Reflections on Part III exam in physics (Biophysics)
Hyun Youk
Exam date: April 9, 2009 (Start time: 3 PM (Total duration ~ 1.5 hours))

Part III exam committee: Profs. Kardar, Litster, and Benedek.
Thesis advisor: Alexander van Oudenaarden

Your thesis advisor will assign you a single question (often with multiple parts) a week before the exam. You will prepare a solution to this question and will start the exam by presenting it to the committee. In general, you should expect the entire exam to be about presenting this prepared solution; there will not be much time left for the committee to ask other questions (based on the experience of three other students who took the exam in my year).

<u>1. What to expect once you're in the exam room:</u>

My committee was very friendly and genuinely wanted me to succeed on the exam. You should think of the exam as a "lecture", yourself as the "lecturer", the committee members as the "students", and your prepared solutions as the "lecture material" that you're in the room to teach thoroughly. Since your question will usually (based on the experience of three other students who took the exam in my year) be based on a recently published paper, the material is new and sophisticated enough to be taught as a lecture material to the professors. So it shouldn't be hard to envision yourself as a genuine lecturer and the committee members as students. You shouldn't assume that the professors know the subject matter completely or that they have even read your question and solved it themselves. Whether or not they can solve it themselves (no doubt they can) is not even the issue; the issue is whether you can communicate and teach well. Do not scoff at this; students who could solve problems better than me and had mastery of the material the question covered were grilled very hard in front of the blackboard in the exam room because they couldn't explain their solution. If you can't explain your solution well, then your committee will be frustrated, and you'll be grilled hard in turn. This is not a typical physics exam; just solving the problem won't get you far. The first thing you should do in front of the board at the start of the exam is explain broadly what you're going to do for the rest of the hour (e.g. "The question assigned to me by my advisor deals with molecular motors. In part (a), I will derive the so-called "randomness parameter", then in parts (b) and (c), I will show how it can be used to show the number of rate limiting internal states of the motor. I will finally end this question by relating it to the paper referenced in the question"). Do not just start calculating random things; that's not why anybody is in that room including yourself. Be sure to state each question you're solving, defining every single variable by writing them on the board with their definitions, then solve step-by-step, not leaving any algebra behind. Be prepared for frequent interruptions which could be for comments, side question related to your problem, or just a request for you to repeat what you just said because you went too fast and weren't clear enough. I did not have any time left for extra questions after I had presented my prepared solutions. Indeed, all the students in my year, including myself, had just enough time to present the solutions to the "warm up" question; no new questions out of the blue were asked after that. The exam should take between 1 and 1.5 hours.

2. How to prepare for the exam:

I'd say that the focus should be on two places. First, be sure to solve, then practice over and over again explaining your solutions step-by-step. It helps to do a mock exam session in front of a blackboard with your fellow exam takers as well as older grad students who's been through the process before. The main focus should be on your prepared solutions and anything that you can think of that may be related to it. In talking to other students, I found that you can usually relate one of the following three general areas to your question: (i) Drift-diffusion process, (ii) Master equation, (iii) Polymers & DNA models (e.g. worm-like-chain model). Second, brush up on some basic concepts in biophysics. I know that sounds rather daunting given how broad the subject of biophysics really is. I found that reading through the "8.592: Statistical physics in biology" (by Mehran Kardar) lecture notes and Philip Nelson's "Biological physics" textbook were more than enough to prepare for basic biological physics questions that were asked intermittently while I presented my prepared solutions. When you go over the 8.592 lecture notes and the problem sets, be sure to keep in mind that they will have much longer calculations than what the committee will ask you to do on the board. This means that you won't be asked to do integrals involving more than a line (if any; I wasn't asked one), partition functions involving many terms and whose simplification involves many lines, and so on. Rather, you should go through the notes and problem sets, and understand the main concepts (usually qualitative or involving simple one-liner central equation). Some examples include drift-diffusion equation, variance of random walker's position, stokes relation, Einstein's relation (kT = D * viscosity coeff), etc. In Nelson's book, I would focus on chapters dealing with entropic forces, drift-diffusion, polymers (DNA models such as worm-like-chain model), and molecular motors. That's actually most of the book (excludes just the last two chapters dealing with neurons) but it doesn't take long to read and it's actually an enjoyable read because the book is very well written in a personable tone. As I stressed before, knowing the material isn't good enough; After you read each chapter, be sure to practice explaining the main concepts covered in that book (nothing wrong with talking to yourself and explaining things).

Be sure to memorize orders of magnitude of parts of cell (size of E. coli, etc.) and key parameters such as diffusion constant of typical particles, viscosity of water, kT = 4.1 pN nm (T = room temp, k = Boltzman contant), etc. These are sprinkled throughout Nelson's book.

Finally, if the question you've been assigned before the exam refers to a paper, read that paper thoroughly and be able to summarize the main (not detailed) points of the paper. If the paper deals with an experiment, you'll very likely be asked to explain the experimental set up, and some key parameters in that experiment (e.g. In an experiment studying molecular motors, what is the size of the microbead to which the motor is attached? What is the radius of the cross-section of the optical trap beam?). As another example, if your question deals with microtubules, it's a good idea to read about what microtubules are, what are their subunits, how they assemble, etc.

3. Summary

This is probably the only one of the three general exams that you have an absolute control over. This is because you're given the problem you need to solve a week beforehand, and the miscellaneous questions you'll get from the committee will be related to this question. So you can really prepare very well for the exam if you put in the time. The committee really does not want you to fail and will help you out if you get stuck in front of the blackboard. There is no quota on how many students pass the exam in a given year or anything silly like that. So don't worry, remember that the effort you put into preparing well is the main determinant of the outcome of the exam.

~~Victim~~ Student: Dong Hyun Kim
Date: Mid-April , 2009.
Examiners: Kardar, Litster, Benedek
Question: Microtubule growth Model

<u>Preparation</u>
I was aware of the old model from kardars lecture notes, and so felt okay about the problem. But solving it on a sheet of paper was different from explaining the solution. Alexander stressed about teaching the committee, assuming that they know nothing about the stuff you are presenting.

I spent most of the week, coming up with easier simpler ways to explain the physical reasoning behind the model. Questions such as: what is quasi equilibrium?(only need slowly varying modes omega~o(k)). I also tried to explain equations with something more visual. For instance- to come up with the master equation, I started from scratch with boxes and arrows, got the discrete master equation and then moved to the continuous limit.

I found it very helpful to have multiple practice sessions with my friends. I would prepare a presentation for them and they would ask me a bunch of questions and I would keep revising it, making it simpler and direct.

<u>Exam</u>
My question had 3 subparts but i was only able to do only 1 sub-part. The first 30 mins were spent discussing the biology and background of the model. They asked questions like-

Why do the caps shrink, differences between gtp, gdp cats., what makes the hydrolysis happen, why are they shrinking from the end and not from the middle, etc. Some of these questions were not directly relevant to the model. They tried to understand the biology using the model from the question. They asked of questions about assumptions of the model. This bit was was tough because there was a gap between the real biology and the idealized model.

If I increase this number, is the cap shrinking or growing? model is not about gtp cap but switching between two states. In the model, it is shrinking microtubule can switch to a growing phase, but without gtp cap, it can only shrink.

<u>Style of Questioning</u>
I felt they were trying to understand something rather than test me. An example: Benedek asked a question I couldnt answer, then Lister tried to answer Benedek, “I think I know that” and tried to explain that to him. So Benedek was relieved because he didn’t care whether the answer came from me or someone else.

Total time: 1hr 30 mins

~~Victim~~ Student: Jialing li
Date: Mid-April , 2009.
Examiners: Kardar, Litster, Benedek
Question: DNA looping

To summarize, the committee chair will tell you to study the practice questions and the Nelson Biophysics book. But past students will tell you to focus mainly on the question you get one week before the exam. As for my case, the past students were totally right. None of my questions during the exam was a general biophysics question. Make sure you know a lot of biology as well, even the committee chair assured us no biology would get asked. The thing is, Professor Karkar, as the committee chair, probably had a plan to test our general biophysics knowledge, but we couldn't know whether the other committee members follow his plan.

For my question, number 10 in the practice questions, was super easy by itself. But Professor Benedek likes a lot of background information and things like the cellular concentration of regulatory proteins. And both he and Professor Lister like you to know everything about the figures. Alexander told us to state everything clearly, which is very very important. So, you only need to study for one week, and focus on the question you get from Alexander, and study everything related to it.

My presentation was aimed at answering the questions, but I was interrupted a billion times just telling the setup of the question, before even starting answering part a of the question. The exam ran out of time, because of all the interruptions, and I didn't quite get to finish all I wanted to say.

Prepare thoroughly and prepare to get interrupted for all sorts of random questions...