Physics 7B Midterm 1 - Fall 2018
Professor A. Lanzara

Total Points: 100 (5 Problems)

This exam is out of 100 points. Show all your work and take particular care to explain your steps. Partial credit will be given. Use symbols defined in problems and define any new symbols you introduce. If a problem requires that you obtain a numerical result, first write a symbolic answer and then plug in numbers. Label any drawings you make. **Good luck!**

Problem 1 (20 pts.)

In the demonstration from lecture, we heated a metal ball so that it would be unable to pass through a ring. Let us assume that the ball, which had a radius of 2 cm at room temperature, was made of brass, which has $\alpha_B = 20 \cdot 10^{-6}$ (C°).$^{-1}$.

(a) How hot do we have to make the ball to increase its diameter by 0.004 cm?

(b) By what fraction does the volume expand for this temperature change?

Problem 2 (20 pts.)

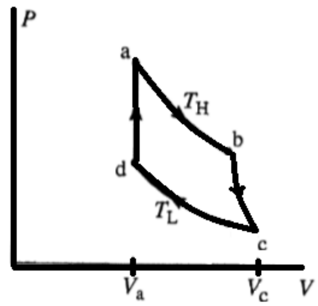
Suppose a gas of N monatomic particles each with mass m live on a plane, meaning they can only move in 2 dimensions. Furthermore, a square box of size L encloses the gas within its walls. The gas particles do not interact with each other, but when they reach the walls they elastically collide and change direction. Assume the gas has a temperature T.

(a) If a molecule has velocity components $v = \hat{x}v_x + \hat{y}v_y$ and $v_x = v_y$, how much time would go by between collisions on a given wall? Express your answer in terms of the variables provided.

(b) How much force F needs to be applied at each wall to balance the force exerted by the gas molecules. (Assume all molecules behave like in (a).)

(c) Using the equipartition theorem, derive the equation of state of the gas in terms of a "pressure" $P^* = F/L$.

Problem 3 (20 pts.)
An engine works between temperatures T_H and T_L and volumes V_a and V_c, as shown below. Paths a→b and c→d are isothermal, path d→ a is isovolumetric, and b→ c is adiabatic. Assume that the engine uses n moles of a monatomic gas.



(a) Calculate Q_{in}, Q_{out}, and W for the cycle.

(b) Find the efficiency of the cycle in terms of the given variables. How does this efficiency compare to that of the Carnot cycle?

(c) Calculate the change in entropy along each part of the cycle

Problem 4 (20 pts.)
Two ideal gas systems made up of n moles of a monatomic particle undergo expansion under different conditions starting from the same P and V. At the end of the expansion, the two systems have the same volume, V_f. The first system has undergone adiabatic expansion and the second has undergone free expansion.

(a) Which system will have the lowest pressure? Explain your answer.

For each process, calculate:

(b) The work done by the gas

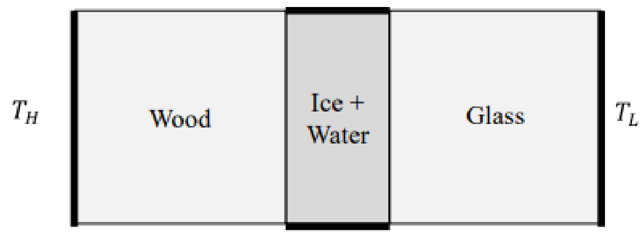
(c) The change in internal energy

(d) The change in entropy

Problem 5 (20 pts.)
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, $T_H > 0°C$, through a piece of wood with cross-sectional area, A, and length, l. The other side is connected to a refrigerator at a temperature, $T_L < 0°C$, 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}.



Formula Sheet: Physics 7B, Midterm 1

Thermodynamics

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

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

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

$$C_P - C_V = R = N_A k_B$$

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

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

$$v_{rms} = \sqrt{\frac{3k_B T}{m}} \text{ (for a monatomic gas)}$$

$$e = \frac{W_{net}}{Q_{in}}$$

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

$$dQ = TdS$$

$$\Delta S_{syst} + \Delta S_{env} > 0$$

$$\oint dS = 0$$