33-341 Thermal Physics I, Fall 2018 Syllabus

Course

Lecture	MWF	1:30am – 2:20am	DH A301D
Recitation	T	12:30pm – 1:20pm	DH A200
Units	10		

Lecturer

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Facebook page

www.facebook.com/groups/2005332043035284

Textbook

Robert H. Swendsen, "An Introduction to Statistical Mechanics and Thermodynamics" Oxford University Press, 2012.

Other useful textbooks

Mehran Kardar, "Statistical Physics of Particles", Cambridge University Press, 2007.
Donald A. McQuarrie, "Statistical Mechanics", University Science Books, 2000.
Terrell L. Hill, "An Introduction to Statistical Thermodynamics", Dover, 1987.
Hermann Schulz, "Statistische Physik", Harry Deutsch GmbH, 2005

William Feller, "An Introduction to Probability and Statistics", Vol. I & II, Wiley, 1968
Jesse M. Kinder and Philip Nelson, "A student's guide to PYTHON for physical modeling", Princeton University Press, 2015.

Content of this course

Arena

Thermal Physics investigates the phenomenon of heat, and the beautiful physics that arises when contemplating it more deeply. It ultimately gives rise to Statistical Physics, the discipline in physics that strives to explain macroscopic phenomena in terms of underlying microscopic laws. The large-scale behavior of systems, which we characterize by means of a small number of variables, emerges after eliminating the many microscopic degrees of freedom of their fundamental constituents. These generally unobservable degrees of freedom are far too numerous to follow, but precisely for this reason they can be treated *statistically*, making use of the law of large numbers and the central limit theorem: averages of a large number of random variables tend to converge to well defined distribution functions, and their relative fluctuations become smaller than other experimental errors. For instance, the pressure of a gas, the electric conductivity of a wire, or the Young modulus of rubber result from a proper statistical treatment of gas molecules, electrons in a solid, and entangled polymer chains, respectively. For this reason, Statistical Physics is the microscopic foundation of Thermodynamics.

Topics

The key topics to be covered in every "Introduction to Thermal Physics" course only vary in small degrees. Central to all discussions is an understanding of some essential probability theory, statistical ensembles, the connection to thermodynamics, and various illuminating model systems (such as the ideal gas or the harmonic crystal). In this course, we will begin with the (classical) ideal gas, introduce the notion of entropy, then move on to an overview of thermodynamics, and return to visit statistical mechanical. The necessary probability theory will be filled in as we go.

I will follow approximately the first half of Swendsen's text sequentially, but will bring in extra material from other sources, for instance to illuminate or expand on some aspects in a different way.

In case of doubt, I will rather spend more time on the elementary but absolutely crucial basics, rather than rush through and strive to cover some beautiful but advanced material. I know that many students eager to study this (or in fact any) material yearn to go to the more advanced stuff—the fancy, the modern, the challenging. But alas, I have seen far too many times that if learners approach advanced material without truly owning the foundation, they are incapable of working creatively on the advanced level. Conversely, once you have really thoroughly understood the basics, the advanced topics will always come naturally and could even be read up on your own. But if you miss the basics, the door to all the beautiful stuff will invariably remain shut. Don't let that happen! Open this door by diligently studying the foundations of Thermal Physics.

Goals

After having taken this course, you should be able to do the following:

- Understand, how macroscopic behavior emerges from suitable averages over a huge number of microscopic degrees of freedom, and give examples illustrating this process.
- Master those concepts of probability theory that lie at the heart of our physical discussion, such as probabilities and probability densities, Bayes theorem, transformations, moments, correlation and dependence, characteristic functions, central limit theorem.
- Be familiar with the basics of Thermodynamics (laws, heat engines, Maxwell relations, deriving identities), and how it links to Statistical Physics.
- Ideally, know what the canonical partition function is, and how to calculate the free energy from it in some simple example cases.

Organization

Homework

Homework will be assigned and graded somewhere between a daily and a weekly basis. Late homework will *not* be accepted (unless it is the result of an officially excused absence). Some of the homework will require a bit coding, usually with Python. But don't worry, *you can learn this as we go along*. It is both easy and *incredibly* useful!

I will not hand out sample solution, but will *extensively* discuss the solution in class.

I expect that your solutions will be written up *carefully* and *legibly*. Recall that you are striving to receive a professional degree—a Bachelor in Physics—and that part of this degree means that *you are able to <u>professionally</u> communicate technical information*. This means that you don't just hand in scratch paper with scribbled down but disorganized pieces of a solution, and a final answer recognizable only by the fact that it's doubly underlined. Rather, a professional solution explains cogently, how to get the right answer from what's been given and from what you know. (Imagine having to present this to a supervisor in your future job, who you want to impress.)

Over the years I have spent *a lot* of time thinking about good homework problems. You should take them as opportunities to solidify your knowledge, apply it in new circumstances, and chart the limits of your own understanding (that you then need to work on!). If you rely too much on external help (e.g. Google or your friends) in solving your homework problems, you deprive yourself of a valuable opportunity to learn the material and identify what you struggle with. Same if you do the homework in the last minute. Since the exam problems will be quite similar to homework problems, I can *guarantee* from experience that such an approach *will* come and haunt you in the exams.

Exams

There will be two midterm exams and one final exam. The date of the midterms will be announced early in the course; they will take place during usual class hours. I will let you know about the date for the final as soon as it becomes available (this is decided by the registrar, not me). Don't make any travel plans before you know this date as you *have* to take it to pass the class.

Grading

The weighting of the homework, midterms, and final is as follows:

Homework: 30%
Midterms: 30%
Final: 40%

Working together

It is OK to work together on homework. However, when the time comes to write up the solutions, I expect you to do this on your own, and it would be best for your own understanding if you put aside your notes from the discussions with your classmates and write up your own solutions entirely from scratch. Remember that the problems in the exam will not be all that different from the homework problems, and if you are unable to reconstruct by yourself a solution you have figured out in a group effort, you will not be able to do this in an exam either. *Trust me, I have seen this before many times*. Homework isn't just a way to get points. It is your most direct feedback on whether you understand what I'm trying to teach. If you begin to struggle, work on it and talk to me.
Of course, working together on exams is *expressly forbidden*.

Attendance

I *strongly* believe it is in your best interest to *attend class on a regular basis*. If you decide to skip class, then don't count on catching up by meeting with me during office hour, since my time is valuable too, and I will not spend it on repeating a lecture that you decided to miss. If you could not attend for very good reasons, *this is different*; but in this case, please come prepared by (a) having read the pertinent chapter of the book and (b) obtained and studied the lecture notes from your classmates, so that we can directly focus on the part that might still be unclear.

Important: If you are not able to turn in a homework assignment or take an exam because of an unexcused absence, *you will not be able to turn the homework in late or take the exam*. This does *not* apply if extraordinary circumstances prevented you from showing up, but they indeed have to be severe. The list of *non*-extraordinary circumstances contains, but is not limited to: forgetting, too busy, visit of friends or family, missed bus, printer failure, anything for which you could have gotten an excused absence ahead of time.

What I expect from you

Thermal Physics is one of the core topics of Physics. In fact, it can be argued that Physics itself is the art of reducing a massively complicated real-world situation to a manageable model in which many or most of the details are ignored, and the statistical underpinning of Thermal Physics is a unifying framework in which to formalize this thinking. It is therefore in your own best interest as budding physicists learn this subject well.

If you have questions about the material, *please feel free to ask them in class*, if at all possible. This will give me a fighting chance to see whether I'm keeping everyone on board. If you are uncomfortable with this, please come to office hours and/or send me an email with your question. Well, and then there's the course's facebook page, on which I'd *love* to see a vibrant discussions of all things thermal!

I will have class information, occasional extra notes, homework sets, and all kinds of other useful material posted on the following website for this course:

http://www.andrew.cmu.edu/course/33-341

Be sure to check this site on a regular basis.

And finally…

Please take care of yourself! *Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep, and taking some time to relax. This will help you achieve your goals and cope with stress.*
All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

CaPS: 412-268-2922
Re:solve Crisis Network: 888-796-8226
If the situation is life threatening, call the police:
On campus: CMU Police: 412-268-2323
Off campus: 911

If you have questions about this, or your coursework, please let me know.