

# Studying Physics

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In the 40-some years that I have been interacting with undergraduate Physics students, I have learned a little bit about how to effectively study by watching what works and what doesn't work for students. This document outlines some of the things that I have learned. Some of what appears below is applicable to studying subjects other than Physics, both in the sciences and in other disciplines, although I will concentrate on Physics.

Of course, the best way to do as well as possible on the tests and exam requires knowing the material on which you are being tested. The final section of this document discusses some further ideas about how to do well on the tests and exam.

## ***General Principles***

Physics involves only a few powerful concepts. Once you fully understand those concepts, applying them to answer questions about a physical situation or solve a problem is easy. However, full understanding of those concepts takes some time. The data show that in Physics a last-minute cram is not nearly as effective as working at a steady pace each and every week. So the 1<sup>st</sup> general principle is:

1. Keep up with your studies

Some disciplines will require you to know a large number of facts for the tests and examinations. For those disciplines, a last-minute cram can actually work. It won't work in Physics.

Physics is like building a house: we first build a foundation, and then build the 1<sup>st</sup> floor on the foundation, and then a 2<sup>nd</sup> floor on top of the 1<sup>st</sup> floor, etc. If the foundation is not strong, then the 1<sup>st</sup> floor may fall down. Similarly, if the 1<sup>st</sup> floor is poor the 2<sup>nd</sup> floor will be too. So the 2<sup>nd</sup> general principle is:

2. Be sure to understand the previous concepts before trying to learn the new ones.

A few years ago Harvard identified a large number of characteristics and behaviours of their 1<sup>st</sup> year students, and looked for correlations with academic success. The only thing that they found that was a good predictor of success was whether or not the student was a participant in a study group with his/her classmates. There is a large body of data that

show that this is a general rule, not just for Harvard students, so the 3<sup>rd</sup> general principle is:

3. Join or form a study group.

Some students learned a survival strategy in their high school Physics class of memorising all the equations. Then on the tests just find the right equation and “plug and chug” to the answer. This strategy will not work for University-level Physics. So:

4. Don't try to memorise your way through the course.

A typical physicist's education about, say, classical mechanics first consisted of learning about it in high school. Then their 1<sup>st</sup> year University Physics course devoted a lot of the term to studying classical mechanics again. In their 2<sup>nd</sup> or 3<sup>rd</sup> year of undergraduate studies they took a full half-course in classical mechanics. Then in their 1<sup>st</sup> year of graduate studies they took yet another full half-course in classical mechanics. Each iteration of the course studied the topic in much greater depth and sophistication. Similarly, you may have studied many of the topics of this course in your high school Physics course. However the level in this course will be considerably deeper and more sophisticated than the high school version.

5. Don't think that you already know the material of the course at an appropriate level.

A common model, used by both students and teachers, is that the process of learning is basically filling up the brain with knowledge. In this model, the learner need only passively absorb the information being presented by the teacher, textbook, lab or Practical, homework problem, etc. The data are clear that good learning doesn't happen this way. To learn, you must expend time and effort. Often you will need to “wrestle” with the ideas. When you don't understand, don't just blow the concept off. So, our final general principle is:



6. Be aggressive in your learning.

The next section discusses one way to make your learning more aggressive.

## **Note Taking**

### **While Reading**

When we read a work of fiction, we typically read at about a page a minute. When reading a science textbook or course notes, this is much too fast to assimilate the large quantity of information that typically appears on each and every page. One good way to force ourselves to slow down and pay close attention is to take detailed notes while reading. The notes should be **complete**. In particular, it is worthwhile to:

- Write down all definitions.
- Write down a summary of all physical arguments leading to a conclusion.
- Write down all equations. When all of the steps between one equation and the next are not given, fill in those steps.
- Sketch all figures and diagrams. Include the labels and captions. Often the figures are more important than the words in understanding the topic being discussed.

Buying a ream (500 sheets) of cheap paper for your notes is usually a good investment.

What to do with the notes at the end is up to you. Some people just throw them in the blue box. Others find they form a useful study guide. What is important is the *process* of taking the notes while reading the course material. Part of that process is getting your hand, eye, and brain all coordinated. This coordination is a skill that will be very useful when you are writing the tests and exams for the course.

### **During Class**

Often in class, we find ourselves “tuning out” the instructor. Taking notes in class helps you to focus on what is being said. These notes should also be as complete as possible.

Shortly after class, it is an excellent idea to copy the notes you took in class into a more complete form, adding anything that was said and done during the class that you didn't have time to write down. The revised notes can often be a useful study guide later, so consider keeping them.

As with the notes you take while reading the textbook or course notes, the process of taking the revising the notes will also help in getting your hand, eye, and brain coordinated.

## ***Problem Solving***

One of the greatest physicists and teachers of the 20<sup>th</sup> century was Richard Feynman. He summarised the process of problem solving like this:

1. Write down the problem
2. Think very hard
3. Write down the answer

For most of the rest of us, a more complete list is necessary. Here is one such list:

1. **Form a model.** The real physical world is very complex, and almost always we form a simplified model of it to solve a particular problem. Explicitly writing down what model and simplifying assumptions are being made is often helpful.
2. **Visualise.** This is where most experienced problem-solvers spend most of their time. It is a crucial part of Feynman's "Write down the problem" step. The visualisation can include free-body diagrams, graphs, sketches of molecules, pictorial representations, and more.
3. **Guess the answer.** Use any physical principle, intuition, symmetry, or conservation law that you can think of to guess the answer. A correct guess reinforces your instincts. A wrong guess brings the refreshment of surprise. Guessing the answer like this before going any further is called *Wheeler's First Moral Principle* after John Archibald Wheeler, another great 20<sup>th</sup> century physicist and teacher.
4. **Solve.** For numeric problems, often this step mean casting the problem into one or more equations, and then solving the equations to get a final answer. Casting the problem into one or more equations is Physics; pushing the symbols around on a piece of paper with a pencil to get an answer is just mathematics.
5. **Assess.** Often we get a final answer and just stop, or perhaps check the answer against the answer in the back of the textbook or posted online without further thought. This is a poor idea. Instead, think about the answer first. Is it physically reasonable? Is it consistent with your guess? Are the units correct?

It definitely takes some self-discipline to explicitly go through each of these five steps when solving a problem, but experience shows that the time spent is definitely worthwhile.

I have some remarks to make about the **Solve** step #4 above. If a problem is numeric, often one solves some of the equations to get an intermediate one, and then uses the intermediate result to solve to get the final desired result. In such a case, you should **keep the problem algebraic until the very end**, when you put in the numbers. There are a number of reasons why this is important:

1. Putting in the numbers for the intermediate result, and then using that numerical value to get the final answer increases the chances that you will make an error in punching all the numbers into your calculator. By waiting until the very end, you need only use your calculator once.
2. Often there will be cancellations or simplifications in the equations, so you end up with a much simpler algebraic expression at the end to evaluate.
3. By putting the final answer into algebraic form first, you can assess that equation to see if it makes sense.

Here is an example. You have some physical system and find the following equations that describe the situation.

$$y_1 = \frac{1}{2}a_1t^2 \quad (1)$$

$$v = a_1t \quad (2)$$

$$a_2y_2 = \frac{1}{2}v^2 \quad (3)$$

You are to find  $y_1 + y_2$  when  $a_1 = 39.2 \text{ m/s}^2$ ,  $a_2 = 9.80 \text{ m/s}^2$ ,  $t = 10.0 \text{ s}$ . We will solve by putting in the numbers at each step, and then solve it again by putting in the numbers at the end.

Although Eqns. 1 – 3 suggest that this is a problem involving kinematics, that is not important for illustrating the *process* of getting to the answer.

### Putting in the Numbers at Each Step

We can solve Eqn. 1 to get the value of  $y_1$

$$y_1 = \frac{1}{2}a_1t^2 = \frac{1}{2}(39.2 \text{ m/s}^2) \times (10.0 \text{ s})^2 = 1960 \text{ m} \quad (4)$$

Next we can directly solve Eqn. 2 to get the value of  $v$

$$v = a_1t = (39.2 \text{ m/s}^2) \times (10.0 \text{ s}) = 392 \text{ m/s} \quad (5)$$

Then we can solve Eqn. 3 for  $y_2$  using the value of  $v$  from Eqn. 5

$$y_2 = \frac{v^2}{2a_2} = \frac{(392 \text{ m/s})^2}{2 \times (9.80 \text{ m/s}^2)} = 7840 \text{ m} \quad (6)$$

So we can finally get the answer by combining Eqns. 4 and 6

$$y_1 + y_2 = (1960 \text{ m}) + (7840 \text{ m}) = 9800 \text{ m} \quad (7)$$

So this method of solving the problem requires doing four different calculations. There are lots of chances to make a mistake!

### Putting in the Numbers At the End

From Eqns. 2 and 3

$$y_2 = \frac{1}{2} \frac{v^2}{a_2} = \frac{1}{2} \frac{a_1^2 t^2}{a_2} \quad (8)$$

So

$$\begin{aligned} y_1 + y_2 &= \frac{1}{2} a_1 t^2 + \frac{1}{2} \frac{a_1^2 t^2}{a_2} \\ &= \frac{1}{2} a_1 t^2 \left( 1 + \frac{a_1}{a_2} \right) \end{aligned} \quad (9)$$

Now we can put in the numbers.

$$\begin{aligned} y_1 + y_2 &= \frac{1}{2} a_1 t^2 \left( 1 + \frac{a_1}{a_2} \right) \\ &= \frac{1}{2} (39.2 \text{ m/s}^2) \times (10.0 \text{ s})^2 \left( 1 + \frac{39.2 \text{ m/s}^2}{9.80 \text{ m/s}^2} \right) \\ &= 9800 \text{ m} \end{aligned} \quad (10)$$

The two methods give the same answer provided we didn't make any mistakes. But by putting in the numbers at the end we got to the solution faster, and only had to use our calculator once. Further, using your calculator in a simple-minded way the first method required inputting 10 numbers, while the second method only required 6. So the chances of making a mistake are much much less by putting in the numbers at the end.

### Different Components of a Course

A typical science course consists of classes, textbook or course note readings, perhaps a practical, perhaps a tutorial, perhaps a laboratory, homework problems, and sometimes

more. Each component of the course takes a somewhat different perspective on the same underlying content.

It is important to realise that each of these components of the course all have the same goal: to assist you in learning the content so that you may do well on the tests and exams. So, for example, when you are doing a laboratory or practical try to remember that what you are learning there is part of the process of understanding the material of the course. Similarly for all of the other parts of your course: they are all trying to help you understand the important concepts and facts of the course.

### **Do *MasteringPhysics* Yourself!**

We use *MasteringPhysics* software to deliver homework problems. Since the problems are delivered via the web, we cannot be sure that it is actually you sitting at the terminal, and cannot know whether you are solving the problems yourself or are just copying answers that you got from a friend.

One feature of the software is that it tracks everything that you type and when you typed it. So we can identify students who enter the answer to a problem in less than a couple of minutes from when the problem was first shown to them. Perhaps some of these students had a printout of the question, and had solved it before logging in to *MasteringPhysics*. Perhaps some of them had solved the problem in a study group, and so one member of the group had taken a reasonable time from beginning to end, with the other members of the group able to enter the answer very quickly. However, it is reasonable to assume that the vast majority of these “fast” students had gotten the answer from somebody else and just copied it into the system.

When the overall performance of these “fast” students was looked at, it was found that their marks on the tests and examinations were almost a full letter grade less than the students who took a reasonable time to answer the questions. The conclusion is that doing the *MasteringPhysics* questions yourself really does help you learn the material, and that the learning will be demonstrated on the tests and examinations. You can “do the math” and conclude that your final mark in the course will also be much higher if you solve the problems yourself!

### ***Test and Exams***

I often see students who on a test give a pretty good answer to a question that is **not** the one being asked. Of course, marks are only given for correct answers to the question that *is* being asked. Be sure to carefully read the question, so you are sure what the question is.

When we are nervous, adrenaline and all sorts of other chemicals start rushing through our blood stream. If we let them, these chemicals will start thinking for us. But

chemicals are stupid! One of your main goals during a test is to think with your very smart brain, not those stupid chemicals. Some ways to achieve this are:

1. Some time well before the test begins, stop studying! Instead, consider going for a walk. The last-minute cram will get all those chemicals going, and will be almost certain to cause more confusion than understanding.
2. As you walk into the test, tell yourself: "I understand this material so well that this will be really easy." Try to believe yourself! Of course, this is easier said than done, but nonetheless you want to try to achieve a state of calm confidence.
3. During the test, when you don't think you know how to do a question don't stress, just go on to another question. Later when you come back to the difficult question, you will often be pleasantly surprised to discover that you now know how to do it.
4. During the test, remember the advice you may have heard from your mother, grandmother, or maybe Aunt Tilly: good posture and good breathing.

So far our discussion of doing as well as possible applies to a test or exam in any course. In Physics, there is another issue about tests. Typically somewhat over half of the marks on each test are from multiple-choice questions. For a course which emphasises facts, students can answer a typical multiple-choice question in just one minute or so, which allows for many questions on the test, each of which is worth only a small mark. Physics emphasises concepts and applying them to solve problems. A typical multiple-choice question on a Physics test, then, takes about 5 minutes or more to do. This means that a typical Physics test will have about one-fifth as many multiple-choice questions on it than a test in a course which is fact based, and each question will therefore have to count for more marks.

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The figure on page 2 has been around on my discs for so long that I don't remember where I got it. If it is yours and you want it removed or a credit added, please contact me.

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