HOW TO BE A STUDENT OF AN INTRO PHYSICS COURSE

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ABSTRACT

Lecture notes on what the title says and what the subject headings say.

Subject headings: introduction — hardness — learning process — knowledge — problem solving — proofs — tests — grades — instructor

1. INTRODUCTION

This essay is essentially about how to be a student of an intro physics course. Many ideas apply to other courses as well. It is specifically aimed at the calculus-based intro physics course.

Calculus-based intro physics is a hard course. It's not the hardest course that students will ever take—it's nothing like organic chemistry.

But it has to be done. It's a foundational course for those people who are required to take it. If you are majoring in physics, engineering, geology, some branches of chemistry and biology, and other math and matter subjects, intro physics is essential. If you don't like or can't learn to like intro physics and you need it for your major, then you have ask yourself if you are in the right major.

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Intro physics is primarily about matter and motion, time and space. It's often very abstract. But abstract doesn't mean unreal. It's about reality with the complexities and peculiarities of most actual objects discounted. You get to see reality—a certain part of it—in a very clean, simplified way in which basic laws of physics can be applied directly. The objects and the systems they make up are usually very idealized in intro physics. You often dispense with friction, air drag, the effects of object shape and internal motions, complications of actual materials, realistic flexing and fracturing, past history, future history, and that complicated effect human actors. You deal with ideal smooth frictionless plans, thin rods that have no thickness, cars that accelerate forever.

Physical laws and results allow you to predict the time evolution of systems. For the simplified, idealized systems, this can be done with short calculations. Quite often the results you calculate are quite accurate for some real world systems. But frequently they arn't. That's just a consequence of dealing with ideal systems.

Mostly the results for ideal systems can never realized exactly in the real world. But you can often approach realization by taking real systems and progressively eliminating complicating factors. In fact, this is often how physical laws are discovered. Either in actual practice or thought experiments, one eliminates the complicating factors and sees how things behave in their simplest essence.

But if intro physics deals with ideal systems and toy problems, how does it apply in the real world. Well as aforesaid, often idealized results are not so bad. But to deal really exactly with the real world, one has to add the complications onto the ideal systems bit by bit. One builds up to reality. It's a long and complicated process and you cannot start learning physics by diving in the deep end of the pool first. The solution to any real problem of the real world can be 6 months of work and a manual. Certainly this describes many engineering projects and other projects too.

When students demand real world problems, there are two valid answers. First, we are dealing with the real world, but in its idealized essence. Second, as Jack Nicholson once snarled, you arn't ready for the real world.

You may wonder can't we skip physics and just deal with real world problems of engineering using empirical methods. Well no. The ancient Egyptians could build the pyramids and the Medieval masters the catherals without intro physics. But the world now is too advanced for the purely empirical methods and rules of thumb of yore. You can't build a suspension bridge or a jet plane without physics and you can't have physics without intro physics. That's not to say empirical methods can be neglected in solving a real problem. The ideal for building a complex structure is to design it straight from theory and build it and have it work perfectly. The reality is that theoretical design often needs to be corrected by empirical study.

Do you need physics for fields outside of the traditional realms of physics and physics-based engineering? Well it depends on the level. One doesn't traditionally go down to the basic level of physics for psychology, economics, and history—you use emergent principles in those fields—principles that apply to complex aggregates without reference to their low level basic structure. But for engineering, chemistry, geology, and meteorology, you do go down to the basic level of physics.

However, things are changing. Physics has invaded psychology, economics, and history—the Middle Ages have been calculated. It's not physics itself that has been used, but rather physics methods—and often physicists. But it is interesting to note that emergent principles at higher levels often mimic the laws of physics.

2. WHY IS INTRO PHYSICS HARD?

Well why is intro physics hard?

First off its mathematical and logical.

The level of that mathematical and logical thinking needed is often step above what students have had to do before. Not so far above, but above.

Also calculus is being used. Many students are taking calculus concurrently. But inevitably, intro physics needs calculus results before they are introduced in the calculus class. In fact, it must use some integration and vector calculus that will come only in later math classes. These calculus results are gone into as they appear. Students need to get used to the calculus way of thinking about things. For example, they need to understand that integrals over 3-dimensional space can be done in general and learn how they can be done in a few simple cases by turning them into 1-dimensional integrals.

Another difficulty is that one has to learn—memorize really—jargon, concepts, and formulae. It's nothing like what has to be done in chemistry, but it's not chicken feed either.

3. LEARNING PROCESS

The learning process in physics is not different than that in other areas, but because of the difficulty of physics, one must go at the subject with greater effort than in some other courses.

What is learning a subject really?

It's recreating the subject in one mind. If one can recreate, one can create.

No one can recreate completely with a big subject like physics. Lev Landau (1908–1968) once said that he had mastered all theoretical physics—but the person telling the story added that that was in the 1930s. No one could do it now.

A student in intro physics can only do a bit of mastering.

But they should try to see intro physics as whole.

One aspect of seeing it as a whole is to have active memory of concepts and problem-solving tricks. Active memory means that the concepts and strategies spring into your mind when you see a problem that needs them. Passive memory means that you just scroll through a derivation or a solution and are able to follow. Active memory is what is needed for tests and tests are tryouts among other things for that eventual thing the real world.

How does one learn a subject?

As everyone knows, you can't do it by one path.

But there is well known cycle: lecture, individual work, group work.

Going to lectures is important.

Actually, it is difficult to listen to a whole 50-minute lecture intently and probably few do it often. But you can listen to some intently. Also absolutely, positively, going to the regular lecture period of a course keeps students up to date with the course. Students who start skipping can easily fall behind and never fully catch-up. It just common sense not to skip. Going to lectures is also an obligation. Society and parents are investing in the student: they deserve to know the student is doing everything reasonable to achieve learning goals.

Individual work is crucial. Students must do assigned readings. The readings repeat stuff from the lecture. Many things can't be learnt by a single exposure—maybe they need ten or more exposures and refreshers. The readings give new stuff not covered in the lectures.

In the past, lecturers often tried to cover everything in lectures, but in modern pedagogy that is not always the case. Spending time in class on group work often necessitates some material being relegated just to readings—the students still have to know it.

Readings should not be just scrolling through the words and formulae. The student has to read searchingly. How do all the things connect? Do they all congrue? One should go back and forth checking the connections and the logic. One should work the examples along the way and fill in omitted steps in derivations. Ideally, one should go over a reading until it is all familiar and the essence and many details are lodged in active memory. That ideal may be hard to reach, but one should try to approach it.

Besides readings, one also needs to work on problems alone. Doing problems usually involves checking the reading and basic concepts and looking at examples. Frequently, one must seek help. But it's important to try real hard just by yourself, before you run for help. In studying for tests, other problems from the text and other sources must be tackled. For tests, one has to expect the unexpected.

Group work although not absolutely essential has been demonstrated to very effective in learning—Socrates was right. So much so that one should do it if at all possible. Students in small groups gather together. They tackle problems together. A good approach, among others, is for everyone race on a problem individually. Then each one passes the solution along to a neighbor who then marks it—but just for fun. This is peer review. It's enlightening to see a problem solution from the other side of the fence—the marker's side. Arguing concepts and solutions is also good.

Students have always worked in groups out of class. But the modern trend is for more group work as part of the class. Straight lecturing for 50 minutes is less effective than some lecturing and some group work. Group work is fun and social and energizes the brains. It's active rather than passive. Of course, in group work, especially in the classroom setting, it is essential to keep your eye on the ball—as Nabokov has said. Partially, this is the instructor's responsibility: they have to provide sufficient problems and exercises. But partially it is the responsibility of the students. The shouldn't fritter away their time chatting off the topic—a little off-topic chatter is OK.

Of course, group work can't get started without a little lecturing and reading. One has to have a starting point or one has nothing to say.

Listening, reading, talking, arguing physics all adds up to thinking physics. Like any subject, one has to think hard about it to get it. Often times it seems that students will do anything in a course—except think about the subject which is the thing that has to be done.

How much time is needed to learn intro physics?

Well for 3 hours in class per week, 6 hours out of class per week.

That sounds like a lot, but it's not considering that it's your job.

Full-time students typically have 20 hours per week of structured time in classes and labs. Twice that out of class is crucial. So at least a 60-hour week. Being a full-time student is not a 9-to-5 job.

4. HOW MUCH DO YOU HAVE TO KNOW?

Everything.

OK, that is an ideal.

Let's say it just goes on and on.

Students often it seems want to restrict a course to just a few tricks to get them through—“Do we have to know this? Yes.”

The reality is that there are many basic concepts and there are a jillion tricks to learn. Yes, some of each are more important than others, but you need to build up a huge repertoire for all future work. It’s what’s expected.

But how can one learn many basic concepts and a jillion tricks?

They are not isolated entities.

They are nodes in web and they are linked.

If one node/trick is missing, then it can be recreated by going up the web to some more primary trick.

This idea of tricks being linked in a web is common to all subjects.

But it’s particularly clear in intro physics where often students are expected to solve problems starting from a very basic concept or physical principle or physical law.

The solution is the trick in a sense and it’s linked back to basic concept.

The solution is linked to other solutions.

Where are these basic concepts, tricks, and links. Well among other places, in your brain. You have to form neural connections. That takes practice. Doing stuff over and over again until those neural connections are there.

You also have to combine concepts and tricks. Frequently, problems involve multiple ones.

You should note that besides learning physics, people expect you to learn how to solve problems in general from basic principles. For some majors, that may be the main reason for putting physics in your curriculum. Of course, probably all disciplines develop skill in solving problems from basic principles. But physics requires that skill in a rather pure and mathematical form. You see the need for that skill and how it is used rather clearly.

5. HOW DO YOU SOLVE PROBLEMS?

In intro physics or elsewhere identify the concepts needed, identify the variables involved, knowns and unknowns, identify the formulae needed.

Frequently algebra or calculus must be done.

Do it.

The identification part is often hardest. One must have that active memory we mentioned earlier.

When faced with a problem without knowing where to begin. Try stuff, try anything. On a test this might get you marks or it might not. Either way though, the act of trying builds up that active memory.

What should a good solution look like?

Well remember we are at the intro level. No words are needed unless a word answer is asked for. Usually, one should write down the basic formulae one needs and then do the steps to the solution. It's a good practice to box in the final solution. Remember you are trying to communicate to an informed reader, the marker. The marker doesn't want to be confused, doesn't want to have to think; the marker just wants to be see that you know what you are doing.

The actual solution is of no intrinsic interest remember. It's how you got there. How much of getting there is needed? Well that depends on the specific nature of the problem and can only be learnt by experience in the course itself. Giving a bit more than you think is needed is better than giving a bit less.

One should do all the steps using variables (i.e., symbols): e.g., use v for velocity rather than 3 m/s. Only at the last step put in numbers if there are numbers to put in. Well sometimes it's too messy to keep variables all the way—the expression start getting long and cumbersome—but usually one can.

Why use variables in the steps?

Well the instructor wants you to. Cottoning on to the idea of what the instructor wants you to do is generally a good idea.

By why?

A main goal of intro physics is getting used to the idea of relationships between variables. This means getting used how one variable affects another. Using variables all the way to just the end keeps the relationships in mind.

But there are other good reasons. First, you get a general result that is valid for any set of input values. This might not pay off so much in intro physics where frequently you may not need the general result again. But it sure does in life—you are training for life remember. Second, you can see explicitly how the varied input values affect the final result. This gives insight into the true nature of the problem. Third, if you use numbers and make a math error in the first line, then the marker cannot easily reconstruct your work since everything is wrong—and then they are likely to give you zero. By using variables, the marker can see what has been done. Fourth, it's easier to check your own results.

What about significant figures?

That depends a bit on the instructor.

Some like strict adherence to the rules of significant figures, some don't think it important in intro physics.

Yours truly doesn't think it is important. The final values should have about as many figures (i.e., digits) as input values: typically, these have 2 or 3. But if there are more figures in a final answer, that usually isn't considered an error. If you have vastly fewer that might be considered an error.

Of course, in problems about significant figures, then adhere to the significant figure rules.

In laboratory reports, significant figures are essential. In that context, doing significant figures correctly is part of the training.

6. PROOFS

Students often react to proofs (and derivations) by turning off their brains.

Proofs have no educational merit. Proofs have no use in the real world. Proofs don't occur on tests.

Proofs do have educational merit. The same mathematical and logical skills that go into to solving particular problems come up in proofs. So understanding and learning a proof is just as valuable as a mental exercise as doing a problem.

It's more.

A proof tells you why an important result is true. Why you can trust it all the time. A proof provides a solid intellectual basis for much of the material of intro physics. The result of a proof is generally useful. The result of a problem is often of very limited use especially if the problem is just for an ideal or toy system. The solution to a general problem is often a proof. There is no absolute hard line between problem solution and proof finding.

Proofs do turn up in the real world. You've designed a bridge, a power grid, an operating system, an environmental remediation plan. You will be asked for a proof that it works all the time, that it's fail-safe. Well at least a proof of these things within some limitations. No one's going to be too happy with the idea that there is an infinite set unknown circumstances in which a system can fail.

Proofs certainly can occur on tests.

7. TESTS

You should study for tests like training for an athletic event.

Run through the text and notes concentrating on basic concepts.

Then work on problems requiring full answers. Start with easier ones and go back and forth over the whole amount of material being covered. Work your way up to harder problems. You can start with homework problems, but eventually as time allows try yourself against new problems. Expect the unexpected for tests. Remember test problems can often combine two or more concepts.

With each problem, try really hard to get something down without going back to text or notes. Anything. If that fails, then try to find the approach from the text/notes. If that fails, then look at the solution and try really hard to understand it, not just memorize it.

Group work is good in studying for tests. It can make study fun and social, but keep your eye on the ball. Race to answers with each other, mark each other, enlighten each other.

For midterm tests, an evening of study (4 hours maybe) is probably needed. For a final, a day of study (10 hours maybe) is probably needed. It doesn't have to be 10 hours in one day. The study times cited apply if you have kept up with the course. If you havn't kept up with the course, more time is needed. Cramming for test is not an ideal practice, but sometimes it has to be done and it can be done successfully.

Don't tire yourself out studying. Get a good night's sleep beforehand. Make sure you won't get hungry. If you are sick, ask the instructor for a make-up.

8. GRADES

Grades are important, but not that important.

They are after all only a rough assessment of what the student has learnt. What you've learnt is important for the following courses in your program and your whole career. Twenty years on no one, including yourself, will care what grade you got in intro physics. They will care about what you've achieved with your education as whole.

The best way to learn a lot and get a good grade is just to dig into the subject and forget about grades.

Of course, sometimes you need a specific grade for something. First rule, don't undershoot. Don't imagine you can calibrate to the inch just how much effort is needed get to that specific grade—overshoot. Don't imagine you can negotiate a grade—it doesn't happen.

What's a good grade?

If you've learnt a lot, a C is a good grade—especially in a really tough course.

Traditionally, a C was supposed to be average. There's nothing wrong with being average if you are in a strong crowd—an average player on the Boston Celtics is darn good player. But nowadays a C is generally not regarded as average for most courses. But some instructors will hold to it. That's not unfair given that some instructors give a much higher grade for an average. Your average grade will all work out to essentially what you deserve.

It seems to yours truly that for large intro physics classes a class GPA in the range 2.4 to 2.7 is good. But yours truly can go higher or lower depending on cases.

The number of A's? Maybe 10 % of the class. Maybe more or less depending on cases.

Student: Can't there be more A's?

Instructor: Just imagine what it would be like if everyone had an A.

Student: We'd all get scholarships.

Students like to pin instructors down on grades. Well mostly it can't be done. An instructor's job is to keep the student striving and an instructor should not set a student up for a disappointment. This all means no promises.

Some instructors keep a strict scale like the traditional less than 60 % for F, 60 % for D, 70 % for C, 80 % for B, 90 % for A. But then they have to fine tune their tests or curve them to get what they consider a reasonable distribution.

Some like to use an explicit curve.

Some just like assign grades by some rough and ready by-eye distribution.

Yours truly, likes to use an explicit curve during the semester with a GPA of order 2.5 in order to have a simple way of telling people where they stand and then use a rough and ready by-eye distribution at the end to reward people a bit who've improved. For small clases, yours truly uses a by-eye distribution all the way.

Why can't there be a hard-and-fast grading scheme?

Well no one's ever found one that worked well universally. All classes are a bit different, all instructors, all courses. Hard-and-fast schemes would create anomalies: everyone fails, everyone gets A's.

Students can complain that everything is uncertain without a hard-and-fast scheme. But everything is uncertain anyway since students can't determine ahead of time what they'll get on tests.

In fact, there always has to be a uncertain mixture of relative and absolute in grading. This isn't unfair. In matters of assessment, it's the way of the world.

What grade you get affects your opportunities certainly. But in some rough and ready sense, you will usually get the opportunities you deserve. What you make of them doesn't depend on a long ago grade. To a degree it does depend on what you learnt long ago.

9. THE INSTRUCTOR

Instructors present material in lectures, make homeworks and tests, grade same, guide, answer questions, and give a final grade.

Students should remember that instructors don't know all the answers and are still thinking about problems even in intro physics—how do the basic principles apply to this? what's best way to present that? They are still students too.

Now for some wisdom from the *I Ching*:

> Nine in the fifth place means:
>
> Flying dragon in the heavens.
>
> It furthers one to see the great man.
>
> Nine at the top means:
>
> Arrogant dragon will have cause to repent.

When all the lines are nines, it means:

There appears a flight of dragons without heads.

Good fortune.

Translators: Richard Wilhelm & Cary Baynes (Wilhelm & Baynes 1967).

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