0.3: How to Learn Physics

No Shortcuts, No Memorizing

In previous sections we discussed the importance of taking a class in physics, and why a true physics class is so challenging. Here we will try to put together what we learned there to come up with an effective way to get through this daunting task of learning physics.

The first most important principle we need to embrace is that there is no easy path. Trying to gain an understanding of physics (or really, anything) without engaging in it fully is a losing battle. If you want to build muscle by lifting weights, you won't do so by watching videos of other people lifting those weights – you have to get in there and do it yourself.

Students in physics classes tend to focus too much on having problem solutions to study from. Sample problems are only valuable for those that struggle with them. They are worthless if all they are used for is to "study" their solutions. In this case, the word "study" is just a euphemism for "memorize," and indeed physics study shortcuts all boil down to memorization. Going back to the weightlifting analogy, if the weight is lifted for you, and then handed to you to hold up, it may feel like you are accomplishing something (it is not trivial to hold it up), but this does not exercise your muscles. And a physics class, properly taught, seeks to test your "physics muscles," not your ability to regurgitate what you have seen before.

So in the way of study advice, the point is this: Avoid looking at solutions as much as possible! Derive the maximum benefit by putting in your own effort. Even those times you fail to completely figure something out (and you will – physics is hard!), you will learn more than you will by avoiding this discomfort by jumping to the solutions. This is not to say that the solutions are not helpful – but like a spotter that helps you when you lift weights, the less you rely on them, the better.

Deliberate Practice

In the last couple decades a lot of stuff has been written about effective training of athletes and the achievement of expertise in general. One idea that has really taken hold is the idea of *deliberate practice*. Perhaps you have heard the claim that to become elite in some pursuit, one needs to invest on the order of 10,000 hours of practice? The number seems to be what gets all the attention, but what often gets lost in discussion is the *form* that this practice needs to take. For example, a player learning to hit a baseball better will not achieve the goal of elite hitter simply by spending 10,000 hours in a batting cage. Rather, those hours need to include reducing proper hitting technique to its infinitesimal constituent parts: Hours need to be spent on getting the swing-plane of the bat to the correct angle, getting hip rotation right, achieving proper weight transfer, and so on. And many more hours are needed to combine these tiny pieces together properly into an integrated swing. This *deliberate* practice of components is what those 10,000 hours must be comprised of, and coaching from someone knowledgeable about these things is pretty much a necessity.

Now of course you will not have anything close to 10,000 hours available, but the goal here is to get a fruitful first exposure to physics, not become an elite practitioner. But the idea of deliberate practice is still an important one, no matter what the scale of the numbers of hours may be. Fortunately, you have an instructor, teaching assistants, and even this textbook to serve as "coaches" to help direct you through this practice. But the responsibility of maintaining the discipline necessary to do this right is on you, the student.

You will find that there are many tools or templates offered during this and future physics courses that are intended to get you through problem solving. To employ deliberate practice in the context of these tools and template means that you should spend some time getting good at these *without regard to your success in solving the problem itself*. For example, one of the most important tools in this class on mechanics is called the "free-body diagram." A short amount of time is dedicated to teaching you how to draw one of these, but they are a critical part of solving so many different kinds of problems. Most students invest a short time on learning to do these, and move on well before mastering them – they focus much more on getting the answer to the problem, and hardly at all on getting this step right. Often when a problem is stated, if it does not include an explicit step that says, "draw a careful free-body diagram," many students will not bother to do so, or if they do it will be very crude and incomplete – they jump straight to writing down equations, and inevitably get things wrong. Free-body diagrams are not just "busy work" at the start of a problem – drawing them requires deep conceptual thought that is necessary for avoiding misconceptions and modeling the math properly. Failing to master this tiny component to physics problem solving is like failing to master weight transfer in hitting a baseball, the grip of a golf club, or turning one's head to breath properly when swimming. Time must be spent on these components, or the whole pursuit fails.

When in doubt as to whether you are applying proper focus on components when doing practice physics problems, simply remind yourself that your goal needs to be to get better at the process, *not* to get the right answer.

Embrace the Big Picture

Suppose you watch dozens of scenes from a movie, and are later asked to answer some questions about them. Hopefully it is clear that putting them into the context of the movie plot makes them easier to understand and easier to recall details than if they are viewed in random order and out of context. This is a general feature of human understanding – we are better at remembering details and extrapolating conclusions when the information is organized into a contextual framework. The same is true about physics. It's not always easy to see the bigger picture when struggling to understand specific concepts and nuanced mathematical models, but striving to do so can itself help one to overcome those struggles with the details.

Put more succinctly: The best way to learn new ideas in physics is to relate them back to things you already understand. If some new topic seems utterly disjoint from what you have learned already, then you know there is something you are missing, and it is an indication that you need to delve in further. A good instructor will do their best to segue from one subject to the next, so that a big picture is developed. But if this doesn't happen, or if you are unable to grasp the connections the instructor is trying to make, then it is worth your time to go back and make those connections yourself.

Students that have a disjointed understanding of physics feel like a useful approach to studying the subject is to do as many different practice problems as they can. There goal is to commit to memory as many different "tricks" as they can find, in the hope that the exam will involve a trick they have memorized. This approach is utterly ineffective in a properly-taught class that emphasizes understanding over memorization. Practice problems are helpful, but the emphasis should not be on how they are different (the "tricks"), but how they are the *same*. Once it is clear what elements a wide variety of problems have in common, seeing the big picture is easier, and one can focus their deliberate practice of those common elements. This is the path to success – building a simple, understandable, mental big-picture, and mastering the fundamental tools that go with it.

Doing Sample Problems

One of the most common pieces of advice given for studying physics is to "carpet bomb" your brain by doing countless sample problems. This is only half-true, and the fact that most people that give this advice seem to think it is some sort of magic pill shows that they don't understand the importance of the word "deliberate" in "deliberate practice". What unfortunately typically plays out for the unsuspecting student who follows this advice is this:

- Finds a new problem to solve.
- EITHER:
  - Solves it quickly and correctly so it was of no benefit, as nothing new was learned.
- OR:
  - Gets stuck early, as it challenging.
  - Rather than struggling too much with the problem, decides not to "waste time" with blind alleys, and simply peeks at the solutions.
  - The solution makes sense, so after reading it, feels like they have learned something.
- Repeats cycle.

This cycle of "just doing lots of practice problems" is utterly useless for learning physics, and when the student that follows the advice in this way can't seem to solve any exam problems, they are understandably frustrated that so many hours of practice were not effective. That's the tragedy of this advice – it is so incomplete and deceptively simple that it frequently leads to lots of wasted hours of work that could have been better-spent.

One might ask, "If this is all true, why do so many people that have been successful in their study of physics give this advice?" The answer depends upon which category of two categories the adviser belongs to. If it is a practicing physicist, then it is likely in their nature not to quickly resort to looking at solutions. They don't mind "wasting their time" with blind alleys – getting unstuck by themselves is the "fun part".

If it is a fellow student that is claiming that this strategy got them through a class, and they are not of the same mentality described above for the practicing physicist, then the odds are that what made them successful was poor examinations. Some instructors intentionally write their exams so that they closely resemble some subset of a collection of problems given for practice. When this is done, "practicing" by studying the solutions to a large number of sample problems is effective for the test-taking, because memorization is key. Unfortunately, this teaching practice is more common than it should be, and leads to lots of students believing they have learned more than they really have. This does not lead to success down the road, when a robust understanding of physics (and physics problem-solving) is needed, and the short-term memorization from the previously-taken class is useless. The general rule is, if your physics course (and particularly the exams) are easy, then it's not because the instructor is good at teaching it to you (no one can actually "make physics easy") – it's because they are actually not asking you (with their exams) to demonstrate that you have learned anything of any value. And usually, when exams don't require that students learn anything, students don't take the appropriate steps to do so.

Using This Textbook's Sample Problems

This textbook provides you with sample problems to help you get in your deliberate practice, and they are constructed to help you avoid the "study the solutions" pitfall described above. These sample problems come in two parts. The first part (given in the body of a chapter) provides only the physical situation, where you are asked to simply "analyze". There is no question for you to answer here – just flex your muscles with extracting as much as you can from what has been given. The second part of the sample problem appears at the end of the chapter, and it is a question that accompanies the physical situation given earlier. The reason for this split will be explained below, but here is the most effective use of these sample problems:

1. Do as much of the analysis as you possibly can without looking at the analysis provided in the textbook. Write this analysis down on a piece of paper – don't just think this through in your head! This is very important.
2. Open the analysis window to see what analysis has been provided for you. See if the analysis you did matches what is there, and make notes on your piece of paper about where you went wrong. *Add notes to this piece of paper that describe in your own words* any parts of the analysis that you overlooked that was provided by the textbook.
3. Go to the question at the end of the chapter, and try to solve it, referring to the notes you have written on your piece of paper.

So why the split? In the analysis stage, without an end goal of a question to answer, you don't get stuck trying to find a specific path. This is not to say that you won't get stuck! At times you will find that you can hardly think of any information that can be extracted. But when one has a specific question in their heads, it is difficult to free-up their thinking to allow them to see important points of analysis. In essence, this method breaks down the task into smaller parts, and like a coach that provides drills, forces your practice to be more "deliberate".