10^{-8} W/m^2·K^4, $k_{human\ tissue}$ = 0.20 W/m·K, $\rho_{aluminum}$ = 2700 kg/m^3, ρ_{air} = 1.28 kg/m^3, ρ_{water} = 1000 kg/m^3, $\rho_{mercury}$ = 13.6 x 10^3 kg/m^3, ρ_{lead} = 11.3 x 10^3 kg/m^3

$$I_{Hoop} = mR^2 \qquad I_{Disk} = \frac{1}{2}mR^2 \qquad I_{Sphere} = \frac{2}{5}mR^2 \qquad I_{rod} = \frac{1}{3}mR^2$$

1. (8 points) A 14-cm-long string, fixed on both ends, is vibrating in its 4th harmonic. The resonance excites a 92-cm-long organ pipe, open on one end, to resonate in its 2nd harmonic. What is the speed of the transverse waves on the string that are creating the resonance?

String (sym)

$$f_m = m\frac{v}{2L}$$

pipe (Anti sym)

$$f_m = m\frac{v}{4L}$$

Connection

$$f_{string} = f_{pipe}$$

m=4 $\quad f_4 = \frac{4v}{2L_s}$

m=3 $\quad f_3 = \frac{3v_{sound}}{4L_p}$

So, $\quad \frac{4v}{2L_s} = \frac{3v_{sound}}{4L_p} \Rightarrow v = 19.6\ m/s$

Rubric

+1pt - B.C.

+1pt - f_{sym} eq.

+1pt - $f_{antisym}$ eq

+1.5pt - m=3 for pipe

+2pt - $f_{string} = f_{pipe}$

+1pt - algebra

+0.5pt - answer + units

For questions 2 through 6 circle all correct answers, a given problem may have more than one correct answer. Each correctly circled answer will receive two points. There are **9** correct answers in this section and only the first **9** circled answers will be graded. There is no partial credit.

2. If the frequency of a violin string is to be increased by 20%, what change in tension must be applied?

[T] (a) 44%
[F] (b) 20%
[F] (c) 4.5%
[F] (d) 10%

3. Two identical 343 Hz sound sources are facing each other, producing waves. Which of the following statements are true regarding this situation? All statements are referring to points along the line that connects the two sources.

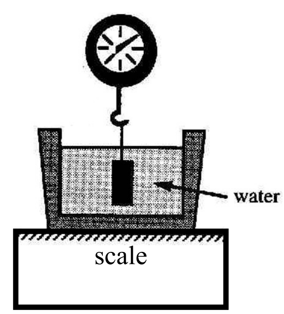
[F] (a) The point halfway between the two is the m = 0 destructive interference point.
[F] (b) The point halfway between the two is the m = 1 constructive interference point.
[T] (c) A point 0.5 m from the midpoint is the m = 1 constructive interference point.
[F] (d) A point 0.5 m from the midpoint is the m = 2 constructive interference point.
[T] (e) A point 0.25 m from the midpoint is the m = 0 destructive interference point.
[F] (f) A point 0.25 m from the midpoint is the m = 1 destructive interference point.

4. An object having an emissivity 0.725 radiates heat at a rate of 10 W when it is at a temperature T. If its temperature is doubled, it will radiate at a rate of

[T] (a) 160 W
[F] (b) 80 W
[F] (c) 40 W
[F] (d) 20 W

5. A container has two chambers separated by a thin wall that allows thermal transport but doesn't allow their contents to mix. One of the chambers is filled with hydrogen while the other is filled with a smaller number of oxygen molecules. The two systems are allowed to reach equilibrium. Which of the following statements are true regarding this situation.

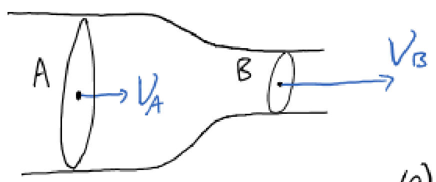
[F] (a) The temperature of the hydrogen is greater than the oxygen.
[F] (b) The average kinetic energy per particle is greater in the hydrogen side.
[F] (c) The average kinetic energy per particle is greater in the oxygen side.
[T] (d) The average kinetic energy per particle is same on both sides.
[T] (e) The total kinetic energy is greater in the hydrogen side.
[F] (f) The total kinetic energy is greater in the oxygen side.
[T] (g) The average speed per particle is greater in the hydrogen side.
[F] (h) The average speed per particle is greater in the oxygen side.



6. A steel block hanging from a scale is slowly lowered into a vat of water that rests on another scale. Consider the time when the block is being lowered and is *partially* submerged. Which of the following statements are true regarding this situation.

[F] (a) The reading on the top scale will decrease while the bottom scale will remain constant.
[F] (b) The reading on the top scale will increase while the bottom scale will remains constant.
[T] (c) The reading on the top scale will decrease while the reading on the bottom scale increases.
[F] (d) The reading on the top scale will increase while the reading on the bottom scale decreases.
[F] (e) The height of the water in the vat will decrease.
[F] (f) The pressure from the vat pushing on the bottom scale will remain constant.
[T] (g) After the block is fully submerged but still not touching the bottom of the vat, the readings on both scales will remain constant.

7. (8 points) A horizontal pipe has an inside diameter of 6.0 cm (point A) that gradually decreases to a value of 4.5 cm (point B). Water is flowing at an unknown rate and the gauge pressures are measured to be 22.6 kPa and 33.5 kPa. (a) Which point has the higher pressure? Explain. (b) What is the volume flow rate in the pipe?



Bernoullis

(i) $P_A + \rho g y_A + \frac{1}{2}\rho_A V_A^2 = P_B + \rho g y_B + \frac{1}{2}\rho V_B^2$

(a) according to Bernoullis equation, if $V\uparrow$, $P\downarrow$

$V_B > V_A$ b/c so $P_A > P_B$

b.) Continuity $V_A A_A = V_B A_B \Rightarrow V_A = \left(\frac{r_B}{r_A}\right)^2 V_B$ (ii)

Combine (i) + (ii)

33.5 kPa - 22.6 kPa

$P_A - P_B = \frac{1}{2}\rho\left(V_B^2 - \left[\left(\frac{r_B}{r_A}\right)^2 V_B\right]^2\right)$

$= \frac{1}{2}\rho V_B^2\left(1 - \left(\frac{r_B}{r_A}\right)^4\right) \Rightarrow V_B = 5.647\ m/s$

so $Q = \pi r_B^2 V_B = 8.98 \times 10^{-3}\ \frac{m^3}{s}$

Rubric

(a)

+0.5pt - Answer

+1pt - Reasoning

(b)

+1pt - Bernoullis eq.

+1pt - Continuity eq.

+1pt - ratio of speeds

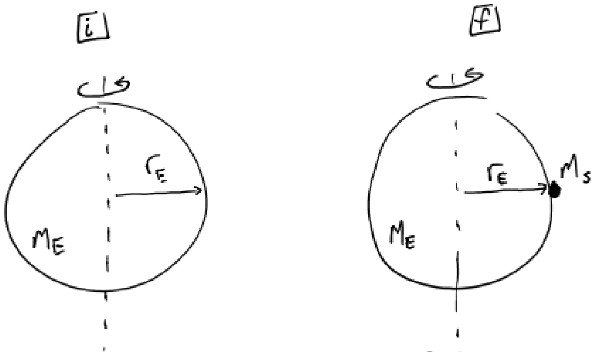
+1pt - Solving Bern for ΔP

+1.5pt - Combining Bern + Continuity

+0.5pt - $Q = AV$ eq.

+0.5pt - Answer + Units

8. (8 points) A small alien ship is landing straight vertically down onto Earth at the equator. There is concern that due to the immense density of the ship's black hole energy source the landing will cause a significant change to the length of a day on Earth. How massive does the ship need to be to increase the length of a day on Earth by one hour? ($M_E = 5.972\text{x}10^{24}$ kg, $R_E = 6.378\text{x}10^{6}$ m)



$\omega_i = \frac{2\pi}{T_i} = 7.2722\times10^{-5}\,\frac{rad}{s}$

$\omega_f = \frac{2\pi}{(T_i + 1\,hr)} = 6.9813\times10^{-5}\,\frac{rad}{s}$

or $\omega \propto \frac{1}{T}$

if $T_f = \frac{25}{24} T_i$

$\omega_f = \frac{24}{25}\omega_i$

w/ $\Sigma \tau_{ext} = 0$, $\Sigma L_i = \Sigma L_f$

$I_i \omega_i = I_f \omega_f$

Point Particle

$\frac{2}{5} M_E r_E^2 \omega_i = \left(\frac{2}{5} M_E r_E^2 + M_s r_E^2\right)\omega_f$

So, $M_s = \frac{2}{5} M_E \left(\frac{\omega_i}{\omega_f} - 1\right) = 9.95\times10^{22}\,Kg$

or $\sim 1.6\%\ M_E$

Rubric

+ 2pt - $\Sigma L_i = \Sigma L_f$

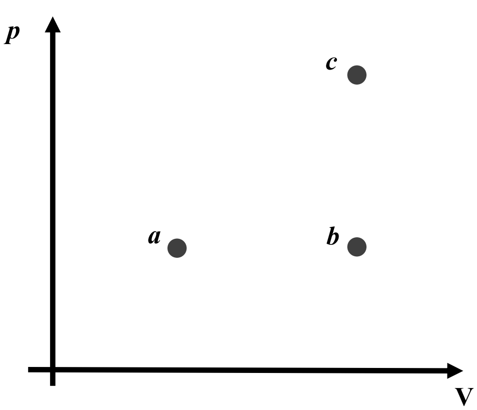
+ 1pt - $L = I\omega$ eq.

+ 2.5pt - applying $I_i\omega_i = I_f\omega_f$

+ 2pt - finding $\frac{\omega_i}{\omega_f}$

+ 0.5pt - Answer + Units

9. (3 points) The states (a, b, c) of three different points on a pressure versus volume diagram for an ideal gas are represented in the figure. Rank them based on the average kinetic energy of the particles in each state.



$PV = nRT$, $T_a < T_B < T_c$,

Since $\bar{K} \propto T$, $\bar{K}_a < \bar{K}_B < \bar{K}_c$

Rubric

+1.5pt - Ranking of T

+1.5pt - Ranking of $\bar{K}$ same as T

10. (8 points) Howler monkeys are the loudest land animal on the planet and a single one can be heard from as far as 2.6 km away. (a) What is the power coming from the monkey during this event? (b) If three monkeys are next to each other screaming at the top of their lungs, what is the decibel level just 2 meters away from them?

a.) $I = \frac{P}{A} = \frac{P_s}{\pi r^2}$, @ $r = 2.6\,km$, $I = I_o = 10^{-12}\frac{W}{m^2}$

So, $P_s = I_o \pi r^2 = 2.1237 \times 10^{-5}\,W$

b.) $\beta = 10dB \log_{10}\left(\frac{I}{I_o}\right)$

$= 10dB \log_{10}\left(\frac{3P_s}{\pi r^2}\frac{1}{I_o}\right) = 67\,dB$

(r = 2m)

Rubric

(a)

+1pt - $I = \frac{P}{A}$ eq.

+1pt - $I = I_o$ @ $r = 2.6\,km$

+0.5pt - Solving for P_s

+0.5pt - Answer + units

(b)

+1pt - dB eq.

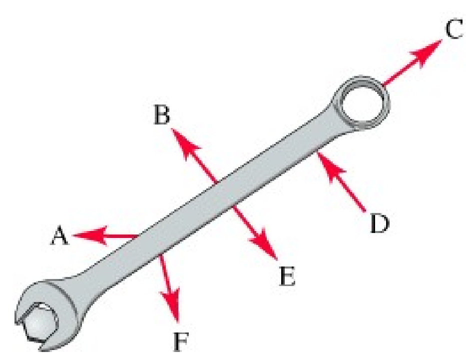
+1pt - $I = \frac{P}{A}$ in dB eq.

+1.5pt - $P = 3P_s$

+1pt - Application

+0.5pt - Answer + units

11. (5 points) There are six equal forces applied to a wrench, as shown in the figure. (a) Rank the forces based on the magnitude of the torque they apply about the center of the nut. (b) Which way would the wrench begin to rotate if all six forces where applied at the same time?



(a) $\vec{\tau} = \vec{r} \times \vec{F} \Rightarrow |\vec{\tau}| = |\vec{r}||\vec{F}|\sin\theta$

$\tau_C < \tau_A < \tau_F < \tau_B = \tau_E < \tau_D$

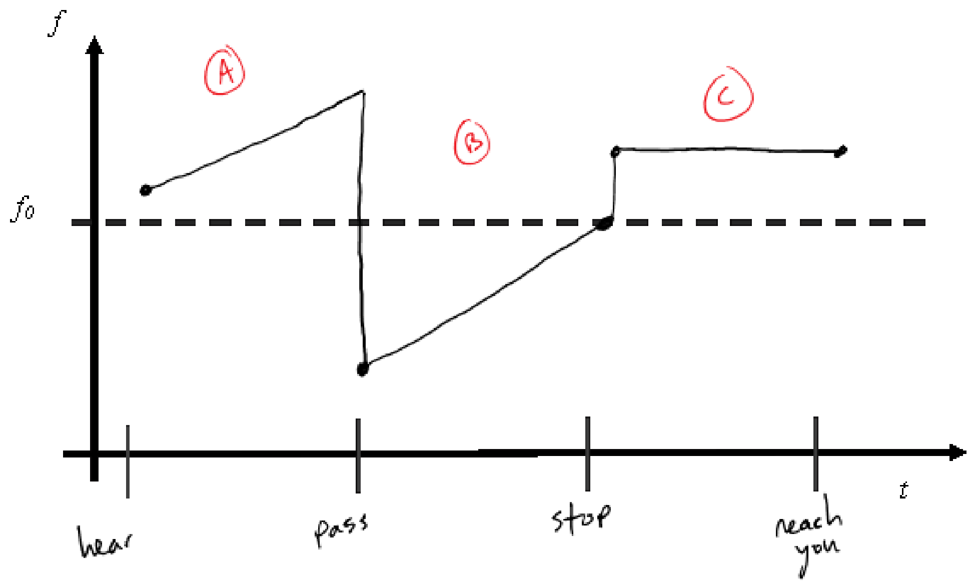
(b) $\Sigma \tau_{ccw} > \Sigma \tau_{cw}$, so Counter Clock-wise

Rubric

(a) 2.5 pts

(b) 2.5 pts

12. (5 points) A galactic law enforcer is racing towards you, speeding up at a constant rate, blasting their sirens. Right as they pass, you flip them the finger for the incident at planet Alderaan. They immediately hit the brakes and begin to slow down at a constant rate. After momentarily coming to a stop, they race back towards you with zero acceleration. Use the provided axis to sketch a plot of the frequency you hear as a function of time, relative to their normal frequency of f_0.



Rubric

+ 2pt - Region (A)

+ 2pt - Region (B)

+ 1pt - Region (C)

13. (2 points) At some point during the exam I will walk through the room and play my hollowed out wooden frog. To play the frog you run a drum stick up or down the frog's notched back. This creates a loud frog sound. Why is this toy able to make such a loud sound?

Standing Wave Resonance

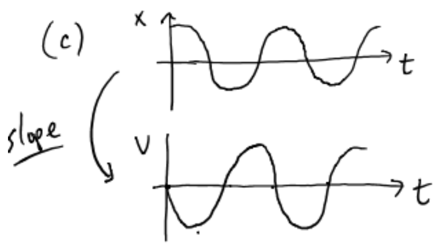
14. (10 points) A 2.0 kg block on a horizontal frictionless surface is attached to a spring whose force constant is 590 N/m. The block is pulled from its equilibrium position at x = 0 m to a displacement x = +0.080 m and is released from rest. The block then executes simple harmonic motion along the x-axis (horizontal). (a) What is the period of the resulting motion? (b) Write a function for the position of the block versus time. (c) What is the velocity of the block at time t = 0.10 s?

(a) $\omega = \sqrt{\frac{k}{m}} = \frac{2\pi}{T} \Rightarrow T = 2\pi\sqrt{\frac{m}{k}} = 0.3658\,s$

(b) general form $X(t) = \pm X_{max} \begin{matrix}\sin \\ \text{or} \\ \cos\end{matrix}(\omega t)$, our starts @ + max w/ $\omega = 17.18 \frac{rad}{s}$

So, $X(t) = +\,0.08\,m \cos(17.17556\,t)$

(c)



general $V(t) = \pm\, V_{max} \begin{matrix}\sin \\ \text{or} \\ \cos\end{matrix}(\omega t)$, $V_{max} = X_{max}\,\omega$

So $V(t) = -\,X_{max}\,\omega \sin(\omega t)$

$= -1.374\,\frac{m}{s} \sin(17.17556\,t)$

$V(t{=}0.1s) = -1.34\,\frac{m}{s}$

Rubric

(a)

+1pt - $\omega = \sqrt{\frac{k}{m}}$ eq.

+1pt - $\omega = \frac{2\pi}{T}$ eq.

+0.5pt - Answer + Units

(b)

+1pt - general form eq.

+0.5pt - finding ω

+1.5pt - Applying I.C. to get $+\cos(\omega t)$

+0.5pt - Answer

(c)

+1pt - general form eq.

+1pt - $V_{max} = X_{max}\,\omega$ eq.

+1.5pt - finding neg sine function

+0.5pt - Answer + Units

extra space if needed