<u>3.020 – Thermodynamics of Materials Recitation 1</u>

<u>Problem 1</u>

As was introduced in the class, in thermodynamics, we study how a balance between the entropy and energy gained/lost by a <u>system</u>, as it undergoes a certain <u>process</u>, helps us predict what eventually happens to that system. The generality of thermodynamics lies in the fact that we can work with *any system* and *any process* that you can imagine. However, even for a particular situation, choice of the system is not unique. Therefore, before we rigorously define terms like *energy* and *entropy*, we will learn how to choose our thermodynamic system for the problem at hand, because this choice, if made judiciously, has the power to simplify the problem tremendously. To start off, I'll provide you with a simple example problem and show you how to choose the system for that particular problem. As we allow for some variability and extend it further, hopefully you'll get an idea of how to approach such problems. We'll seek to answer the following questions for all the problems:

- What system should we choose?
- Is the system unary (U) or multicomponent (M)? What are the boundaries of this system? Characterize the boundaries of this system as: open(O)/closed(C), rigid(R)/non-rigid(NR), adiabatic(A)/diathermal(D)?
- What are the phases present in this system?

1. I have a sealed plastic bottle full of water that is initially kept at room temperature. I then take it and keep it inside the refrigerator. After some time, I want to know the new temperature attained by the contents inside the bottle.

2. Now let's say I have some hot water and some ice cubes inside a thermos flask, which is then placed inside the refrigerator. We want to analyze the final temperature attained by the water.

3. Let's now do a final problem under this category. This should demonstrate the idea that there could be multiple ways of choosing the thermodynamic system. We have a block of copper acted upon by a force *F* so that it slides at uniform velocity over another piece of copper, which itself is kept on a wooden desk. We want to know the new temperature of the block sitting at the top.

Problem 2

Now that we have some idea on choosing thermodynamic systems for our problems, the next step would be to answer the question of what happens to that system when it undergoes the outlined process. The question of 'what happens' is answered by knowing the values of only a few, important properties/variables of the system in its initial and final state. Depending on the system, you may have an equation that tells you how these properties change for the given process. In this example, we will practice working with such equations and using these, try to answer this question of 'what happens'.

1. Consider nitrogen gas kept inside an industrial vessel at an initial pressure of 90 atm and an initial temperature of 300 K. The gas is subsequently heated to a temperature of 500 K. What is the new pressure exerted by the gas?

2. a) We have nitrogen gas kept at a pressure of 1 Pa such that it occupies a volume of 0.05 m^3 at a temperature of 298 K. We now increase the pressure and maintain it at its new value of 10^{-3} atm, keeping the temperature constant. What is the new volume acquired by the gas?

   b) We have nitrogen gas kept at a pressure of 1 Pa such that it occupies a volume of 0.05 m^3 at a temperature of 298 K. We now increase the pressure inside the vessel to a value of 10^{-3} atm keeping the volume fixed. The gas attains an intermediate temperature, *T*. Now, we compress the gas, keeping the pressure constant, such that the temperature gets back to its initial value of 298 K. What final volume should we aim for?

   c) Compare the final values in both (a) and (b).

Problem 3

The equations used in problem 2 (ideal gas), may not always be this simple though. Consider the following general equation:

$$V = f(T; P)$$

1. Use this equation to derive a general expression that relates the infinitesimal change in volume *(dV)* with an infinitesimal change in temperature *(dT)* and pressure (*dP*).

2. Consider a process that occurs under a constant temperature. Derive an expression that relates the infinitesimal change in volume with the infinitesimal change in pressure. Make use of the thermal expansion and/or compressibility coefficients.

3. Assume now β is constant over the initial and the final states. Relate the final and initial pressure values to their final and initial volume values.

4. Consider again an ideal gas. Use the equation derived in (2) to relate the final and initial pressure with the final and initial volume. Compare this relation with the relation used for the isothermal process in Problem 2 2a.