CARE PHYS 213 Midterm Worksheet

Please note, worksheets are a guide to practice and are not a guarantee of what will be on your exam!

Counting:
Suppose we placed 3 quanta in 5 quantum harmonic oscillators, what is the entropy of the system?
   a) $7.78 \times 10^{-23}$ J/K
   b) $2.69 \times 10^{-23}$ J/K
   c) $4.91 \times 10^{-23}$ J/K
   d) $6.42 \times 10^{-23}$ J/K
   e) $7.72 \times 10^{-24}$ J/K

Ideal Gas:
The next two questions pertain to the situation described below.

Suppose that we have a balloon at atmospheric pressure ($1.01 \times 10^5$ Pa), initial volume $4 \, \text{m}^3$, and temperature $300 \, \text{K}$. It is filled with diatomic ideal gas.

How many atoms of He are in the balloon?
   a) $6.02 \times 10^{23}$
   b) $9.76 \times 10^{25}$
   c) $2.93 \times 10^{28}$

Suppose we now compress the balloon to $2.5 \, \text{m}^3$ while keeping the temperature constant. How much pressure (including the pressure exerted by the atmosphere) must we apply to keep it at that smaller volume?
   a) $1.47 \times 10^5$ Pa
   b) $1.01 \times 10^6$ Pa
   c) $1.13 \times 10^5$ Pa
   d) $1.01 \times 10^5$ Pa
   e) $1.62 \times 10^5$ Pa
Equipartition:
Suppose that I begin with a container containing 2 mol of helium gas, which can be approximated as a monatomic ideal gas. The environment is kept at 1 atm pressure and 300 Kelvin, and the container maintains a constant volume.

Now we insert a 5-W heater into the container and keep heating for 5 minutes if all the energy goes into heating the helium, how much will the temperature of the helium change?
   a) 0.6 K
   b) 1.0 K
   c) 15.7 K
   d) 36.1 K
   e) 60.2 K

Now suppose that we repeat the experiment, this time replacing the 2 mol of helium with 2 mol of nitrogen gas. Assume that the nitrogen is an ideal diatomic gas, how will the temperature change here compare to that in the previous question?

The change in temperature with nitrogen is:
   a) Less than with helium
   b) The same as with helium
   c) Greater than with helium

Heat Capacity:
A 10kg block of aluminum initially at 90°C is placed in contact with a 12kg block of copper initially at 10°C. The molar heat capacities of aluminum and copper are 24.2 J/(K-mol) and 24.5 J/(K-mol), respectively.

When the two blocks come into thermal equilibrium, what temperature will they reach?
   a) 75.4 K
   b) 62.9 K
   c) 49.8 K
   d) 33.5 K
   e) 24.5 K

How does the entropy of the aluminum change during this process?
   a) 0
   b) $+3.21 \times 10^3$ J/K
   c) $-3.21 \times 10^3$ J/K
   d) $+8.45 \times 10^3$ J/K
   e) $-8.45 \times 10^3$ J/K
Boltzmann:
The next three questions pertain to the situation described below.

Suppose we have a proton placed in a magnetic field $B = 3$ Tesla. Like electrons, protons have two possible states of their magnetic moments, either aligned or anti-aligned with the magnetic field, and we can model it as a two-state system. The energy of a proton with its magnetic moment aligned with the magnetic field is $E_{\text{align}} = -\mu_P B$ where $\mu_P = 1.4 \times 10^{-26}$ J/Tesla is the magnetic moment of the proton. The energy of the anti-aligned state is $E_{\text{anti}} = +\mu_P B$. The proton is in contact with a thermal reservoir at temperature $T = 0.4$K.

At this temperature what is the probability that the proton has its magnetic moment anti-aligned with the magnetic field, i.e., is in the state with higher energy?

a) 0  
b) 0.5  
c) 0.538  
d) 0.462  
e) 0.481

At this temperature the entropy $S$ of the system is

a) Less than $k \ln(2)$  
b) Greater than $k \ln(2)$  
c) Equal to $k \ln(2)$

If we increase the magnetic field to $B=15$ Tesla does the entropy of the proton system at this temperature

a) Increase  
b) Stay the same  
c) Decrease