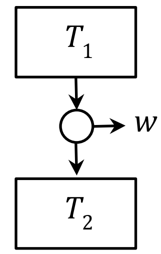
PHYS 4200 Exam 2 Name____________________________

Exam is open book, open notes; each problem is worth 10 points.

1. A reversible (quasi-static) heat engine operates between two reservoirs with temperatures T_1 and T_2 where $T_1 > T_2$. The colder reservoir is so large that T_2 remains essentially constant. However, the hotter reservoir consists of a finite amount of ideal gas at constant volume, for which the heat capacity C_V is a given constant.



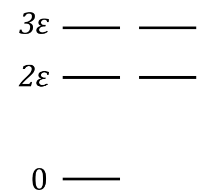
After the heat engine has run for some period of time, the temperature of the hotter reservoir gets reduced from T_1 to T_2.

(a) What is the change in the entropy ΔS of the hotter reservoir during this period?

(b) How much work did the engine do during this period?

(c) What is the total change in the entropy of the system during this period?

2. An impurity atom in a solid has 3 electrons (spin 1/2 fermions) above a filled, inert electronic shell. These electrons have 5 single-particle "spatial" states available to them: 1 has energy 0, 2 have energy 2ε, and 2 have energy 3ε. Assume that there is no interaction between the electrons.



(a) How many 3-particle states are available to the atom? Be sure to take into account for the 2 spin states of each electron.

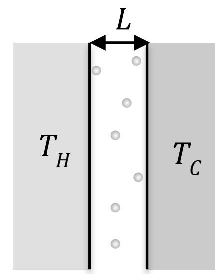
(b) Write down the terms in the partition function $Z(T)$ arising from the states corresponding to the *two* lowest 3-particle energies.

(c) What is the entropy at $T = 0$?

(d) What value does the entropy approach asymptotically at very high T?

(e) What is the asymptotic value for the heat capacity at very high T?

3. Consider the wall of a vacuum flask (i.e. Thermos) that is keeping a hot drink hot. The drink has temperature T_H and the outside temperature is T_C. Assume that both inside faces of the double wall absorb all incident light (i.e. they are black). The space between these two faces sides has thickness L. It is filled with an ideal monatomic gas that has pressure p, of which each atom has mass m. Assume that $\Delta T << \bar{T}$, where $\Delta T = T_H - T_C$ and $\bar{T} = (T_H+T_C)/2$.



(a) Compute the net rate of energy transfer from the hot side to the cold side, per m^2 of wall area, carried by electromagnetic radiation. Assume the gas atoms don't interact with the radiation.

(b) Estimate the net rate of energy transfer (per m^2 of wall area) that is transferred by the gas atoms. Assume that gas atoms thermally equilibrate with the glass at each collision and do not collide with other gas atoms (because of the low pressure). Do not try for an exact solution, but derive an approximate rate instead.

4. The surface of the sun is a partially ionized plasma, in which most electrons are separated from their positively charged nuclei. The electron density is $n = 2\text{x}10^{19}\ \text{m}^{-3}$. The temperature is 5778 K.

Useful constants: $h = 6.63\times10^{-34}$ J s, $m_e = 9.11\times10^{-31}$ kg, $k = 1.38\times10^{-23}$ J/K.

(a) Using a calculation, determine whether Fermi-Dirac statistics are necessary for describing the electrons, or whether Maxwell-Boltzmann statistics are adequate.

(b) Compute *either* the root-mean square electron velocity or the electron Fermi velocity, whichever is more meaningful for this situation.