Name:______________________________

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Physics 202

Final Exam

03/20/2023

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

For questions 1 through 8 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **11** correct answers in this section and only the first **11** filled in answers will be graded. There is no partial credit.

1. A system is observed to have five different macroscopic states (**V** through **Z**). Each macroscopic state is made up of a certain number of micro states given in the table. It is observed that state **W** has a larger multiplicity than all the other macro states. Which of the following values could be the number of microstates for macrostate **W**?

   ☐ (a) 0
   ☐ (b) 2
   ☐ (c) 4
   ☐ (d) 8
   ☐ (e) 10
   ☐ **(f) 12**

Macrostate	**# of Microstates**
V	8
W	?
X	10
Y	8
Z	4

2. Two stars are observed in the night sky. Star **A** has a radius **R** and temperature **T**. Star **B** has a radius 2**R** and Temperature 2**T**. By what factor does star **B** radiate energy per time compared to star **A**? Both stars have an emissivity of 1.

   ☐ (a) 1
   ☐ (b) 2
   ☐ (c) 4
   ☐ (d) 8
   ☐ (e) 16
   ☐ (f) 32
   ☐ **(f) 64**

3. A wheel is spinning freely at a constant angular velocity on a frictionless axel. The wheel is brought into contact with a stationary wall which causes the wheel to slow down. Which of the following energies of the wheel increases when in contact with the wall?

   ☐ (a) Rotational kinetic energy.
   ☐ (b) Spring potential energy.
   ☐ (c) **Thermal energy.**
   ☐ (d) Chemical energy.
   ☐ (e) None increase, all energies related to the wheel decrease.

4. A cube (equal length sides) of 10 kg mass rests on a table. Which of the following statements must be true?

   ☐ **(a) If the density of the cube is doubled without changing the length of any side, the pressure exerted on the table will increase.**
   ☐ (b) If the volume of the cube is doubled while still maintaining a cube shape, and the mass of the cube is not changed, the pressure exerted on the table will increase.
   ☐ (c) If the mass of the cube is doubled while still maintaining a cube shape, and the density of the cube remains unchanged, the pressure exerted on the table will increase.

5. A non-insulated container is in thermal equilibrium in a large bath of ice. Room temperature water and a hot piece of metal are placed together inside the container. Which of the following statements must be true?

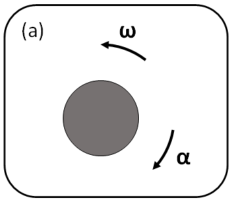
   ☐ (a) All the heat lost by the hot metal is absorbed by the room temperature water.
   ☐ (b) Heat is being added to the water + metal system from the ice bath.
   ☐ (c) **Heat is being lost to the ice bath from the water + metal system.**
   ☐ (d) No heat leaves or enters the water + metal system.
   ☐ (e) The energy of the water + metal system is conserved.
   ☐ (f) All of the water will boil because the hot metal is at a larger initial temperature.

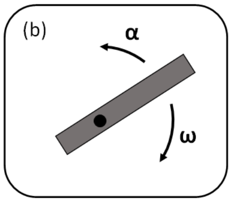
6. Water is flowing in a pipe. Which of the following statements must be true?

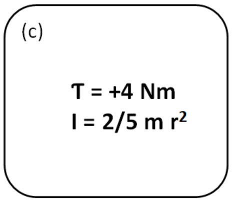
   ☐ (a) If the pipe increases in height without changing diameter, the pressure in the water will increase.
   ☐ **(b) If the pipe diameter decreases, the speed of the water must increase.**
   ☐ (c) If the pipe decreases in height, the speed of the water must increase.
   ☐ **(d) If the pipe diameter increases and the pipe height decreases, the pressure in the water must increase.**

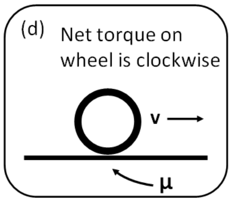
7. Which of the following situations depicts negative angular acceleration?

   ☐ **(a)**
   ☐ (b)
   ☐ (c)
   ☐ **(d)**

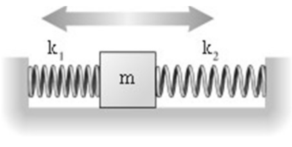








8. A mass is compressed between two ideal springs on a frictionless horizontal surface, as shown in the figure. When the mass is in equilibrium, both springs are at their relaxed length. Which of the following statements are true regarding this situation?



   ☐ (a) **The mass experiences the largest net force when the potential energy in the springs is the greatest.**
   ☐ (b) The mass accelerates most when its kinetic energy is the highest.
   ☐ (c) The maximum potential energy is greater than the maximum kinetic energy.
   ☐ (d) If the energy of the oscillation is increased, the frequency will decrease.
   ☐ (e) If the energy of the oscillation is increased, the frequency will also increase.
   ☐ (f) **If the energy of the oscillation is increased, the frequency will remain constant.**

9. (4 points) It's been observed that during some earthquakes, short and tall buildings are less damaged than medium height buildings.

   (a) Is a building an example of symmetric or asymmetric boundary conditions? Briefly explain your reasoning?

   Buildings are fixed at the base and free at the top. This makes them an asymmetric boundary condition.

   (b) How can standing wave resonance account for only certain height buildings showing damage?

   Standing wave resonance is a phenomena where certain driving frequencies will create a resonance in the system. Not all frequencies match the boundary conditions to create such a resonance. This means the buildings with a height that has one of their resonant frequencies equal to that of the earthquake shake, are the most vulnerable to damage.

Rubric

Part (a)
- 1 pt - answer
- 1 pt - reasoning

Part (b)
- 2 pt - answer and reasoning

10. (10 points) A wave is sent down 5 meters of string that weighs 0.250 N. The wave can be described by the equation **D**(**x**,**t**) = (3.00 cm) sin[(12.0 rad/m)**x** - (650 rad/s)**t**], where **x** is in meters and **t** is in second.

(a) What is the amplitude of the wave's oscillation?

$$\underline{D_{max} = 3.00\,\text{cm}}$$

(b) What is the wavelength of the traveling wave?

$$k = \frac{2\pi}{\lambda} = 12\,\frac{\text{rad}}{\text{m}} \Rightarrow \underline{\lambda = \frac{\pi}{6}\,\text{m}}$$

(c) What is the tension in the string?

$$\left.\begin{array}{l} v = \sqrt{\frac{F^T}{\mu}} \\ v = f\lambda \end{array}\right\} F^T = \mu f^2 \lambda^2 , \quad w/ \ \omega = 2\pi f, \quad F^T = \frac{\omega^2}{4\pi^2}\mu\lambda^2$$

$$\underline{\text{find }\mu}: \quad \mu = \frac{\text{mass}}{\text{length}} = \frac{F^g/g}{L} = 5.102 \times 10^{-3}\,\frac{\text{kg}}{\text{m}}$$

$$w/ \quad \omega = 650\,\frac{\text{rads}}{\text{s}} , \quad \underline{F^T = 15.0\,\text{N}}$$

(d) What is the fastest speed a portion of the string will move while the wave passes by?

$$V_{max} = D_{max}\,\omega = \underline{19.5\,\text{m/s}}$$

Rubric

Part (a)
1 pt - answer + units

Part (b)
1 pt - wave number equation
1 pt - answer + units

Part (d)
1 pt - max velocity equation
0.5 pt - anwer + units

Part (c)
1 pt - speed related to tension equation
1 pt - speed related to frequency and wavelength equation
0.5 pt - angular frequency related to frequency equation
0.5 pt - definition of mu
1 pt - Finding mu
1 pt - algebra to combine equations
0.5 pt - answer plus units

11. (7 points) A small earthquake causes a lamppost to begin a slight oscillation back and forth. It's noticed it takes 10.0 seconds to undergo 4 oscillations. When the earthquake ceases, the amplitude of the top of the lamppost oscillation is 7.50 cm. Then 9.00 seconds later, that amplitude is 1.60 cm.

(a) What is the time constant of the damped oscillation?

model $$D_{max}(t) = D_{max}(t=0)\, e^{-t/\tau}$$

@ $t = 9.0\,s$, $$1.6\,cm = 7.5\,cm\, e^{-9s/\tau}$$

$$\ln \frac{1.6}{7.5} = -\frac{9s}{\tau} \Rightarrow \tau = -\frac{9s}{\ln\left(\frac{1.6}{7.5}\right)} = \underline{5.83\ s}$$

(b) **Sensemaking**: In general, what does the time constant represent in a system like this? Would you expect your time constant to be larger or smaller than the given 9 second value? Using this logic, explain if your answer to part (a) makes sense.

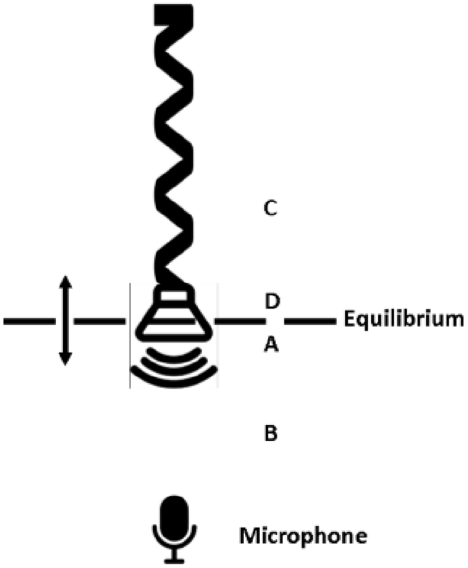
The time constant tau represents the time it would take to reduce the amplitude by a factor of 1/e, or to about 37% the original amplitude. By 9 s this oscillation has decreased to about 21%, so I expect the time constant to be less than 9 s.

Rubric

Part (a)
- 2 pt - correct model
- 2 pt - application and algebra
- 1 pt - correct answer + units

Part (b)
- 1 pt - time constant in general
- 1 pt - explanation of whether answer in (a) makes sense

12. (5 points) A speaker playing a single tone is attached to a vertical spring and set into oscillation above a microphone. At point **A**, the speaker is moving downward through the equilibrium point. At point **D**, the speaker is moving upward through the equilibrium point. Points **B** and **C** are the turning points of the oscillation. Rank the frequency recorded by the microphone for these four points of the motion. Explain the reasoning behind your ranking.



Rubric

2.5 pt - answer
2.5 pt - reasoning

$$\boxed{f_A > f_C = f_B > f_D}$$

at points C & B, the speaker has no speed

$\Rightarrow f_o = f_s$

at point D, the speaker's velocity is away from the microphone

$$\Rightarrow f_o = f_s\left(\frac{v \pm \cancelto{0}{v_o}}{v \pm v_s}\right)$$

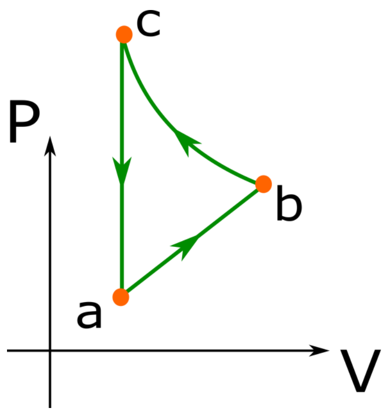
$$= f_s\left(\frac{v}{v + v_s}\right)$$

$$\Rightarrow f_o < f_s$$

at point A, speakers velocity is towards mic

$\Rightarrow f_o > f_s$ b/c $f_o = f_s\left(\frac{v}{v - v_s}\right)$

13. (8 points) A monatomic ideal gas is taken through the cycle shown on the pressure vs volume diagram. The gas absorbs 60 J of heat during the process from **a** to **b**, undergoes an adiabatic process from **b** to **c**, and rejects 80 J of heat during the process **c** back to **a**. During the adiabatic process, 35 J of work is done on the gas. Fill in the remaining energies for each process in the table below. Clearly label your work that justifies each energy you need to fill in.



- adiabat ⇒ $Q = 0$ for $b \to c$
- $\Delta E^{th} = W + Q \Rightarrow \Delta E^{th}_{b\to c} = +35$
- $W_{c\to a} = 0$ b/c no area under curve
- $\Delta E^{th} = 0$ for cycle $\Rightarrow W_{tot} = +20 J$

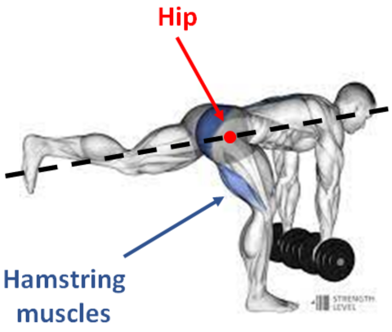
Energy	**a → b**	**b → c**	**c → a**	**Complete cycle**
ΔE^{th} (J)	+45	+35	-80	0
W (J)	-15	35	0	+20
Q (J)	60	0	-80	-20

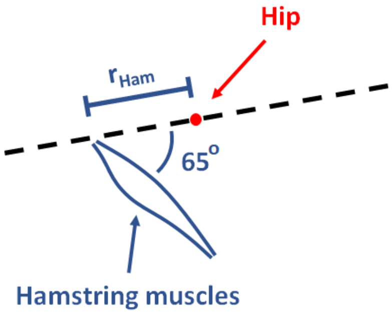
← $\Delta E^{th} = 0$ for cycle

← $\Sigma Q = Q_{tot}$

- $W_{tot} = +20 J$, $W_{b\to c} = 35$, $W_{c\to a} = 0 \Rightarrow W_{a\to b} = -15 J$
- $\Delta E^{th} = W + Q \Rightarrow \Delta E^{th}_{a\to b} = 45$, $\Delta E^{th}_{c\to a} = -80$
- $\Delta E^{th}_{tot} = +45 + 35 - 80 = 0$ ✓

14. (8 points) A common weight lifting exercise is called the single-leg deadlift. In this exercise, the lifter bends over, pivoting at their hip joint, balancing on one leg (see image). Their arms are held vertically, holding additional weight. Assume the person is stationary and not rotating in this position. The hamstring of the weight lifter's lower (right) leg attaches to their pelvis $\mathbf{r}_{\mathbf{ham}}$ from the hip joint, making an angle of 65 degrees with the line formed by their raised (left) leg and upper body.

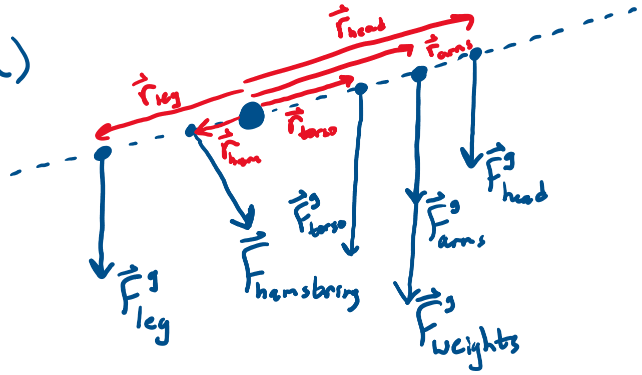




(a) Draw an extended free body diagram that includes gravitational forces acting at the centers of mass of the raised left leg, torso, head, arms, and the weights. Also include the torque from the hamstring muscles of the right leg. Clearly label all forces and displacement vectors symbolically (do not give them numerical values). Also, clearly state any assumptions you make, such as the location of the center of mass of a certain body part, or the angle between a force and it's associated displacement vector.

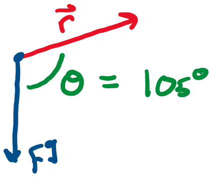
(b) Write a torque analysis that matches your extended free body diagram. **Do not solve**. The only numbers in the final equation should be angles, either given in the problem statement or estimated in your assumptions.

(a)



assumptions

- $\vec{r}_{arms} = \vec{r}_{weights}$
- θ between body line & ground is 15°



(b) $\Sigma \tau = 0$ b/c $\alpha = 0$

$\tau = |\vec{r}||\vec{F}| \sin\theta$

180°-65°

$$\Rightarrow \Sigma \tau = 0 = +|\vec{r}_{leg}||\vec{F}^g_{leg}| \sin(105°) + |\vec{r}_{ham}||\vec{F}_{ham}| \sin(115°) - |\vec{r}_{Torso}||\vec{F}_{torso}| \sin(105°)$$

$$- |\vec{r}_{arms}||\vec{F}_{arms}| \sin(105°) - |\vec{r}_{weight}||\vec{F}_{weight}| \sin(105°) - |\vec{r}_{head}||\vec{F}_{head}| \sin(105°)$$