PHYSICS 7B – Fall 2022
Midterm 1, R. Birgeneau
Monday, Sept. 26, 7-9 pm

- Name:
- Student ID #:

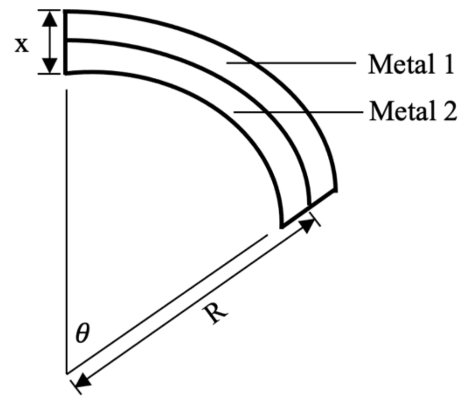
- ***Rules:*** *You may work on this exam from 7:10-9:10 pm PT. This midterm is closed book and closed notes and you are* **not** *allowed to use any electronic devices besides your calculator. You are* **not** *allowed to communicate with any other students or discuss the content of the exam with anyone besides the Physics 7B teaching staff. Any violations of this policy will be considered a breach of academic integrity.*

- ***Equation sheet:*** *Only the equations given on the equation sheet can be used without derivation.*

- ***Partial/Full Credit:*** *We will give partial credit on this midterm, so if you are not sure how to do a problem, or if you do not have time to complete a problem, try to demonstrate your understanding of the physics involved by drawing a clear diagram and explaining (in physics terms) why you believe your answer to be incorrect, or how you would do the problem if you had time. Please be aware, however, that writing irrelevant or incorrect information will result in less partial credit. Remember that you need to show your work and justify your answers in order to get full credit.*

- ***Honors Statement:*** *It is expected that during this examination, as with any examination that they undertake at the university, students adhere to the usual standards of academic integrity at the University of California at Berkeley as outlined on by the [Center for Teaching and Learning](). Therefore, by submitting your exam, you are affirming the following statement:*
  "I swear on my honor that I have neither given nor received aid on this exam. In addition, I abided by all the examination policies as outlined above."

<u>Problem 1</u> – 20 pts



The double metal stripe consists of two metal parts glued together with thickness of $\frac{x}{2}$ for each at temperature T. When heated up, the two parts expand with linear expansion coefficients $\boldsymbol{\alpha_1}$ and $\boldsymbol{\alpha_2}$ ($\boldsymbol{\alpha_1} > \boldsymbol{\alpha_2}$). Ignore any change of the thickness in the double stripe. Assume that the thickness $\boldsymbol{x} \ll \boldsymbol{R}$. Calculate the radius of curvature R for the double stripe when heated to $\boldsymbol{T} + \boldsymbol{\Delta T}$. Express your result in terms of $\boldsymbol{x}, \boldsymbol{\Delta T}, \boldsymbol{\alpha_1}, \boldsymbol{\alpha_2}$.

Problem 2 – 25 pts

a) ***(13 points)*** For an ideal gas of helium atoms derive the relationship between the mean kinetic energy of the atoms and the temperature using kinetic theory. Assume that the helium is confined to a cubic box with sides of length a and that the mass and mean velocity of the atoms are m and v respectively. Assume that all collisions are elastic.

b) ***(4 points)*** What is the same relationship for a hypercube in d dimensions?

c) ***(4 points)*** If the helium is replaced by molecular oxygen for the cube how does the relationship between the temperature and the kinetic energy of the molecules change?

d) ***(4 points)*** Generalize your answer in c) to a d-dimensional hypercube. Ignore vibrational degrees of freedom.

Problem 3 - 15 points

Derive an expression for the work done on ideal gas in each of (i) isothermal, (ii) isovolumetric, (iii) isobaric and (iv) adiabatic processes? Clearly define the variables you use. For the adiabatic process, do not assume that the gas is monoatomic.

Problem 4 - 20 points

A 300-gram copper object is dropped into a 100-gram copper calorimeter containing 200 grams of water at 20°C. This causes the water to boil, with 5.0 grams of water being converted to steam. What was the original temperature of the copper? Use the appropriate constants from the table below. The numbers below are rounded off to make the calculation more straight forward.

	Specific Heat $\left(\frac{J}{kg\cdot°C}\right)$	**Laten Heats** $\left(\frac{kJ}{kg}\right)$	
		Heat of Fusion	**Heat of Vaporization**
Water (Liquid)	4000	300	2000
Water (Steam)	2000		
Copper	400	---	

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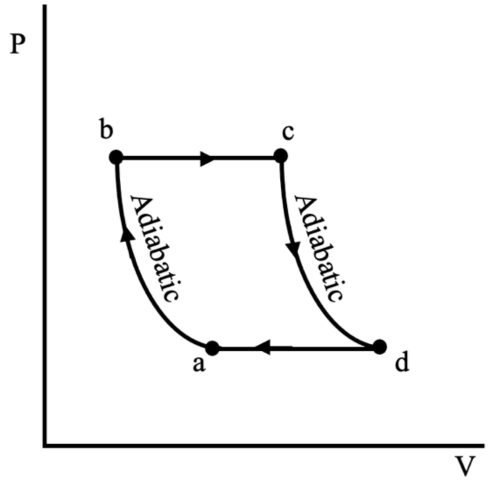
<u>Problem 5</u> - 20 points

A gas turbine operates under the *Brayton cycle*, which is depicted in the PV diagram below. In process ab the air-fuel mixture undergoes an adiabatic compression. This is followed, in process bc, with an isobaric (constant pressure) heating, by combustion. Process cd is an adiabatic expansion with expulsion of the products to the atmosphere. The return step, da, takes place at constant pressure. If the working gas behaves like an ideal gas, show that the efficiency of the Brayton cycle is



$$\boldsymbol{e = 1 - \left(\frac{P_b}{P_a}\right)^{\frac{1-\gamma}{\gamma}}}$$

Bonus Question – 5 points: What are the possible degrees of freedom of a triatomic molecule like CO_2? Include clarifying sketches where appropriate. Which of these degrees of freedom are active at room temperature?