33–765 Statistical Physics, Spring 2019

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Introductory remarks

1. I use Bob Swendsen's textbook "An Introduction to Statistical Mechanics and Thermodynamics", occasionally supplemented by other material I deem either useful or exciting (or both, ideally).
2. Bob's book is primarily written for undergrads; *however*:
    a. The material is essentially what I consider the canon for an introduction.
    b. He takes *two* semesters to cover the book. We'll do it in *one*.
    c. If you're nervous about the pace, consider taking the undergraduate course.
3. The book is a pedagogically written account of all material. It is a better presentation than any abbreviated version I could possibly write on the blackboard, of which you copy an abbreviated version into your notes. Hence, *I will not aim for a coherent script to be written on the board and copied down*. There simply does not seem to be any point to waste precious lecture time like this. Instead, I aim to run this course in the following way:
    a. *Reading the book is absolutely essential*; I should say "*mandatory*."
    b. In fact, I'd like you to read the pertinent chapters *before I talk about them in class*. (Yes, you read that correctly.) I will try to announce the material ahead of time on the course's webpage, but it will soon become clear anyways which chapters and sections I will be dealing with next. I aim to spend most of my time on the difficult bits and illustrate some potentially tricky derivations that (in my experience) students tend to find difficult. I will also supplement material here or there, drawing on other books or webpages I find instructive, and adding some notes written by myself on the course's webpage.
    c. Again: with few exceptions, what I write on the blackboard will *not* constitute a coherent (let alone complete or rhetorically exemplary) narrative. Don't expect it to be. You have the book. Many of my remarks will (hopefully) serve as clarifying comments you might want to add to the book. (*Write into it*. You will *not* go to hell for this!) The extra remarks (alternative derivations, material beyond the book, etc.) might be worthwhile to keep as your personalized "Supplementary Material to Bob's Book".
    d. I confess I have tried this before, but since lecturing is so strongly ingrained in a lecturer, chances are I slip back into some old-fashioned version of ex-cathedra teaching. If so, please save me and your classmates from this derailment and rescue me out of my somnambulism *by asking questions*.
    e. I imagine that a good way to keep track as we move on is the following:

i. *Before class*, study the relevant chapter of the book.[1]

ii. *During class*, take notes—maybe in the book, maybe on paper.

iii. *After class*, go through the relevant book chapter *again* (yes, you read that correctly, too!) and copy any remarks that are short enough and worthwhile to keep into the book.

iv. Copy any longer passages that are worthwhile to keep into a *new notebook*, which you might call "Supplementary Material to Bob's Book," or "Deserno's Ramblings," or "My Own Thoughts." *Don't just file your lecture notes*, which you took while not yet completely sure where the argument is going. Write this material *anew*, organize it *neatly* (now that you know where it's aiming!), add your *own comments*, re-draw figures *nicely*. (You might even want to LaTeX it, but this is a big commitment. I'd rather you do this hand-written, than aim high and not do it at all!)

v. It sure seems like all that might take a lot of time. Well, yes—*it does*. But then, this is a 12-unit course, and you should aim to dedicate 12 hours to it per week. Moreover, I *guarantee* that this is time worth spent. Statistical Physics is *incredibly* important for everything you will do, even if you don't end up doing theory. The time you invest this semester in *creating a personalized copy of an already good textbook*, supplemented by well-processed notes that add interesting detail, will substantially shorten the time needed to refresh your memory at any given point in the future.

4. Since I don't plan to spend a lot of time writing lengthy notes on the board, this will free up time to do other more interesting things in class. Here's what I hope for:

   a. We will focus on those sections in the chapter that are most important, least obvious, and prone to cause difficulties.

   b. I want to have ***lively discussions*** about the material during class. Actively mulling things over (as opposed to passively copying things down) *substantially* helps retention. Needless to say, this also applies outside the classroom. I encourage you to meet and talk about the class and the homework problems. Like, *a lot*. However, you should write down your own solution all by yourself, *without* the notes you took when discussing the problems with your friends. View this as a test whether you've actually understood what's going on. (See also point 7 below.)

   c. I really want your participation, but *you have to come prepared*! You cannot engage in a meaningful discussion if you haven't read the pertinent chapter. If you skip reading, you either deprive yourself of participation in a lively and instructive discourse, or find yourself asking elementary questions that the book answers quite exhaustively. In the first case you waste your time, in the second you waste that of the others.

   d. Contrary to an old habit of mine, I will *not* hand out sample solutions to the homework problems. Instead, we will talk about how to solve the problems in recitation. It will be a good idea to file the homework sheets together with your graded solution and the extra discussion we went through while talking about it into your "Supple-

[1] Some people define studying as *the act of texting, eating and watching TV while having a textbook open nearby*. You ought to be old enough to see through this myth. Reading a textbook is a demanding and highly active process that takes all your attention. Ideally, it involves a sharpened pencil (HB, which is US #2, will do fine) and lots of scratch paper!

mentary Material" notebook. I often use the homework to deepen the understanding of material from the book, but also occasionally to introduce you to new topics that you should be capable to explore with the background you now have.

5. I have come across the following quote by the late Herbert Simon, who was a faculty member at CMU in both computer science and psychology, winner of the Nobel Prize in economics and the Turing Award, and after whom not only Newell-Simon Hall is (co-) named but also CMU's *Simon Initiative*. The quote is dedicated to Human Learning. He said:

   > *"Learning results from what the student does and thinks, and only from what the student does and thinks. The teacher can advance learning only by influencing what the student does to learn."*

   I believe this to be true (as much as it sometimes frustrates me as a teacher!), and it has implications for how I want to organize the class and what I believe you ought to do in order to get the most out of it:

   a. You have to actively engage in the class. I will try to make the material as interesting as I possibly can, but if you don't strive to learn it, *I cannot understand it for you*.
   b. Many theories have been proposed for how knowledge moves from one brain to another. I like the one promoted by David Deutsch: *The learner creates a trial-and-error version of the material to-be-learned in their own brain and refines it on the basis of the feedback they receive when applying their tentative new knowledge*.[2] This evidently requires opportunities to confront your newly acquired knowledge with the version I am trying to impart on you. Of course, this is a major part of what homework is all about. Hence:
      i. It is <u>*absolutely essential*</u> that you do the homework. There is virtually no other way for you to find out whether you can successfully apply the skills I'm trying to teach. Meaning also, whether what you crammed into your brain is the correct knowledge and not a wrong guess.
      ii. It is easy to find solutions to many homework problems—online, or by asking your classmates from last year. <u>*Resist the temptation*</u>! You deprive yourself of a very important and efficient learning tool. (Also, it is way more work than you can imagine to come up with exciting and original homework problems that are both doable and pedagogically instructive. I tend to spend a lot of time on this, and surely not just for fun. Don't thwart my attempts to provide you with custom-made learning tools!)
      iii. It is *infuriating* that these opportunities to practice the material, in which you necessarily have to be free to explore and make mistakes, are simultaneously used as a basis for your grade. Trust me, I hate this as much as you might hate it, but I see no way to avoid it at the present moment. Ample experience shows that without an incentive to do well, this part of your education will drop way down on your priority list—and I perfectly understand that you need a priority list, since the first year of grad school is brutal (in case you

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[2] Observe that this is *precisely* how science works: Nature doesn't write the knowledge of physical laws into our brains. Rather, we *guess* versions of these laws and then refine our guesses based on every imaginable feedback, ranging from random observations to carefully planned experiments. If you want to read more about this view, you find it explained in great and exciting detail in Deutsch's book "The Beginning of Infinity."

haven't noticed yet). You can rest assured, though, that you can still receive an "A" even if you make some mistakes.

iv. If you get the graded version back, *reflect on more than just the grade*. Reflect on what went wrong and where you erred. Revise your knowledge of the material by actively understanding why you made a mistake here or there, or maybe why the particular approach you chose is needlessly longwinded or circuitous. Reflect even on the stuff you got right: Do you still believe that this was the best way to solve it? Are there *simpler* ways? *Shorter* ones? More *general* ones? Remember that feedback is the only way to refine your own brain copy of the knowledge I try desperately to transmit to you. If you forgo that feedback opportunity, then you essentially miss out on learning—*and there is absolutely nothing I can do about it*.

v. No grader is perfect. This means that you should not blindly say "oh well, then this is apparently how it is." Make sure you truly understand why a problem is solved in a particular way or why your favored line of reasoning may not be valid or applicable; for if you don't, you either haven't mastered the material yet, or—god forbid!—the grader made a mistake.

vi. Follow-up: I will obviously not be able to cross-check every graded homework before I hand it back, so there is always a possibility that something is incorrectly graded. I confess that I'm less worried about you getting too few points somewhere (this hardly ever matters in the grand scheme of things); I am *much more* worried that something was considered correct that in fact wasn't—because this could fool you into believing that you understood something when in fact you didn't. So you should even strive to make sure that the stuff that is considered correct is in fact correct. That will only work by talking to others, comparing solutions, and *continuing to think about the material*. If in some exam problem I subtract points for a mistake, and then you show me that you made the same mistake in a homework and the grader didn't subtract points or didn't even mark it as wrong, I'm afraid that *I cannot count this as a valid excuse*. A wrong answer is a wrong answer, and occasionally it goes undetected (and we now understand why this is a bad thing). But *this doesn't give you the right to have it overlooked in the future*.

vii. Since mulling over the material never stops, this also means that you will continue to need feedback on questions that remain open, even after class, book, and homework. But that's what the teacher is for. *Talk to me*!

6. As much as I like the book, there will invariably be points where I have a slightly different view, or emphasis. Rather than ignore my view, or ignore the book, I will try to point out where the issues are, thus giving you an opportunity to see that even practitioners in the field store virtually the same information in different ways in their brains.

7. It is statistically inevitable that some people will do better in any given course than others. I trust you want to do well, but then, maybe things don't quite work out the way you hope. What do you do then? Please know that I will always be there for you. But since I can't learn the material *for* you, you need to develop learning habits that work for you.

   I believe that one of the best things you can do is to interact extensively with your classmates—in and out of class. "Peer instruction" is *en vogue* for a reason: talking about the material will assist both understanding and retention. However, there lies a substantial danger in relying too much on the help of others (e.g. discussion leaders in homework study

groups): *it might give you a false sense of your own proficiency*. You might think that you have mastered the material, while in fact—when push comes to shove—you cannot apply it on your own. This will haunt you later (and most immediately: in the exam).

I have often seen that students, who did poorly on an exam, professed their *genuine* puzzlement about their low grade. They did quite well in their homework and felt they were on top of things. I am sure they fully believed what they told me, but nevertheless they objectively erred in their self-assessment. This, incidentally, is a well-known and very well researched phenomenon in education research. Students often go on to suspect that the trouble lies in them being "bad test takers". While there clearly is such a thing as nervousness and exam anxiety, I am not always convinced that this is where the actual trouble lies. For instance, the mistakes leading to a poor performance are often quite fundamental and document difficulties with basic knowledge. Even without being nervous, the exam problem couldn't have been solved with these gaps in one's understanding. Of course, one can *still* blame nervousness and anxiety as the root cause of these deep gaps, but that may come at the price of closing the door to a real solution. Instead of blaming a vague and fickle enemy ("exam angst"), it might be more productive to entertain the possibility that one simply overestimated one's level of proficiency. This of course means that *you need to find ways to correctly calibrate the extent of your knowledge*. You must learn to monitor and adjust your approach towards learning itself (acquire "metacognitive abilities"), especially finding means to evaluate your strengths and weaknesses. There are many ways for how to do that, for instance:

a. Use your feedback on the homework as an indicator for how well you cope with new problems. This of course presupposes that you didn't just hand in a solution that arose out of a group effort upon which you didn't personally reflect.
b. Monitor how much of the classroom discussion you can knowledgeably follow. Do you understand the issue? Can you contribute to the discussion? If not, why not? Can you at least understand the solution we arrived at? Could you recreate that solution on your own, later? (Try!) Could you explain it to one of your classmates? (Try!)
c. Join a study group in which you continue discussing the material. There is no study group? *Establish one*! Explain concepts to your classmates. Pick arguments apart and see when and why they fail. Try to identify what is key to an argument, what is technical embellishment, and what can in fact be generalized.
d. Participate in discussions on the course's facebook group page.
e. Look up material you are now supposed to know, *but in a different book*. Can you follow the alternative presentation? How is it different? Does it strike you as better or worse? If so, why? Is the presentation in the different book more general? Or maybe more specific? Are there new examples, and are they helpful?
f. Think up new examples to which you could apply your budding StatMech skills. Push the homework problems further. Invent new problems. Can you solve them? If not, do you get stuck at a mere technicality (e.g., some integral is just too tough) or something more fundamental (e.g., some basic assumption turns out no longer to be true)? If the former, can you simplify (approximate the integral, look at a special case or limit, do numerics, etc.)? If the latter, is there a way to adjust the problem to render it solvable?
g. Talk to me.