Class Meeting: **M** & **W** 3-5pm
Class Location: Heg 201
Office Hours: **W** 1:45-2:45pm & **F** 4-5pm

Email: haggard@bard.edu
Office: Rose 112
Office Phone: (845) 758-7302

**Course Description** — Thermal physics is a thrilling intersection of physical and mathematical ideas with real world applications. These applications span biology, chemistry, geology, meteorology, environmental science, engineering, low-temperature and solid state physics, astrophysics, cosmology, and quantum gravity. Whatever path you choose in life, understanding thermal physics will enrich the experiences of every day. Better yet, non-equilibrium thermal physics is so full of mysteries that many seekers of Nature will spend their lives exploring this rich landscape.

Thermal physics deals with large collections of particles—typically $10^{23}$ or so. Examples include the air in a balloon, the water in a lake, the electrons in a chunk of metal, and the photons (electromagnetic wave packets) given off by the sun. Anything big enough to see with our eyes' (or even a microscope) has enough particles in it to qualify as a subject of thermal physics. We can't possibly follow every detail of the motions of all these particles. So instead, in thermal physics, we assume that the particles jostle about randomly, and we use the laws of probability to predict how, for example, a chunk of metal as a whole ought to behave. Alternatively, we can measure the bulk properties of the metal (stiffness, conductivity, heat capacity, magnetization, and so on), and from these infer something about the particles of which it is made.

Some properties of bulk matter do not depend on the microscopic details of atomic physics. Heat always flows spontaneously from an hot object to a cold one, never the other way. Liquids boil more readily at lower pressure. The maximum possible efficiency of an engine, working over a given temperature range, is the same whether the engine uses steam or air or anything else. These kinds of results, and the principles that generalize them, comprise thermodynamics.

To understand matter in more detail, we must also take into account both the quantum behavior of atoms and the laws of statistics that make the connection between one atom and $10^{23}$ atoms. Then we can not only predict the properties of metals and other materials, but also explain why the principles of thermodynamics are what they are—why heat flows from hot to cold, for example. This underlying explanation of thermodynamics, and the many applications that come along with it, comprise statistical mechanics.

Our course will strive to demonstrate the unity of these perspectives.

**Text**: *Fundamentals of Statistical and Thermal Physics*, by D. Reif (Waveland Press, 2009)
Also recommended: *Thermal Physics*, by D. V. Schroeder (Addison-Wesley, 2000)

**Grading Structure**:

| | |
|---|---|
| Weekly Homework (due on Wednesdays) | 60% |
| Take home 1 | 20% |
| Take home 2 | 20% |

**Take homes** — Twice during the semester I will give you take home exams. These will be 4 hour, open book, self-timed exams. You can study as much as you like using any resource up to opening the exam. However, once you have opened the exam I ask that you only refer to your class notes and our primary text. I ask that you honor your peers and the effort that we all put into the class by not going over time or referencing any outside materials.

| Week | Topics | Chap. |
|---|---|---|
| 9/1 | Prediction: statistics as elaborated counting | 1 |
| 9/8 | Statistics & particle mechanics | 2 |
| 9/15 | Thermodynamics: general laws arising from statistical reasoning | 3 |
| 9/22 | Human scale quantities & their measurement | 4 |
| 9/29 | Applications of Thermodynamics | 5 |
| 10/6 | Applications of Thermodynamics cont. | 5 |
| 10/13 | Intro to Statistical Mechanics. **1st take home due 10/15, 6pm** | 6 |
| 10/20 | Intro to Stat. Mech. cont. Applications of Statistical Mechanics. | MT & 6 |
| 10/27 | Applications of Statistical Mechanics cont. | 6 & 7 |
| 11/3 | Equilibrium between phases | 7 |
| 11/10 | Equilib. between phases. Quantum statistics. | 8 |
| 11/17 | Quantum statistics and indistinguishable particles | 9 |
| 11/24 | Quantum stat. and indist. part. cont. **Thanksgiving 11/27-30** | 9 |
| 12/1 | Systems of interacting particles | 10 |
| 12/8 | Irreversible processes & fluctuations | 15 |
| 12/15 | **Completion days. 2nd take home due 12/17, 5pm** | Focus on topics post 10/13 |

**Note**: I reserve the right to adjust this syllabus during the semester

**Homework** — There will be homework due every Friday, problems from the text and some of my own problems. The assignment should be given to me or put into the box outside my office (Rose 112) by 6 pm on Friday. Complete solutions will be posted. I will grade a portion of the problems on a 0-5 scale. These scores mean roughly the following: 5=clear and complete solution, 4=good solution missing one conceptual point or calculation, 3=clear attempt but with substantive flaw, 2=effort made but incomplete plan, 1=little effort, 0=nothing appearing. I care most about the effort you invest and you can receive credit on this basis. The goal of the homework is for us to engage each other in a discussion of physics regularly, please come and visit as often as you like to discuss. Along these lines, I recommend that you work together; this is invaluable in learning physics. Please write things up yourself to show me and you that you understand it (this helps battle the illusion of explanatory depth, which is worth looking up). I will always answer any questions in class, as well. Please do not use the internet as a resource for anything but physics books.

**Lateness and Other Anomalies** — Anything handed in more than a week late will not be accepted. If you tell me about something ahead of time, almost any situation can be accommodated.