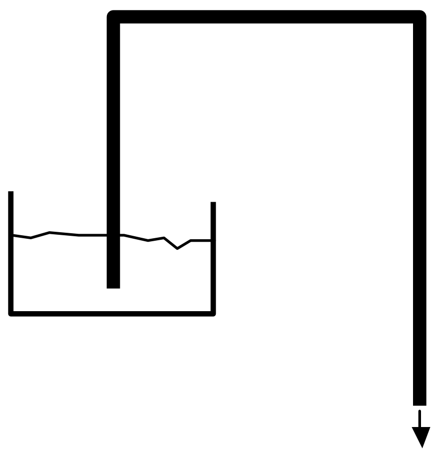
Final Physics 9B section D fall 2004 **Name and ID:**

Use a law blue book. Closed book. Two 3"x5" note cards. PRINT your name and your ID on your blue book and on this problem sheet. When you are finished, place this page inside your bluebook and turn them in together. Finals without problem sheets will not be graded. When you start a new problem, also start a new page in your bluebook. To get credit, you must show your work. **Every** answer must be justified with a calculation or an explanation. Be neat, clear, and organized. If we can't read it or figure it out, we can't give you any points. You **will** lose points for solutions that are poorly presented. Give the units for your answers. You **will** lose points for an answer with incorrect units.

1) (15) Water (density 10^3 kg/m^3) being siphoned out of a very large tank. The pipe extends a distance 3 m into the water and rises to a height 4 m above the water before dropping a distance 8 m. On the surface of the water, the pressure is 10^5 N/m^2. Hint: You may wish to consider a point in the water where the pressure is known and the speed of flow is negligible.

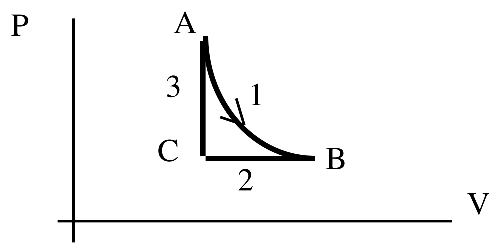


a) What is the flow speed in the pipe?
b) Is there a limit on how high the siphon top can rise above the surface of the water and still work? Explain. If so, what is the limit?

2) (20) Consider a cubic meter of air in the room. T=300K. P=10^5N/m^3. To make it a little easier, assume the air is 100% (rather than the actual 80%) nitrogen molecules each with a mass of 47 x 10^{-27} kg and an effective γ of 7/5. N_A = 6.02 10^{23}/mol.
R = 8.31 J/(mol K)
a) How many molecules are there?
b) What is the internal energy for the cubic meter of gas?
c) What is the average translational kinetic energy per molecule?
d) To what speed does that correspond?

3) (20) The insulation of your freezer is not perfect. When the room temperature is 300K and the temperature in the freezer is 260K, the heat flow through the insulation and into the freezer is 25 J in 1 second. a) Assuming the freezer is maximally efficient, what energy per second does the freezer compressor draw from the wall socket to maintain the temperature difference 300K and 260K? b) Your “clever” roommate says that he will run a heat engine between the inside and outside of the freezer to produce electricity to help run the freezer compressor. Suppose his engine is as efficient as possible and produces 2 watts to help run the freezer compressor. Now how much energy is needed from the wall socket each second? Explain.

4) (30) A heat engine using 1 mole of a monatomic ideal gas uses the cycle



The volume at A is 50 liters. The volume at B is 100 liters. Step 1 is in equilibrium with a reservoir at 600 K. Step 2 is in contact with a reservoir at T_C . Step 3 is in contact with the reservoir at 600 K.

a) What is the temperature T_C at C?

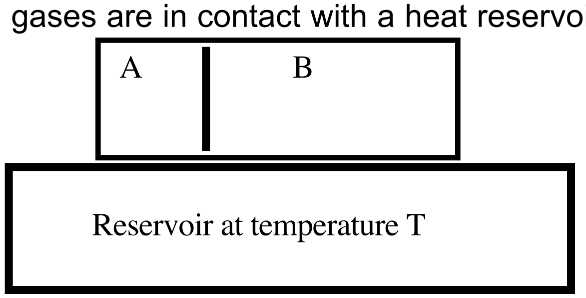
b) How much work is done by the engine in one cycle?

c) What is the efficiency of the engine? (Be careful with the heat flows.)

d) What is ΔS of the universe for one cycle of this engine?

e) What is the efficiency of a Carnot engine operating between reservoirs at 600K and T_C ? Explain why your answer is either the same or different from your answer to part c.

5) (15) Two volumes A and B of ideal gas with N_A and N_B molecules respectively are separated by a piston that is free to move while the total volume $V = V_A + V_B$ is constant. Both gases are in contact with a heat reservoir at a fixed temperature T.



For each volumes of gas A and B, the multiplicity depends on the volume according to

$$w_A = aV_A^{N_A} \qquad w_B = bV_B^{N_B}$$

with a and b independent of V_A and V_B . After the piston comes to equilibrium, what is the pressure in the gas? Express it in terms of k, V, N_A, N_B, T, a, and b. Do the problem using the given information and the ideas of statistical mechanics. There are at least a couple ways to do the problem. If you want to use the equation of state, you must derive it from the information given above and general results on the properties of entropy.