Physics 7B, Speliotopoulos
First Midterm, Fall 2014
Berkeley, CA

Rules: This midterm is closed book and closed notes. **Anyone who does use a wireless-capable device will automatically receive a zero for this midterm.** Cell phones must be turned off during the exam, and placed in your backpacks. **In particular, cell-phone-based calculators cannot be used.**

Please make sure that you do the following during the midterm:

- **Show all your work in your blue book**
- Write your name, discussion number, ID number on all documents you hand in.
- Make sure that the grader knows what s/he should grade by circling your final answer.
- Cross out any parts of your solutions that you do not want the grader to grade.

Each problem is worth 20 points. We will give partial credit on this midterm, so if you are not altogether sure how to do a problem, or if you do not have time to complete a problem, be sure to write down as much information as you can on the problem. This includes any or all of the following: Drawing a clear diagram of the problem, telling us how you would do the problem if you had the time, telling us why you believe (in terms of physics) the answer you got to a problem is incorrect, and telling us how you would mathematically solve an equation or set of equations once the physics is given and the equations have been derived. D*on't get* too bogged down in the mathematics; we are looking to see how much physics you know, not how well you can solve math problems.

If at any point in the exam you have any questions, just raise your hand, and we will see if we are able to answer them.

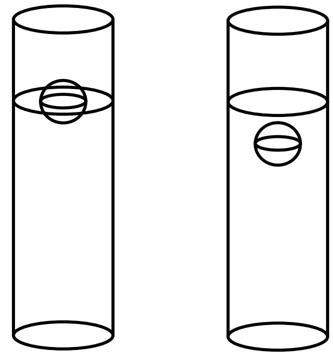
Copy and fill in the following information on the front of your bluebook:

Name: ______________________________ Disc Sec Number: _______________________

Signature: ___________________________ Disc Sec GSI: __________________________

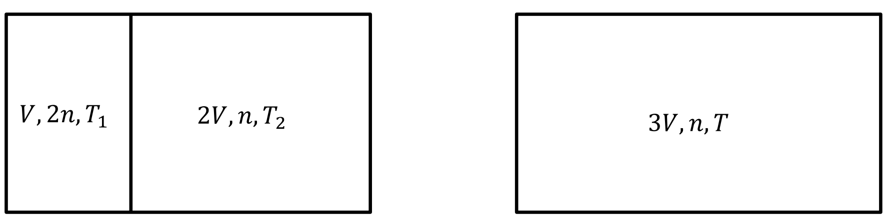
Student ID Number: ____________________

1. The figure on the right shows an outdoor sculpture consisting of hollow, aluminum sphere in a column of water. As the temperature of the system changes during the day, the sphere either floats to the top of the column, or sinks to the bottom of it depending on the buoyancy force on the sphere. Shown in the figure is the system at temperature T_0 when the sphere has volume V_0, a mass, M, and the density of water is ρ_0. At this temperature, the sphere floats on top of the liquid with part of the sphere out of the water. The temperature of the system then changes to T. The coefficient of volumetric expansion of aluminum is β while that of water is 3β.
   a. What is the density of water, ρ, at temperature, T? Express it in terms of ρ_0, T, T_0, and β.
   b. When $T = T_B$, the sphere is suspended completely submerged in the column of water. What is T_B in terms of ρ_0, T_0, V_0, M, and β?



At T_0 At T

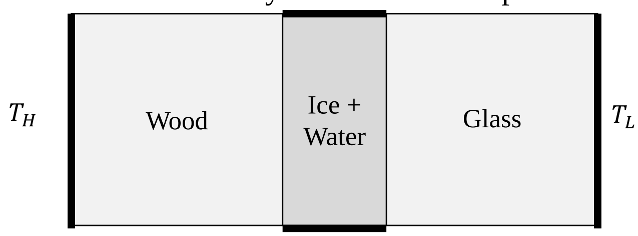
2. The figure below shows two containers monotonic gas. One container has a volume, V, that contains $2n$ moles of gas at temperature T_1. The other has a volume, $2V$, that contains n moles of gas at temperature T_2. The two gasses are allowed to mix and they react to form n moles of a molecule. The pressure in the system after mixing does not change, and remains constant while the gases react to form the molecule. The degrees of freedom of the molecule are five.



Before After Reaction

   a. What is temperature, T, of the gas of molecules?
   b. How much heat is released by the reaction? Assume T is low enough that vibrational modes in the molecules are not excited. (Hint: Is there any work done?)

3. The figure below shows a cell consisting of water plus m_{ice} kilograms of ice. One side of a cell is connected to a hot plate at a temperature, $T_H > 0^\circ$C, through a piece of wood with cross-sectional area, A, and length, l. The other side is connected to a refrigerator at a temperature, $T_L < 0^\circ$C, through a piece of glass with the same cross-sectional area, A, and length, l. The thermal conductivity of wood is k_w, while the thermal conductivity of glass is k_g. The other sides of the cell are thermally isolated. All temperatures are in Celsius.

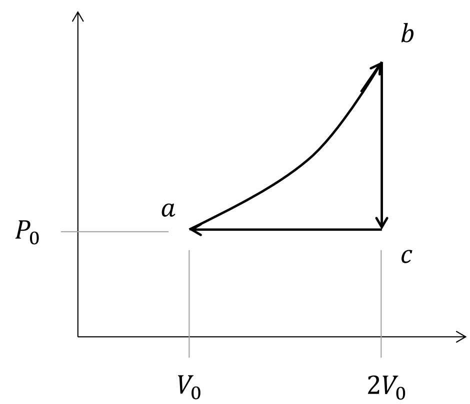


   a. Find the temperature, T_B, for the hot plate so that the ice in the cell does not melt. Express T_B in terms of T_L, k_w, and k_g.
   b. Suppose that $T_H = 2T_B$. How much time, t, does it take the ice to melt? Express it in terms of T_L, k_w, k_g, m_{ice}, A, l, and the latent heat of fusion, L_{ice}. (You will get partial credit for this part of you express your answer in terms of T_B.)

4. The figure on the right shows a thermal cycle where along the path from $a \rightarrow b$ the volume of a diatomic gas increases as

$$V(T) = V_0 \left(\frac{T}{T_a}\right)^s,$$

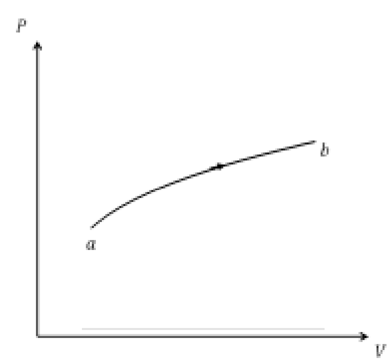
where s is a constant at T_a is the temperature of the gas at point a in the cycle.



   a. Given the $P - V$ diagram shown, is $s > 1$ or is $s < 1$? Why?
   b. What is the work done in the cycle? Express it in terms of s, V_0, and P_0.
   c. What is the efficiency of the cycle? Express it in terms of s.

5. While for an adiabatic processes, $dQ = 0$, the figure on the right shows a gas of n moles of monatomic molecules that undergoes instead a process for which

$$dQ = \frac{1}{2} dW.$$



   a. For each point along the PV diagram for the process, $PV^\beta =$ Constant. Using the first law of thermodynamics and the equation of state for the gas, determine β.
   b. If the temperature at the beginning and end points of the process is T_a and T_b, respectively, what is the change in entropy, ΔS_{ab} for the process? Express it in terms of n, R, T_A and T_B.

$$\Delta l = \alpha l_0 \Delta T$$

$$\Delta V = \beta V_0 \Delta T$$

$$PV = NkT = nRT$$

$$\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$$

$$f_{Maxwell}(v) = 4\pi N\left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-\frac{mv^2}{2kT}}$$

$$E_{int} = \frac{d}{2}NkT$$

$$Q = mc\Delta T = nC\Delta T$$

$$Q = mL \text{ (For a phase transition)}$$

$$\Delta E_{int} = Q - W$$

$$dE_{int} = dQ - PdV$$

$$W = \int PdV$$

$$C_P - C_V = R = N_A k$$

$$PV^\gamma = \text{const. (For a reversible adiabatic process)}$$

$$\gamma = \frac{C_P}{C_V} = \frac{d+2}{d}$$

$$C_V = \frac{d}{2}R$$

$$\frac{dQ}{dt} = -kA\frac{dT}{dx}$$

$$e = \frac{W}{Q_h}$$

$$e_{ideal} = 1 - \frac{T_L}{T_H}$$

$$S = \int \frac{dQ}{T} \text{ (For reversible processes)}$$

$$dQ = TdS$$

$$\Delta S_{syst} + \Delta S_{env} > 0 \text{ (For irreversible processes)}$$

$$\overline{g(v)} = \int_0^\infty g(v)\frac{f(v)}{N}dv \;\; (f(v) \text{ a speed distribution})$$

$$\int_0^\infty x^n e^{-ax}dx = \frac{n!}{a^{n+1}}$$

$$\int_0^\infty x^{2n}e^{-ax^2}dx = \frac{(2n)!}{n!2^{2n+1}}\sqrt{\frac{\pi}{a^{2n+1}}}$$

$$\int_0^\infty x^{2n+1}e^{-ax^2}dx = \frac{n!}{2a^{n+1}}$$

$$\int (1+x^2)^{-1/2}dx = \ln(x + \sqrt{1+x^2})$$

$$\int (1+x^2)^{-1}dx = \arctan(x)$$

$$\int (1+x^2)^{-3/2}dx = \frac{x}{\sqrt{1+x^2}}$$

$$\int \frac{x}{1+x^2}dx = \frac{1}{2}\ln(1+x^2)$$

$$\int \frac{1}{\cos(x)}dx = \ln\left(\left|\tan\left(\frac{x}{2}+\frac{\pi}{4}\right)\right|\right)$$

$$\int \frac{1}{\sin(x)}dx = \ln\left(\left|\tan\left(\frac{x}{2}\right)\right|\right)$$

$$\sin(x) \approx x$$

$$\cos(x) \approx 1 - \frac{x^2}{2}$$

$$e^x \approx 1 + x + \frac{x^2}{2}$$

$$(1+x)^\alpha \approx 1 + \alpha x + \frac{(\alpha-1)\alpha}{2}x^2$$

$$\ln(1+x) \approx x - \frac{x^2}{2}$$

$$\sin(2x) = 2\sin(x)\cos(x)$$

$$\cos(2x) = 2\cos^2(x) - 1$$

$$\sin(a+b) = \sin(a)\cos(b) + \cos(a)\sin(b)$$

$$\cos(a+b) = \cos(a)\cos(b) - \sin(a)\sin(b)$$

$$1 + \cot^2(x) = \csc^2(x)$$

$$1 + \tan^2(x) = \sec^2(x)$$

	Q	W
Isobaric	$C_P n\Delta T$	$P\Delta V$
Isochoric	$C_V n\Delta T$	0
Isothermal	$nRT\ln\left(\frac{V_f}{V_0}\right)$	$nRT\ln\left(\frac{V_f}{V_0}\right)$
Adiabatic	0	$-\frac{d}{2}(P_f V_f - P_0 V_0)$