# EK424 – Thermodynamics and Statistical Mechanics

**Fall 2022**
**Lecture:** Tues/Thurs, 9 am – 10:45 am, PSY B33 (66 Cummington mall)
**Recitation:** Friday **11:15** (Dev) or **1:25** (Jiayi)

| Instructor | Email | Office Location & Hours |
|---|---|---|
| Dr. Joshua Kays | jkays@bu.edu | ERB, Rm 341<br>Tues 11am-12pm, or by appointment (if scheduled in advance) |
| **TAs:** | | |
| Dev Mehrotra | By slack | Weds 10-11am, location tbd |
| Jiayi Li | By slack | Wed 4-5 pm, SLB Room 207. |

## Course description

Thermodynamics is the study energy exchange in processes at equilibrium. More deeply, thermodynamics fundamentally explains *why* many everyday phenomena occur, such as why fog covers a lake, why you get warmer when you work out (and why your body sweats to cool you!), and why oil and water don't mix.

This class emphasizes a statistical mechanical approach (thermodynamics on the microscopy scale) to explain macroscopic properties (temperature, pressure, chemical potential). Thermodynamics integrates physics, chemistry, probability, and differential equations to enable the learner to understand the driving forces behind our universe.

## Prerequisites

ENG EK 381 (probability); CAS MA 226 (diff eq); CH 102 (chemistry); CAS PY 212 (physics). I would add that these are roughly in order of necessity, with the first half of the class requiring more probability and differential equations, and the second half leaning heavily upon chemistry and chemical potential

## Grading

Course grading will be based on the following:

- Homework (8 assignments, 1 free-drop) 25%
- Participation/in-class "assessment" 20%
- Midterm 20%
- Final 35%

## Class expectations and participation

- Respect the TA(s) – they are here to help you learn, not to give you free answers on your HW
- This class is going to be hard, intellectually. However, I have *no desire* for this to be "stupid hard" – that means *I will not* make you memorize lots of stuff, nor give you problems that use hard math tricks (why get good at that, when Wolfram Alpha exists?). You should expect, though, that lectures and HWs will have hard problems that require you to **concentrate and think deeply.** See next point for the best way of handling that
- This is meant to be an interactive class – there will be in-person demonstrations, questions asked throughout the lecture, and so forth. Attendance is part of your participation grade, as is your involvement in class. You will do best if you **attend and be an active learner** during the class.

- However, this doesn't mean you have to talk constantly/be an extrovert to do well in this. A significant bulk of the participation grade will be attendance and responding to digital questions (where 3/4$^{th}$ of the points is attendance), and other ways of engaging are taken into consideration. The key here is demonstrating your learning and your engagement with the content.

## Homework

Students must submit their own work for homework assignments. You may work with others, but you list anyone you worked with on the top of the HW, *and must demonstrate your own work*. HW turned in 1 day late will be received a 20% deduction: later than 1 day will not be accepted unless in the case of emergencies (death in the family, medical emergency).

## Tests

One midterm and one final, final is cumulative. **Any suspected violation of the Academic Conduct Code will be immediately referred to the College of Engineering Academic Conduct Committee.** Don't hurt yourself by cheating.

## Topics

**Introduction**

- Intro and thermodynamic systems
- Review probability and multiplicity
- Work+heat

**First and second laws, Boltzmann eq + distribution**

- First law
- Kinetic theory of gases
- Degrees of freedom in a system, equipartition of energy
- Entropy, the second law, and Boltzmann distribution (first look)
- Fundamental thermodynamic relation
    - Understanding what drives chemical, thermal, and mechanical equilibrium
- State variables and thermodynamic cycles
- Free energies
- Maxwell relations
- Boltzmann distribution and partition coefficient
    - What is temperature? Understanding population inversion

First half of HWs + Midterm

**Chemical equilibrium, phase transitions, and phase separation**

- Rest of chapters 11-12 if needed (stat mech)
- Chemical equilibria from atomic structure
- Phase equilibrium – solid, liq, gas
    - Why liquids boil; what is vapor pressure; how refrigerators work(!)
- Mixtures and boiling point depression
- Phase separation
- Cooperativity* and Chem. kinetics* (possibly)

2$^{nd}$ half of HWs + Final

## Textbook

There are no required textbook for this class, though I am using *Molecular Driving Forces* by Dill+Bromberg as the main organizing text of the class. Specifically, we are covering chapters 3,6-16,and 25, with 26 and 19 also possible if time permits. I will supplement when necessary.