Class Meeting: **MWF** 10:20-11:40pm
Class Location: Heg 106
Office Hours: **WTh** 5-6pm

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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. Thus, we can predict not only 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: *Thermal Physics*, by D. V. Schroeder (Addison-Wesley, 2000)
Recs.: *Fundamentals of Statistical and Thermal Physics*, by D. Reif (Waveland Press, 2009)
Thermodynamics and an Introduction to Thermostatistics, by H. B. Callen (Wiley & Sons, 1985)

Take homes — Twice during the semester I will give you take home exams. These will be roughly 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.

Grading Structure

Weekly Homework (due on TBD)	35%
Student lectures	13%
In-class Exam	12%
Take-home Exam	20%
Take-home Final	20%

Week	Topics	Chap.
8/31	Energy and Temperature in Thermal Physics	1
9/7	Temperature, Work, and Heat	1
9/14	Entropy in Thermodynamics, **In-class Exam**	2
9/21	The 2nd Law	2
9/28	Thermal Interaction & Kinetic Theory	3
10/5	Heat Engines	4
10/12	Thermodynamic Potentials & Transformations	5
10/19	Phase Transitions **1st take-home due 10/23, 6pm**	5
10/26	Boltzmann Statistics	6
11/2	Partition Functions & The Gibbs Factor	6&7
11/9	Boson & Fermion Distribution Functions	7
11/16	Degenerate Fermi Gas	7
11/23	Blackbody Radiation **Thanksgiving 11/26-29**	7
11/30	Debye Theory of Solids	7
12/7	Bose-Einstein Condensation (**12/9 Advising Day**)	Notes
12/14	**Completion days. 2nd take-home due 12/18, 5pm**	Focus on topics post 10/13

Note: I reserve the right to adjust this syllabus during the semester.
Course website: `faculty.bard.edu/hhaggard/teaching/phys314Fa20/`

Homework — There will be homework due every Wednesday night at 10pm. The goal of the homework is for us to engage each other in a discussion of physics regularly, please visit or arrange online meetings with me as often as you like to chat. 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, or knowledge illusion). Please do not use the internet as a resource for anything but definitions of terms; if ever you are in doubt about the appropriateness of a resource, just ask me.

Homework Feedback — In the spirit of promoting discussion, I would like to go through and score homework together in small group or individual meetings. I believe that most of you did this last semester (or in a previous semester) with Paul. Let's discuss this option together on the first day of class and finalize how we will proceed with it.

Simulating Thermal Systems — I would like to include computer simulations of thermal systems as a consistent part of the course. For these we would use the open source Python coding platform. I hope to get you up to the point where you can use the powerful Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS) code. I will not assume any background in coding, which means that we will have to do several things before we are simulating thermal systems: we will need to learn the basics of Python, go through several steps to learn how to numerically solve differential equations, learn how to setup the simulation of large numbers of particles, and then proceed to learn how to use LAMMPS. I believe you will find all of this invaluable, and it will require some patience on your part.

Student Lectures — I would like each of you to give a guest lecture once during the semester. It has always been my belief that teaching is one of the best ways to learn and if it weren't so much work for you, I would have you do every lecture. These guest lectures will be 25 minutes, with 5-10 minutes set aside for us to discuss afterwards. I will meet with you twice before you lecture, once briefly to discuss what material you will cover, and then again to do a mock run through of the lecture. In previous years students have really enjoyed this opportunity, I hope you will too!

I have read over this syllabus. I commit to stick to the parameters of the take home exam. I will strive to be my best self in this course, both in how I interact with everyone involved and with respect to my efforts.

Signed: Date: