Statistical and Thermal Physics Exam 1 63 pts will be graded out of 60 pts: Test

Due:

1 Venus' atmosphere 6 pts

The atmosphere of Titan consists nearly entirely of molecular nitrogen (mass of 1 mol = 0.028 kg. The surface pressure is about $147 \times 10^3 Pa$ and the surface temperature is about 94 K.

a) Determine the density of Titans atmosphere at its surface.

2 Compression of an ideal gas 9 pts

A monoatomic ideal gas undergoes a compression taking its initial pressure from 1 atmosphere to 2 atmospheres. Its initial volume is $1m^3$ and its initial temperature is 300K.

a) Determine the new temperature and volume assuming the process is isothermal.

b) Determine the new temperature and volume assuming the process is adiabatic.

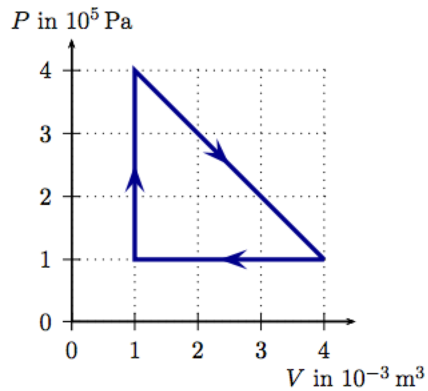
3 Entropy and the arrow of time 10 pts

Using the fundamental thermodynamic relationship $dE = TdS - PdV + \mu dN$.

a) Write down what T, P, and μ are in terms of partial derivatives with respect to entropy, make sure to write down what is being held constant and what is not.

b) Now, imagine a system with two subsystems that are in contact via a barrier that does not allow a transfer of particles or a change in volume but does allow thermal transfer. Show, using the second law of thermodynamics and arguments using partial derivatives of entropy that relate to temperature that if $T_A > T_B$ heat will flow from A to B.

4 A heat engine operates by having a monoatomic ideal gas undergo the process indicated on the P V diagram. 18 pts



a) Determine the work done BY the engine in one cycle. Hint, 1 block = 100 Joules.

b) Determine the efficiency of the engine. Remember, you are only interested in heat ADDED. The efficiency is the work done BY the gas divided by the heat added to the gas.

5 Enthalpy and thermodynamic variables 6 pts

a) Express $\mathrm{d}H$ in terms of $\mathrm{d}P, \mathrm{d}S$ and $\mathrm{d}N$ and use the result to express T, V, μ in terms of relevant derivatives of H (remember to indicate variables in the parenthesis subscript).

b) Show that

$$\left(\frac{\partial T}{\partial P}\right)_{S,N} = \left(\frac{\partial V}{\partial S}\right)_{P,N}$$

for any system.

6 Ideal gas and Van der Waals gas 4 pts

a) What happens to the change in energy for an ideal gas undergoing free expansion, why?

b) What happens to the change in energy for a Van der Waals gas undergoing free expansion, why?

7 Quasi-static vs non-quasistatic processes 3 pts

a) What is the difference in the two processes? For which can the work be integrated?

8 Entropy and heat baths 8 pts

a) 1 kilogram of water at $T_A = 0C^\circ$ is brought into contact with a heat bath at $T_B = 50C^\circ$. What is the change in entropy of the water, the heat bath, and the system? C_V water is 4186 J/K.

Physical constants
$R = 8.31 J/molK$
$NA = 6.02 \times 10^{23} mol^{-1}$
$k = 1.38 \times 10^{-23} J/K$
$atm = 1.01 \times 10^{5} Pa$