Physics 410 -- Spring 2001

Homework #11, due Wednesday April 25

The Last One!

1. [4] Kittel & Kroemer, Chapter 14, problem 1. Appendix A in our textbook contains some relevant Gaussian integrals.

2. [2] (from Reif, Chapter 12, problem 5)
The total scattering cross section for an electron-air molecule collision is about 10^{-15} cm^2. At what gas pressure will 90 percent of the electrons emitted from a cathode reach an anode 20 cm away? (Assume that any electron scattered out of the beam does not reach the anode; i.e. neglect multiple scattering.)

3. [3] A monatomic ideal gas of N atoms at initial temperature τ_1 expands from an initial volume V_1 to a final volume $V_2=3V_1$ in one of the three ways described at the end of Chapter 6. Copy the table below onto your homework paper and fill in the cells, but DO NOT COPY the answers from Table 6.3 in the book. Instead, justify your answers in parts (a), (b) and (c) below. All of your answers should be expressed in terms of N, τ_1, and V_1. W is the work done by the gas, following our usual convention (not the book's).

Type of expansion	τ_2	p_2	$\Delta U=U_2-U_1$	$\Delta\sigma=\sigma_2-\sigma_1$	W	Q
Isothermal						
Isentropic						
Sudden						

a) For the isothermal expansion, show how you got your answers in the table.

b) For the isentropic expansion, show how you got your answers in the table.

c) For the sudden expansion, show how you got your answers in the table.

DO ANY 2 OF THE REMAINING 4 PROBLEMS:

4. [3] From MSU Graduate Qualifying Exam, Jan. 12, 1998:
10 g of water at a temperature of 10°C are mixed with 30 g of water at a temperature of 90°C. (Useful information: The specific heat capacity of water is 4.19 J/(g·K).)

a) What is the final temperature of the system, consisting of 40 g of water, after thermal equilibrium is established?
b) What is the change in total entropy of the combined system, consisting of 40 g of water, caused by mixing the two volumes of water together?

5. [3] From MSU Graduate Qualifying Exam, Jan. 7, 1999:
Consider a gas of noninteracting atoms in a magnetic field $B\hat{e}_z$ in the z-direction. Each atom has total spin ½. Each atom has a permanent dipole moment, with magnitude m_0, in the direction of the spin; for spin up $\vec{m} = m_0\hat{e}_z$, and for spin down $\vec{m} = -m_0\hat{e}_z$. The magnetic energy of the atom is $-m_0B$ for spin up, and $+m_0B$ for spin down.

a) Determine the mean dipole moment of an atom as a function of the temperature T. (Recall that the probability for a system to be in a state with energy E is proportional to $e^{-E/kT}$.)
b) Sketch a graph of the mean dipole moment versus T.

6. [3] From MSU Graduate Qualifying Exam, Oct. 9, 1989:
Given an entropy

$$S = AV^{1/3}E^{1/2}$$

where A is a constant; V is the volume, and E is the internal energy, derive the relation among p, V, and T.

7. [3] From MSU Graduate Qualifying Exam, Jan. 12, 1998:
A particular ideal gas has entropy S which satisfies the equation

$$S = Nk_B \ln(VT^{5/2}) + \text{constant}$$

where N is the number of molecules, V is the volume, T is the temperature, and k_B is Boltzmann's constant. The gas starts from an initial volume V_1 and temperature T_1, and expands adiabatically to a final volume V_2.

a) What is the change in entropy of the gas?
b) What is the change in the temperature of the gas?
c) What is the change in the pressure of the gas?
d) (The following question was not on the Qualifier, and is rather difficult.) What is wrong with the definition of S given above? Or, what term must be included in the so-called "constant" in S so that S behaves correctly as an extensive variable?