Physics 114 Statistical Mechanics Spring 2021
Week 1 Reading and Problem Assignment

Overview:

Things fall. -Isaac Newton
Things fall apart. -William Butler Yeats; Chinua Achebe

We will revisit what you know of thermodynamics this week ... reminding ourselves of the 0th law (thermometers work) and 1st law (increase in energy of a system = work on it + heat into it), and allude to the 2nd law (things fall apart). Thermo is an extremely important field which brought about the industrialization of society and revolutionized transportation, power generation, chemical engineering ... It is a wholly self-consistent set of ideas and equations based on experimental definitions and multivariable calculus. Weirdly, thermo is largely immune to microscopic details of the gasses, liquids, solids and plasmas that it describes.

Why is thermodynamics valid? The answer lies in *statistical mechanics* which treats large systems comprised of small objects. Stat mech rests on some ridiculously simple postulates about these systems, like ergodicity and equal a priori probabilities. "From micro to macro" is the first theme in one of our texts, Gould and Tobochnik (G&T). The implication is that there are many microscopic details that we *do not need to know*, to calculate the macroscopic properties correctly. (Details that we *do* need include whether the objects obey classical or quantum mechanics, whether they are relativistic or not, and if there are constraints on what they can do ... like from walls, insulation, etc.) Thanks to the laws of probability, *stat mech provides the definitions and supports the equations that comprise thermodynamics.* Moreover, non-equilibrium stat mech takes us beyond thermo, to systems whose macroscopic properties evolve in time. Stat mech even applies to non-physics systems like biological and economic ones where the "laws of motion" are not Newtonian or the Schrodinger Equation, but particular to those disciplines. *Stat mech rocks!*

Suggested Reading:

G&T

- chapter 1
- from chapter 2, sections 2.1 - 2.11

B&B [1]

- from chapter 1, sections 1.1-1.3
- chapter 2
- chapter 11
- chapter 12

Warmup Problems: *Due two days before we meet.*

1. **PV = NkT on Earth and Mars** G&T Problem 2.49
2. **modeling a bicycle pump** G&T Problem 2.9

Problems to discuss in our meeting:

Note 1: Please refer to the document "Doing seminar problems". For problems that involve actual calculations (so not Problem 1, but most of the others) try to write up Steps 1 - 3, which means being able to take leadership in a discussion about how you set them up to be solved. For as many as you have time for, go further by writing up answers and assessing them, Steps 4, 5.

Note 2: The * means that these problems are to be **handed in**
They are due the day after we meet.

1: reversible or not? G&T Problem 2.6

2: work G&T Problem 2.8

3*: adiabatic and isothermal compression G&T Problem 2.17

[1] There's ample redundancy between the two books. It's a blessing and a curse :-) Some repetitious material is not assigned, though I know it exists. For example, B&B Sections 4.1 and 4.2 are about the 0^{th} law and thermometers. (We'll circle back to them in a later week.) I never want you feel you *must* reread something which you understand. I will try to offer guidance on our weekly Moodle page about the overlap, and my advice on navigating it.

4: transfer of heat between two bodies If you place a 2L bottle of a mystery liquid at $T = 23.00^o C$ into a bathtub filled with 200L of ice-cold water at $T = 0.00^o C$, and the liquid comes to a final temperature of $T = 0.01^o C$, what is the specific heat of the mystery liquid?

5: isothermal expansion B&B Problem 11.1

6*: using partial derivatives in thermo B&B Problem 12.2

7: a puzzle about taking partial derivatives B&B Problem 11.4

8: work, heat and thermal energy for different thermodynamic processes G&T Problem 2.56

9*: free expansion *(A part of G&T Problem 2.24, which we might revisit.)* An ideal gas of N particles in a box of volume V_2 is initially confined to only part of the box, with volume $V_1 < V_2$. The remaining volume of the box is empty - a vacuum. The gas has initial temperature T. The gas is then allowed to expand freely to fill the entire volume V_2. The box is thermally insulated from the outside world. What is the change in energy of the gas? What is the change in temperature of the gas?

10: approach to equilibrium G&T Problem 1.2 (a)-(e) and Problem 1.10
If the `VideoCapture` feature of these applications doesn't work for you (It doesn't for me.) you can make a video some other way. E.g. Quicktime player or CTRL Shift 5 does it on a Mac.