PHYS 430 SUPPLEMENTARY EXAMINATION FOR GRADUATION
September 5, 2007

Name and Surname:
Student ID:
Department:
Signature:

INSTRUCTIONS

Write all your steps with explanations of why you do those steps. The questions might contain extra information or too few information. If the question does not contain sufficient information, make the necessary assumptions, stating why those assumptions are necessary.

1. Consider a gas of point like non-interacting particles confined to move on a surface of area A. Assume that the energy of each one of the particles depends on the momentum as: $\epsilon = cp^n$, where c is some constant and p is the magnitude of the momenta. Moreover, assume that the relative separation between the particles is sufficiently large so that you do not need to make a distinction between fermions and bosons. If the system has temperature T, calculate the free energy, F, the entropy S, and the chemical potential μ of the system.

2. Consider a heat engine that has the PV diagram shown in Fig. 1. Calculate the efficiency of the heat engine, if the heat capacities at constant pressure and volume of the working medium is given as $C_V = 3N$ and $C_P = 4N$

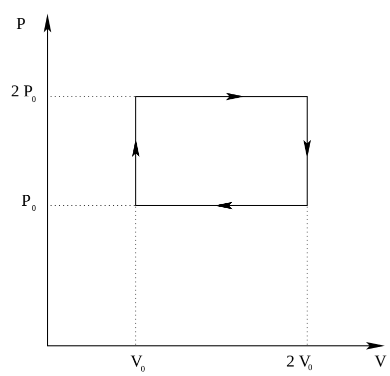

Figure 1: Figure for Q2

3. What are the three laws of thermodynamics?

4. Consider two particles which can be only in 3 states, two of which has energy ϵ_1 and the other has energy ϵ_2. If the system is at temperature T, write the partition function of the system if the particles are:

   (a) Distinguishable particles

   (b) Identical particles satisfying the Boltzmann distribution

   (c) Identical particles which are fermions

   (d) Identical particles which are bosons.

5. Consider a quantum harmonic oscillator that has a frequency ω (the energy levels are given by $\epsilon_n = \hbar\omega(n + \frac{1}{2})$). If the oscillator is at temperature T, calculate its average energy. According to the equipartition theorem of energy, what should have been its energy?

You can use the following formulas/definitions without deriving them:

$$
\begin{aligned}
dE &= TdS - PdV + \mu dN \\
dF &= -SdT - PdV + \mu dN \\
dW &= TdS + VdP + \mu dN \\
d\Phi &= -SdT + VdP + \mu dN \\
d\Omega &= -SdT - PdV - Nd\mu \\
F &= E - ST \ ; \quad W = E + PV \ ; \quad \Phi = E - ST + PV \ ; \quad \Omega = F - \mu N \\
S &= \ln \Delta\Gamma(E) \ ; \quad \Delta\Gamma(E) = \Delta E \frac{\partial}{\partial E}\Gamma(E) \\
\ln N! &\simeq N \ln N - N \\
\int_0^\infty dx x^n e^{-x} &= n! \\
\int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dy &= \int_0^{2\pi} d\phi \int_0^\infty d\rho \rho, \qquad \rho^2 = x^2 + y^2, \qquad \tan\phi = \frac{x}{y} \\
\beta &= \frac{1}{T}, \qquad k = 1
\end{aligned}
$$

For anything else, you need to derive it.