Name:______________________

SID: ______________________

Physics 7B Midterm 1 – Fall 2019
Professor A. Lanzara

TOTAL POINTS: 100

Show all work, and take particular care to explain what you are doing. Partial credit is given. Please use the symbols described in the problems, define any new symbol that you introduce and label any drawings that you make. All answers should be in terms of variables. If you get stuck, skip to the next problem and return to the difficult section later in the exam period.

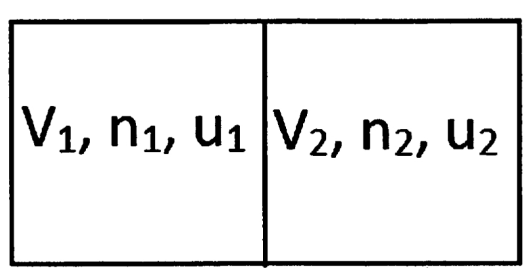
Problem 1. (20pts.)

Consider an isolated system consisting of a box divided in two parts of volume V_1 and V_2 each containing n_1 moles of a monoatomic ideal gas and n_2 moles of a diatomic ideal gas respectively as shown in the figure below. The two gases have rms velocities u_1 and u_2, respectively.

a) Find the temperature of each gas in terms of the given variables

We now remove the partition and let the gases mix. (note that the gases are chemically inert)

b) Find the temperature and the pressure of the mixture of the two gas when the new equilibrium is reached. Neglect the specific heat of the container.



Problem 2. (20 pts.)

A copper bowl of mass m_b contains a mass m_w of water; both bowl and water are at an initial temperature of T_0. A very hot copper cylinder of mass m_c is dropped into the water. This causes the water to boil, with a mass m_s of the water being converted to steam, and the final temperature of the entire system is T_f.

a) How much heat was transferred to the water?
b) How much to the bowl?
c) What was the original temperature of the cylinder?

Problem 3. (15 pts.)

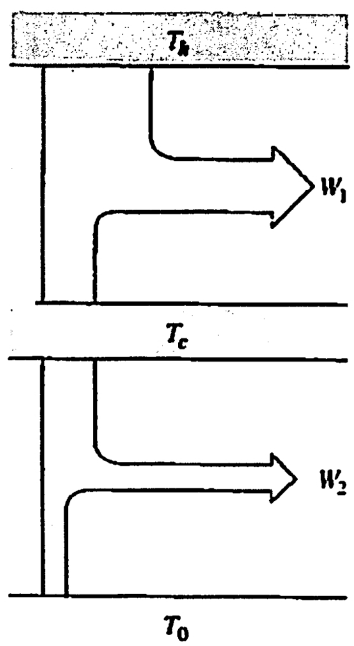
A mole of water vapor at temperature T_0 undergoes a reversible isotherm transformation expanding from a volume V_0 to a volume V_1.

Find the total work done by the system:

a) If the water vapor behaves as an ideal gas
b) If the water vapor behaves as a real gas and follows the van der Waals equation $(P + a/V^2)(V-b) = RT$

Problem 4. (25 pts.)

Consider a Carnot engine operating between temperatures T_h and T_c, where T_c is still above the ambient temperature T_0 (see figure below). It should be possible to operate a second engine between T_c and T_0. Show that the maximum overall efficiency of such a two-stage engine is the same as that of a single engine operating between T_h and T_0.

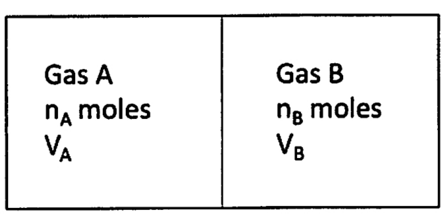


Problem 5. (20 pts)
Consider two ways to mix two perfect gases that are at the same temperature T. In the first an adiabatically isolated container is divided into two chambers with a pure gas A in the left hand side and a pure as B in the right. The mixing is accomplished by opening a hole in the dividing wall.

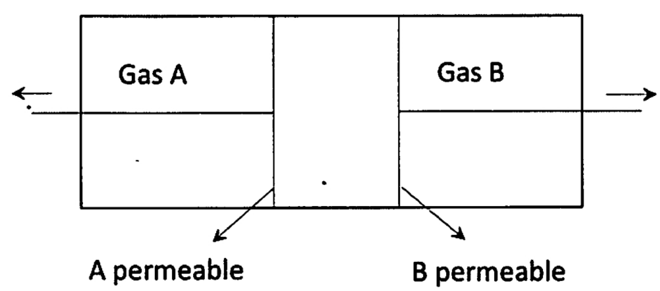
In the second case the chamber is divided by two rigid, perfectly selective membranes: the membrane on the left is perfectly permeable to gas A but impermeable to gas B. The membrane on the right is just the reverse. The two membranes are connected by rods to the outside and the whole chamber is connected to a heat reservoir at temperature T. The gases can be mixed in this case by pulling left hand membrane to the left and right hand one to the right. Assume that the initial volume and number of moles in this case are identical to the first case.

a) Find the change in entropy of the container and its contents for the second process
b) Find the change in entropy of the container and its contents for the first process
c) What is the change in entropy of the heat reservoir in part a?

Case I



Case 2



Formula Sheet: Physics 7B, Midterm 1

Thermodynamics

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

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

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

$C_P - C_V = R = N_A k_B$

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

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

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

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

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

$dQ = TdS$

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

$\oint dS = 0$