Solutions

Wednesday, February 18, 2026 1:53 PM

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Name:_____ ID: _____

Physics 202

Midterm 2

2/18/2026

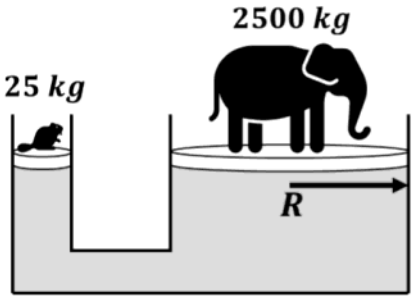
Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled-sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

For questions 1 through 4 **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 **5** correct answers in this section and only the first **5** filled in answers will be graded. There is no partial credit.

1. A heavy robot is tied to a balloon which has been filled with an ideal monatomic gas. The robot and balloon are thrown overboard into the deep ocean from an OSU research vessel. The robot is too heavy to float and sinks downwards. As the robot and balloon sink, which of the following statements are true about the balloon? Assume the temperature stays the same.

   - ☐ (a) The pressure **increases**, the volume **increases**, and the buoyant force **stays the same**
   - ☐ (b) The pressure **increases**, the volume **stays the same**, and the buoyant force **increases**
   - ☑ (c) The pressure **increases**, the volume **decreases**, and the buoyant force **decreases**
   - ☐ (d) The pressure, volume, and buoyant force **remain constant**
   - ☐ (e) The pressure **decreases**, the volume **increases**, and the buoyant force **increases**
   - ☐ (f) The pressure **decreases**, the volume **decreases**, and the buoyant force **decreases**

2. Packy, a big elephant, and Benny, a small beaver, are sitting in equilibrium on hydraulic pistons as shown. If the radius of the piston supporting Packy is **R**, what would you expect the radius to be of the piston supporting Benny?



   - ☐ (a) **1** R
   - ☐ (b) **2500** R
   - ☐ (c) **25** R
   - ☑ (d) **0.1** R
   - ☐ (e) **0.01** R
   - ☐ (f) **0.0001** R

3. Ben finds a strange cube in his tea. Which two properties, by themselves, can be used to identify the material of the cube?

   - ☐ (a) mass
   - ☑ (b) density
   - ☑ (c) specific heat
   - ☐ (d) temperature
   - ☐ (e) total thermal energy
   - ☐ (f) gravitational potential energy
   - ☐ (g) kinetic energy of the particles
   - ☐ (h) gravitational force

4. Imagine you have a game where there are four identical light-up buttons and when you press one of them, it randomly changes between red and blue. Every round you must press all four buttons once. Which state of the game has the most entropy?

   - ☐ (a) all four buttons are **red**
   - ☐ (b) all four buttons are **blue**
   - ☐ (c) 1 **red** button and 3 **blue** buttons
   - ☐ (d) 3 **red** buttons and 1 **blue** button
   - ☑ (e) 2 **red** buttons and 2 **blue** buttons

5. (8 points) Chocolate lava cake is a rich dessert baked at a high temperature for a short period of time. To make this delicious confection, a baker places **170 grams** of batter, at an initial temperature of **20 °C**, into an oven, full of hot air at **218 °C**, for **12.5** minutes. This produces a fully baked outer shell with a signature "molten" center which has only reached **71 °C**.

(a) Give one example each of how conduction, convection, and radiation contribute to the baking of chocolate lava cake. Include a short explanation of each example.

Convection → air inside oven moves around, equalizing Temp. and cooking batter more evenly.

conduction → heat transfers from outer layers of batter inwards through chemical bonds between neighboring molecules.

radiation → hot oven air radiates energy into batter while batter radiates less heat ($\propto T^4$) back into air.

(b) Use dimensional analysis to determine which of the following equations is for the volume of a sphere and which is for the surface area of a sphere? $\mathbf{4/3\ \pi\ r^3}$ and $\mathbf{4\ \pi\ r^2}$

$\frac{4}{3}\pi r^3 \Rightarrow [m]^3 \Rightarrow$ volume

$4\pi r^2 \Rightarrow [m]^2 \Rightarrow$ area

(c) Assume the chocolate cake batter is spherical, with a **3 cm** radius, and has an emissivity of **0.85**. After the batter is placed in the oven, what is the initial rate of radiative energy transfer to the batter? ($\boldsymbol{\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}}$)

$\frac{Q_{in}}{\Delta t} \Rightarrow \sigma e A T_{environment}^4$

$\frac{Q_{out}}{\Delta t} \Rightarrow \sigma e A T_{batter}^4$

$\frac{\Sigma Q}{\Delta t} = \sigma e A \left(T_{oven}^4 - T_{batter}^4\right)$

$= \left(5.67 \times 10^{-8} \frac{W}{m^2 K^4}\right)(0.85)\left(4\pi (0.03m)^2\right)$

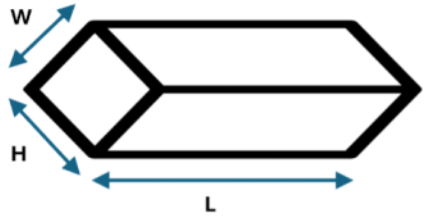
$\times \left((491.15K)^4 - (293.15K)^4\right)$

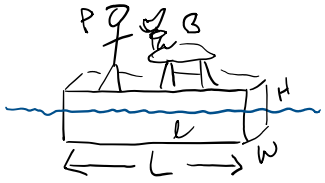
$218°C = 491.15\ K$

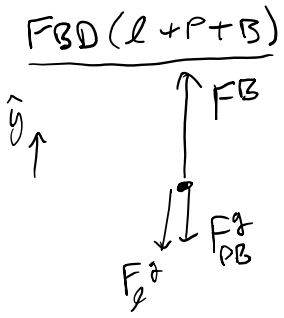
$20°C = 293.15\ K$

$$\Sigma \frac{Q}{\Delta t} = 27.7\ W$$

6. (8 points) Pablo Bunyan, a renowned lumberjack, is standing on a large rectangular log with Babe, the cubist ox. The log and two friends are floating in a lake. Pablo and Babe together have a mass of **1500 kg**. The pine wood log has a width (W) of **1.1 m**, and height (H) of **1.2 m**. The density of pine wood is **425 kg/m^3**. Assume the log is floating with only **10%** of its volume out of the water and Pablo and Babe are on top of the log, out of the water. What is the length of the log?







$\Sigma F_y \Rightarrow F^B - F^g_l - F^g_{PB} = M_{tot}\cancel{a_y}^{0}$, F^B = weight displaced fluid

$\rho_w (0.9) V_l g - \rho_l V_l g - M_{PB} g = 0$

$(W)(H)(L)\left(\frac{9}{10}\rho_w - \rho_l\right) = M_{PB}$

$L = \frac{M_{PB}}{(W)(H)} \frac{1}{\left(\frac{9}{10}\rho_w - \rho_l\right)} = 2.39\ m$

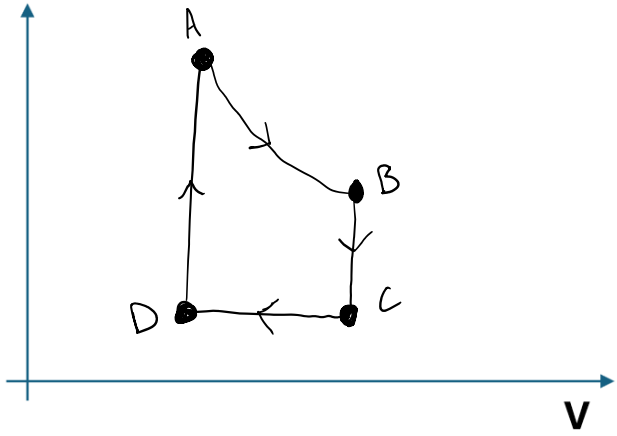
7. (12 points) An ideal monatomic gas expands isothermally from state A to state B. It then cools isochorically to state C. The gas is then compressed isobarically to D, where it is then heated isochorically until it returns to state A. Refer to the table of state variables.

$P_A = 1{,}013{,}250$ Pa
$P_C = 202{,}650$ Pa
$V_A = V_D = 0.002$ m^3
$V_B = V_C = 0.004$ m^3
$T_A = 600$ K

(a) Sketch a PV diagram for this cycle, labeling the points.

Rubric

Part (a) - 2 points
Part (b) - 2 points
1 pt - ideal gas eq.
1 pt - application
Part (c) - 2 points
Part (d) - 4 points
2 pt - values
2 pt - reasoning
Part (e) - 2 points
1 pt - equation
1 pt - application



(b) How many moles are present in the gas? ($R = 8.31$ J/K·mol)

$P_A V_A = n R T_A$

$n = \frac{P_A V_A}{R T_A} = 0.406$ moles

(c) What is the pressure in state B?

A→B $PV = nRT$, w/ T = constant, $P \propto \frac{1}{V}$

if $V \to 2V$, $P \to \frac{P}{2}$; $P_B = \frac{P_A}{2} = 506{,}625$ Pa

(d) Complete the table of energies below for the system. Explain briefly how you found the following values: (i) ΔE_{AB}, (ii) Q_{BC}, (iii) W_{cycle}.

	ΔE (J)	W (J)	Q (J)
A – B	? 0	-1404	? 1404
B – C	-1824	? 0	? -1824
C – D	? -608	405	-1013
D – A	2432	? 0	? 2432
Entire Cycle	? 0	? -999	? 999

(i) w/ $\Delta E = \frac{3}{2} n R \Delta T$

↳ $\Delta T_{AB} = 0$ for isothermal

$\Delta E_{AB} = 0$

(ii) w/ $\Delta E = W + Q$

↳ $W = 0$ for isochoric

$Q_{BC} = \Delta E_{BC}$

Area under PV curve is zero

(iii) $W_{cycle} = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

(e) What is the efficiency of this cycle?

$e = \frac{|\Sigma W|}{\Sigma Q_{in}} = \frac{999\text{ J}}{3836\text{ J}} = 0.26$

or

26%