Physics 360
Review 1

Note that calculators will not be permitted in this exam.

This test will consist of three parts:

I. Qualitative Questions

(4 problems, 10 points each)

Understand the following basic ideas. Be sure to be able to describe them in terms of concepts as well as in terms of equations. For some For example, if you were to define enthalpy, only half credit would be given for saying enthalpy is internal energy plus pressure times volume. You should also say that it is the energy required to create a system out of nothing and do the work necessary to push the atmosphere out of the way.

You should understand the following ideas in addition to equations, and be able to describe the meaning of them.

Heat - spontaneous flow of energy caused by temperature differences
Work - other transfer of energy in or out of a system
Compression work - mechanical work done to a gas (positive) in changing its volume
First Law of Thermodynamics = conservation of energy
Heat capacity - the heat flowing in to raise temperature one degree
Specific heat - Heat capacity per unit mass
Latent heat - the amount of heat necessary to (melt, boil) a unit of mass.
Degree of freedom - independent ways in which potential or kinetic energy can be shared
State variable - uniquely specified on PV diagram with N given.
Enthalpy - the energy it takes to make something out of nothing and put it in its environment
Thermal conductivity - The amount of heat that flows per unit time per unit area per unit temperature gradient
R-value - the ration of thickness to thermal conductivity
Mean free path - the average distance between collision (of a molecule in gas, for example)
Microstate - A state of a system that is specified by the values of every possible observable quantity (of interest).
Macrostate - A state that is specified by some value of a measurable quantity.
Multiplicity - the number of microstates in a macrostate.
Fundamental assumption of statistical mechanics - All microstates are equally probable

II. Basic Problems

(4 problems, 10 points each) – Except I inadvertently have two questions labeled 4 – so there are 5 problems in this section.

• Use the ideal gas law in many applications.
• Find $Q, W, \Delta U, \Delta T, \Delta H$ for constant pressure, constant volume, isothermal, and adiabatic processes.
• Be able to do calorimetery problems.
• Know that $C_V = Nkf/2$, $C_p Nk(f+2)/2$.
• Know that $\Delta U = C_V \Delta T$ always (not just for constant volume processes).
• Know that pV^γ = constant for adiabatic processes and that $\gamma = (f+2)/f = C_p/C_V$
• Know that $H = U + PV$ and be able to calculate ΔH for ideal gasses or from tables (as in the homework).
• Be able to calculate *R*-values for a wall.
• Derive the formula for the mean free path of a gas molecule.
• You do not need to know anything about viscosity or diffusion for the test.
• Be able to describe microstates, macrostates, multiplicities and probabilities for coin tossing, dice, two-state paramagnets, and Einstein solids. Know that there are three oscillators per atom in an Einstein solid.
• Know how to calculate the different number of ways the result 1123345556 can result from the toss of 10 dice.
• Recognize that macrostates can be defined in different ways for a given system. (*eg.* The number of atoms aligned with B, the total energy of the system, etc.)
• Be able to calculate the joint probability of two Einstein oscillators in a macrostate specifying the number of energy units in each oscillator.
• Be able to derive formula (2.9) based on the drawing just below the formula.

III. Synthesis Problems

(2 problems, 10 points each)

These are problems that test your ability to apply familiar concepts in slightly unfamiliar applications. Some possible problems would be:

• Calculate quantities from a PV diagram where the ideal gas law is replaced by another law (such as the van der Waals Equation of State) that I would provide.
• Calculate probabilities involving a deck of cards.
• Calculate probabilities involving an unfair coin.
• Calculate problems for a physical system other than a two-sate paramagnet or an Einstein solid. – I would give you details of the system's structure.

Sample Test

I. Qualitative Questions

1. How many degrees of freedom does an atom in a crystal lattice possess? Describe these degrees of freedom.

2. Write the First Law of Thermodynamics. State in words what it means. What are the sign conventions for heat and work; that is, when is heat positive and when is work positive?

3. What is the difference between heat capacity, specific heat, and latent heat?

4. Two Einstein solids weakly interact. Each solid has *N* oscillators and the there is a total of *q* units of energy shared between them. What are the macrostates and microstates we usually use to describe such a system.

Section II. Basic Problems.

5. *N* atoms of a monatomic ideal gas go from an initial pressure and volume P_A, V_A to a final volume V_B. Your answers may involve only these variables along with Boltzmann's constant, *k.*
(A) Assume the process is isothermal. Find an expression for the *Q*.
(B) Assume the process is adiabatic. Find *W*. (Use the book's sign convention for work.)

6. In rolling two dice, what is the fractional probability of the sum of the dice being less than 7?

7. An Einstein solid has *N* oscillators and *q* total units of energy. Prove that the multiplicity of this state is given by

$$\Omega = C\binom{q + N - 1}{q}$$

8. Energy can be transferred between two two-state paramagnets. The first paramagnet has twelve atoms and the second has eight atoms aligned. The first initially has four atoms aligned with the magnetic field and the second initially has three aligned. After a long time the energy between the two oscillators is randomly distributed. What is the fractional probability that the first has four atoms aligned with the field and the second has three aligned?

III. Synthesis Problems

9. We define a (totally useless) thermodynamic quantity by the relation $X = Q + \alpha VT$ where α is a constant. Find the change in enthalpy for *N* moles of a monatomic ideal gas undergoing a constant pressure process from P_A, V_A to V_B. You may express your answer in terms of the quantities given and Boltzmann's constant, *k*.

10. A coin has a 60% of coming up heads and a 40% chance of coming up tails. What is the probability of tossing 5 heads in 20 tosses?