Physics 54

Course Syllabus and Description

General Course Information

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Text:

Tipler and Mosca, *Physics for Scientists and Engineers*
Volume 2, sixth edition, ISBN 1-4292-0133-9.

Online Text:

Brown, *Introductory Physics II*
http://www.phy.duke.edu/~rgb/Class/intro_physics_2.php

Course Syllabus:

http://www.phy.duke.edu/~rgb/Class/phy54.php

Wikilinks

In my opinion Wikipedia is well on its way to becoming the "Universal Textbook", with link chapters that span almost any subject especially in physics, mathematics, philosophy – things people care about.

I would suggest that as you study, at your own convenience you take "wikiromps" starting at any of the following links and following article links as it suits you until you have a pretty good understanding of the history and basic concept associated with the following ideas or laws. We'll then work extensively in class and recitation to turn that initial understanding into deep operational knowledge.

This list will expand as we encounter new concepts during the semester, although (as you'll note) you may well get to them quite early on your wikiromps as links will carry you quickly from "intro" level articles to graduate school level articles. Read and become familiar at your own pace, but don't hold back on following links to more difficult or advanced articles.

- Wikipedia: http://www.wikipedia.org/wiki/Electric Charge
- Wikipedia: http://www.wikipedia.org/wiki/Electricity
- Wikipedia: http://www.wikipedia.org/wiki/Coulomb's Law
- Wikipedia: http://www.wikipedia.org/wiki/Electric Field
- Wikipedia: http://www.wikipedia.org/wiki/Gauss's Law
- Wikipedia: http://www.wikipedia.org/wiki/Electric Potential
- Wikipedia: http://www.wikipedia.org/wiki/Capacitance
- Wikipedia: http://www.wikipedia.org/wiki/Dielectric
- Wikipedia: http://www.wikipedia.org/wiki/Electric Current
- Wikipedia: http://www.wikipedia.org/wiki/Electrical Resistance
- Wikipedia: http://www.wikipedia.org/wiki/Ohm's Law
- Wikipedia: http://www.wikipedia.org/wiki/Magnet

- Wikipedia: http://www.wikipedia.org/wiki/Magnetic Field
- Wikipedia: http://www.wikipedia.org/wiki/Magnetization
- Wikipedia: http://www.wikipedia.org/wiki/Ampere's Law
- Wikipedia: http://www.wikipedia.org/wiki/Biot-Savart Law
- Wikipedia: http://www.wikipedia.org/wiki/Electromagnetic Induction
- Wikipedia: http://www.wikipedia.org/wiki/Faraday's Law
- Wikipedia: http://www.wikipedia.org/wiki/Alternating Current
- Wikipedia: http://www.wikipedia.org/wiki/Transformer
- Wikipedia: http://www.wikipedia.org/wiki/High Pass Filter
- Wikipedia: http://www.wikipedia.org/wiki/Low Pass Filter
- Wikipedia: http://www.wikipedia.org/wiki/Band Pass Filter
- Wikipedia: http://www.wikipedia.org/wiki/RLC Circuit
- Wikipedia: http://www.wikipedia.org/wiki/Crystal Radio
- Wikipedia: http://www.wikipedia.org/wiki/Maxwell Displacement Current
- Wikipedia: http://www.wikipedia.org/wiki/Maxwell's Equations
- Wikipedia: http://www.wikipedia.org/wiki/Light
- Wikipedia: http://www.wikipedia.org/wiki/Poynting Vector
- Wikipedia: http://www.wikipedia.org/wiki/Electromagnetic Spectrum
- Wikipedia: http://www.wikipedia.org/wiki/Snell's Law
- Wikipedia: http://www.wikipedia.org/wiki/Polarization
- Wikipedia: http://www.wikipedia.org/wiki/Mirrors
- Wikipedia: http://www.wikipedia.org/wiki/Lenses
- Wikipedia: http://www.wikipedia.org/wiki/The Eye

- Wikipedia: http://www.wikipedia.org/wiki/Simple Magnifier
- Wikipedia: http://www.wikipedia.org/wiki/Microscope
- Wikipedia: http://www.wikipedia.org/wiki/Telescope
- Wikipedia: http://www.wikipedia.org/wiki/Interference
- Wikipedia: http://www.wikipedia.org/wiki/Diffraction
- Wikipedia: http://www.wikipedia.org/wiki/Diffraction Grating

Be sure to not just read these articles, but *wikiromp through the connected links within them!* This can actually be a lot of fun, as many of these ideas are very cool, and link naturally to *other* extremely interesting ideas as well.

Course Description

0.0.1 Course Description

In this course we will cover the following basic topics:

- Electrostatics. Charge, electric force, electric field and Coulomb's law, Gauss's law, electric potential. Capacitance and dielectrics.

- Magnetostatics. Current, magnetic force, magnetic field and the Biot-Savart law, Ampere's law. Magnetic moments, torque, magnetic precession. Magnetic materials (diamagnetism, paramagnetism, ferromagnetism).

- Electromagnetic Induction. Motional EMF, induced voltage, Faraday's law, Lenz's law. Mutual and self inductance. Generators.

- Elementary circuits (DC and AC). Kirchoff's rules. Ohm's law. Time-varying potentials, RC, LR, LRC circuits. High pass, low pass, band pass filters, and Q.

- The Maxwell displacement current and its connection to charge conservation. Maxwell's equations. The electromagnetic wave equation and light. Energy density, the Poynting vector, radiation pressure.

- Properties of light. Snell's law, simple polarization (absorption, scattering, reflection), Huygen's principle, dispersion, the spectrum. Geometric optics and ray diagrams: mirrors, lenses, the eye, optical instruments. Physical (wave) optics: thin film interference, 2,3,4...N slit interference, single slit diffraction, diffraction gratings.

Your grade will be based on *approximately* the following scheme:

20% of grade Homework.

20% Quizzes

20-30% Hour Exams (3)

20-30% Final

10% Lab

Optional, 1/3 letter grade Extra Credit Project

Here's how the scheme works. First of all, note that there will be *lots* of homework problems. Homework is an *essential* part of learning physics and must not be neglected. I expect all students to do the assigned problems and to at least skim-read the chapters before we cover them in class. Remember, we're doing close to a chapter a day, so falling behind is not an option! I will sample-grade homework – grade degree of completeness and effort and one problem I pick out of the assignment (which you will *not* know beforehand).

The final exam can replace any *one* hour exam grade, provided that it is higher. This allows students to make up for their worst single hour exam performance with their final, so one bad exam day won't hurt your grade.

In most years, if you get below a 50 (and the curve is otherwise reasonable) and have not religiously handed in your homework, you fail (F). If you get less than a 60 and have not religiously handed in your homework, you get an D. If you get 60 or more you get a C- or better and "pass". If you have religiously done your homework, but have somehow managed to end up less than a 60 or (worse) 50, this will be taken into account and adjustments *may* be made at my discretion. If you have not consistently done and handed in your homework on time, though, very little consideration will be given!

Note that the class performance *will* be plotted on a histogram and adjustments to the above scheme will be made as required by the distribution. In addition, I reserve the right to make modest changes in the exact percentages I assign to any particular component of the grade – there is some variation from year to year in the amount of homework, the number of quizzes, and the difficulty of the exams. Finally, I reserve the right to adjust your distribution-determined grade (up *or* down) in consultation with Ken if for any reason we feel that this grade does not correctly reflect your degree of learning.

The Rules

- You **may** collaborate with your classmates in any permutation on the **homework**. In fact, I *require* you to work in groups whenever possible, as you will all learn more that way. However, you must **each** write up *all* the solutions even if they are all the same within a group. Writing them up provides learning reinforcement.

- You may **not** get *worked out solutions to Tipler problems* to help you with the homework from more advanced students, from former students of mine , from a Tipler solution manual, from the web, or from anyplace else. It obviously removes the whole point of the homework in the first place. No solutions can be present (except ones you yourselves have worked out and are sharing with each other in your groups) when you are working on the problems.

- You **may** ask more advanced students, former students, other faculty, personal friends, or your household pets for help or tutoring on particular problems, as long as *no worked–out solutions to the assigned problems are present when you work with them.* They must work *with* you collaboratively to solve the problem, not give you a solution to copy. Again, if you work in groups I *encourage* you to take turns teaching each other how to work through to the solutions to the problems you encounter, as teaching is an excellent way (perhaps the best way) to learn.

- You **may** use the library and all available non–human resources to help solve the homework problems. I don't even care if you find the solution somewhere (other than on the web, which is strictly prohibited) and **copy it verbatim** provided that you **understand it afterwards** (which is the primary goal), **cite your source**, and provided that you do **not** use any resource labelled as a solution for Tipler problems I would prefer that you do not routinely look for solutions rather than work them out yourself; save this approach for the toughest problems. Remember, you can't take these resources into an exam with you; you will need to learn to solve the problems on your own. On the other hand, real problem solving often involves a certain amount of library research.

- Ken and I and the graders are important resources. You can always ask us how to solve a problem, and if we can see that you've at least tried it on your own we'll almost always be happy to walk you through it.

- **Quizzes and Exams:** All quiz and exam problems are to be worked out **alone**. Calculators may be used on physics exams but the storing of physics formulae or other crutches in calculator memory or firmware is strictly prohibited. Looking at or copying other students' work is obviously not permitted, and *will be severely penalized if discovered*. I *assume* that all my students are honorable persons and will play the game honestly in accord with the letter and the spirit of the Duke Community Standard – do not damage your own honor and spirit by behaving dishonorably in my class.

  Remember, I don't like grading you any more than you like being graded, and ultimately your *grade in this class does not matter*, at least not nearly as much as you might think it does. What *does* matter is how much you *learn* – if you are getting a poor grade, it most likely reflects a failure to give the course the attention and effort it deserves and requires in order to properly facilitate that learning. Don't try to cheat your way to an empty and meaningless grade – come talk to me and we'll see if we can't repair your learning methodology to *earn* you a better one!

Structure and Expectations

I've been teaching intro physics at Duke now for over 27 years at this point. I know from experience how important it is for you all to establish a healthy work rhythm from the beginning. The primary expectation I have of you is that you will all work *hard* to learn physics, but at the same time I want you to have *fun*. I'll be working just as hard with you, and hopefully having just as good a time (because physics *is* fun, actually, if you aren't scared of it and open your minds). Hard work leads to great rewards in *anything* you put your hand and mind to, and I don't just mean in physics.

This course is extremely problem-oriented. One truly *learns* physics by learning how to think of and solve physics problems. The problems assigned are carefully selected to both illustrate important principles and to make you analyze and develop complex, multistep solutions that require conceptual insight and guidance. You will *not* be expected to do this often difficult work in a vaccuum – the course is carefully designed so that *every* student should be able to get 100% of their homework (at least) perfectly correct.

The following describes the structure of the class and what you should do to take maximum advantage of it.

- We'll be covering the course in a week-by-week rhythm, following the online lecture note style textbook for this course, supplemented with Tipler whereever the online material gets thin. Everything builds on everything that preceded it, and this doesn't give you as much time as you might think to "get" a difficult concept, especially if you wait until each one is taught in class. Get used to reading and studying each chapter on your own right **before** the relevant lectures, and again when you tackle your homework, and again in recitation where we go over the homework, and again when you go over your homework and quizzes, and again before the hour exam, and again before the final. You will need to overlap this in order to get enough "views" of the material to make learning relatively easy.

- Lecture is intended to present a general, conceptual, derivational overview of the principles and laws of the physics being covered. It will be rich with examples, but real problem solving methology will primarily be self-taught and learned in your study groups, with close support from me during recitation.

- Recitation will be used to go over the most difficult homework problems in small groups. This is intended to be a time when you teach each other, and learn thereby. I will move from group to group and provide tutorial support. A graded short quiz will generally terminate recitation.

- There will be 3 hour exams over the course of the semester. This is every four to five weeks. Their location in the schedule below is *approximate*, but I usually speed up or slow down a bit depending on the individual characteristics of each class, so I may reschedule them by a few days either way if we go unusually fast or slow. *Do not count* on these dates being firm.

- Lab. Lab is an important "hands on" part of the course, and Ken has a selection of labs for this course that cover the primary topics. Note well that the *purpose* of lab in an elementary physics course is to *convince yourself that all the stuff you are being taught is true!* This is a one of the most important things about science that you can learn. Science does not proclaim its truth, it *invites your doubt* instead. You can and indeed will be *required* to *test* enough of the things we cover to convince yourself that they, and very likely the rest of what you are trying to learn, is true and agrees with your observations of nature.

- Extra Credit Project. If you (with my help and project approval and with Ken's help) can think up any sort of project that explores some aspect of physics covered in this course and complete the project by the end of the session, you will be awarded a **1/3 letter grade promotion** over the grade you would otherwise receive. This is a significant boost, and is "non-failure insurance" for students that are struggling for any reason, as a promotion from an F is to a D, from a D to a C-.

  We'll all have to do some work to look for suitable projects – they need to require enough work to be worthy of a promotion while not distracting you too much from the course proper, and *good* projects will be at least considered for an even greater promotion.

  Projects you might think of include: Building a crystal radio, a microscope, a telescope, an electromagnetic motor. Projects can be experimental/laboratory, constructional (building something), simulational (programming something), or paper/library/web research (term papers) although this latter is somewhat discouraged.

Projects *must* be approved ahead of time to receive credit. Projects are graded in binary – either you're promoted or you aren't. If the project is handed in in time for me to look at it and give you feedback with some time remaining in the session to fix problems, you will have a chance to repair any weaknesses and still get promoted. Projects handed in at the last minute get what they get (which may be nothing at all).

Note well: Projects cannot be used as failure insurance (or for a promotion) if you have not *done all of your homework* as the semester proceeds. It is designed to help good students, even good students who struggle, not bad students who may well have been able to manage a B on their own but didn't bother.

Personal Availability and Methods of Contact

I am available by appointment at any time I am free during the week. I am teaching every morning between roughly 10 am and noonish, and all Wednesday afternoon, but otherwise I can very likely arrange a meeting. This seems to work better than “office hours”, as any particular time slot I reserved would doubtless conflict with 1/3 of the class’s schedule. Send me email to request a meeting, or talk with me after class or in recitation to set something up.

Ken is available on a similar basis – appointment via email – if email communication alone doesn’t resolve your difficulty.

How to Do Your Homework Effectively

By now in your academic career it should be very apparent just where homework exists in the grand scheme of (learning) things. Ideally, you attend a class where a warm and attentive professor clearly explains some abstruse concept and a whole raft of facts in some moderately interactive way. Alas, there are *too many* facts to fit in short term/immediate memory and *too little time* to move most of them through into long term/working memory before finishing with one and moving on to the next one. As a consequence, by the end of lecture you've already *forgotten* many if not most of the facts, but if you were paying attention, asked questions as needed, and really cared about learning the material you *would* remember a handful of the most important ones, the ones that made your brief understanding of the material hang (for a brief shining moment) together.

Studies show that you are only likely to retain anywhere from 5% to 30% of what you are shown in lecture. Clearly this *is not enough* to make the information conceptually useful, to *learn* it. In order to actually learn, you must *stop* being a passive recipient of facts. You must *actively* develop your understanding, by means of *discussing* the material and kicking it around with others, by *using* the material in some way, by *teaching* the material to peers as you come to understand it.

Medical schools have long been aware of this. In the year 1907, medical schools had two years of coursework to prepare a student to be a physician. In the year 2007, they are *still* two years of coursework – but the amount of science and medicine that is taught in those two years has *exploded*. They have developed the following mantra to help their students understand the only way the process can still work:

- See one. (E.g. a procedure)
- Do one. (with a mentor standing by)
- Teach one. (still with a mentor, but a more advanced one still)

That's it! We will use our own version of this same process in this course. Lecture (seeing it done) is important – it sets the stage for the learning, but by itself it teaches little. Homework (doing it yourself) is far more important.

This is when you *begin* to really learn. Recitation (where you teach each other where you have learned) is where you solidify this learning by articulating it, working with the concepts in your mind at a high level to do so.

To help facilitate this process, associated with lecture your professor (me) gave you an *assignment*. Amazingly enough, its purpose is not to torment you or to be the basis of your grade (although it may well do both). It is to give you some concrete stuff to *do* while thinking about the material to be learned, while discussing the material to be learned, while using the material to be learned to accomplish specific goals, while teaching some of what you figure out to others who are sharing this whole experience while being taught by them in turn.

In other words, to learn you must *do your homework*, ideally at least partly in a *group* setting. The only question is: *how* should you do it to both finish learning all that stuff you sort-of-got in lecture and to re-attain the moment(s) of clarity that you then experienced, until eventually it becomes a permanent characteristic of your awareness and you *know* and *fully understand* it all on your own?

There are two general steps that need to be *iterated* to finish learning anything at all. They are a lot of work. In fact, they are far *more* work than (passively) attending lecture, and are *more important* than attending lecture. You can learn the material with these steps without *ever* attending lecture, as long as you have access to what you need to learn in some media or human form. You in all probability will *never* learn it, lecture or not, without making a few passes through these steps. They are:

1. Review the whole (typically textbooks and/or notes)
2. Work on the parts (do homework, use it for something)

(iterate until you thoroughly understand whatever it is you are trying to learn).

Let's examine these steps.

The first is pretty obvious. You didn't "get it" from one lecture. There was too much material. If you were *lucky* and well prepared and blessed with a good instructor, perhaps you grasped *some* of it for a *moment* (and if your instructor was poor or you were particularly poorly prepared you may not have managed even that) but what you did momentarily understand is fading, flitting further and further away with every moment that passes. You need to review the entire topic, as a whole, as well as all its parts. A set of good summary notes might contain all the relative factoids, but there are *relations* between those factoids – a temporal sequencing, mathematical derivations connecting them to other things you know, a topical association with other things that you know. They tell a *story*, or part of a story, and you need to know that story in *broad* terms, not try to memorize it word for word.

Reviewing the material should be done in layers, skimming the textbook and your notes, creating a *new* set of notes out of the text in combination with your lecture notes, maybe reading in more detail to understand some particular point that puzzles you, reworking a few of the examples presented. Lots of increasingly deep passes through it (starting with the merest skim-reading or reading a summary of the whole thing) are *much* better than trying to work through the whole text one line at a time and not moving on until you understand it. Many things you might want to understand will only come clear from things you are exposed to *later*, as it is not the case that all knowledge is ordinal, hierarchical, and derivatory.

You especially do *not* have to work on *memorizing* the content. In fact, it is *not* desireable to try to memorize content at this point – you want the big picture *first* so that facts have a place to live in your brain. If you build them a house, they'll move right in without a fuss, where if you try to grasp them one at a time with no place to put them, they'll (metaphorically) slip away again as fast as you try to take up the next one. Let's understand this a bit.

Your brain is fabulously efficient at storing information in a *compressed associative* form. It also tends to remember things that are *important* – whatever that means – and forget things that aren't important to make room for more important stuff. There are lots of experiments that demonstrate this – the simplest being trying to memorize a string of ten or so numbers at a glance (more than the 7 one can typically get into short term memory).

Try memorizing 1357902468 from just the *one* glance you got reading this sentence. No fair going back and repeating it to yourself, at least while looking at it! Now look at it and try to remember it. One strategy is to just repeat it to yourself until you get it right, but if you stare at it a while and *think*, you'll see that it has a very simple pattern embedded in it.

In fact, this number "compresses" to a single two-step rule – all the odd digits in ascending order followed by all the even digits ditto. You *already know* what a "digit" is, what odd and even numbers are, what ascending versus descending order is. You only need to remember "ascending" and "odd followed by even digits" – everything else is compressed. You will almost certainly be able to remember the digit string *tomorrow* without further rehearsal because of this rule and the fact that it illustrates an interesting point, where if you didn't notice the pattern and just memorized it as a string of "random" numbers, devoid of any meaning, your brain would have little reason to retain it as it is "unimportant". Even if you *forget* this particular string, you may well remember the point and use a *different* string like 1212121212 (five repetitions of 12) to illustrate the *same* point when teaching it to someone else. This is fine! My goal, too, is to teach you *this*, not some particular patterned set of numbers neither of us really cares about.

This ability to compress goes far beyond what I can explain or you can easily imagine. When I play a game of chess, I've forgotten my first five moves by the time I've made my tenth move. By the time the game finishes, I have no idea how I got into the mess I'm probably in. A chess *master*, on the other hand, can *finish* the game and then can recontruct the *entire game* in order, and can criticize each move as they do so. In fact, they can probably remember the entire game they played yesterday, or the one they played last week. They've built a complex structure of associative memory so that they don't remember moves the same way you or I do.

On the other hand, *I* can often remember what mistakes a student of mine made a week after grading one of their papers. I many not remember the student's *name* (no good associative memory there) but I've got great structures for remembering how to solve or not solve physics problems and remember only what the student did *wrong* – I already know how to do what they did right.

This is the goal of your iterated review process. At first you are memorizing things the hard way, trying to connect what you learn to very simple hierarchical concepts such as this step comes before that step. As you do this over and over again, though, you find that absorbing new information takes you less and less time, and you remember it much more easily and for a longer time without additional rehearsal. Sometimes your brain even *outruns* the learning process and "discovers" a missing part of the structure before you even read about it! By reviewing the whole, well-organized structure over and over again, you gradually build a greatly compressed representation of it in your brain and tremendously reduce the amount of work required to flesh out that structure with increasing levels of detail *and remember them and be able to work with them* for a long, long time.

Now let's understand the second part of doing homework – working problems. As you can probably guess on your own at this point, there are good ways and bad ways to do homework problems. The worst way to do homework (aside from not doing it at all, which is *far too common* a practice and a *bad idea* if you have any intention of learning the material) is to do it all in one sitting, right before it is due, and to never again look at it.

It is left as a *homework exercise* for the student to work out why this is a bad idea from the discussion and facts given above. So take a minute and think about it, then continue...

* * *

Let's see, doing your homework in a single sitting, working on it just one time *fails to repeat and rehearse the material* (essential for turning short term memory into long term in nearly all cases). It *exhausts the neurons in your brain* (quite literally – there is metabolic energy consumed in thinking) as one often ends up working on a problem far too long in one sitting just to get done. It *fails to incrementally build up* in your brain's long term memory the *structures* upon which the more complex solutions are based, so you have to constantly go back to the book to get them into short term memory long enough to get through a problem. Even this simple bit of repetition does *initiate* a learning process. Unfortunately, by not repeating them after this one sitting they soon fade, often without a discernable trace in long term memory.

Just as was the case with memorizing the number above, the problems almost invariably are *not* going to be a matter of random noise. They have certain key facts and ideas that are the basis of their solution, and those ideas are used over and over again. There is plenty of pattern and meaning there for your brain to exploit in information compression, and it may well be *very cool stuff to know* and hence *important* to you once learned, but it takes time and repetition and a certain amount of meditation for the "gestalt" of it to spring into your awareness and burn itself into your conceptual memory as "high order understanding".

You have to *give* it this time, and perform the repetitions, while maintaining an optimistic, philosophical attitude towards the process. You have to do your best to have *fun* with it. You don't get strong by lifting light weights a single time. You get strong lifting weights repeatedly, starting with light weights to be sure, but then working up to the *heaviest weights you can manage*. When you *do* build up to where you're lifting hundreds of pounds, the fifty pounds you started with seems light as a feather to you.

As with the body, so with the brain. Alternate broad-stroke reviews for the big picture with increasingly deep and "heavy" excursions into the material to explore it in detail as the overall picture emerges. Intersperse this with sessions where you *work on problems* and try to *use* the material you've figured out so far. Be sure to *discuss* it and *teach it to others* as you go as much as possible, as articulating what you've figured out to others both uses a different part of your brain than taking it in (and hence solidifies the memory) and it helps you articulate the ideas to *yourself!* This process will help you learn more, better, faster than you ever have before, and to have fun doing it!

Your brain is more complicated than you think. You are very likely used to *working hard* to try to *make* it figure things out, but you've probably observed that this doesn't work very well. A lot of times you simply *cannot* "figure something out" because your brain doesn't yet know the key things required to *do* it, or doesn't "see" how those parts you do know fit together. Learning and discovery is not, alas, "intentional" – it is more like trying to get a bird to light on your hand that flits away the moment you try to grasp at it.

People who do really hard crossword puzzles (one form of great brain exercise) have learned the following. After making a pass through the puzzle and filling in all the words they can "get", and maybe making a couple of extra passes through the puzzle after that thinking hard about ones they *can't* get, looking for patterns, trying partial guesses, they sooner or later arrive at an impasse – they are done. If they continue working hard on the puzzle, they are unlikely to make further progress, no matter how long they stare at it.

On the other hand, if they *put the puzzle down* and *do something else for a while* – especially if the something else is go to bed and sleep – when they come back to the puzzle hours, a day, or even days later, they often can *immediately see* a dozen or more words that the day before were absolutely invisible to them. Sometimes one of the *long theme answers* (perhaps 25 characters long) where they have no more than *two letters* just "gives up" – they can simply "see" what the answer must be.

Where do these answers come from? The person has not "figured them out" with their conscious mind, their conscious mind has "recognized" them. They come all at once, and they don't come about as the result of a logical sequential process.

Often they come from the person's *right brain*. The left brain tries to use logic and simple memory when it works on crossword puzzles. This is usually good for some words, but for many of the words there are *many possible answers* and without any insight one can't even recall *one* of the possibilities. The clues don't suffice to connect you up to a word. Even as letters get filled in this continues to be the case, not because you don't *know* the word (although in really hard puzzles this can sometimes be the case) but because you don't know how to *recognize* the word "all at once" from a cleverly nonlinear clue and a few letters in this context.

The right brain is (to some extent) responsible for *insight* and *non-linear thinking*. It sees *patterns*, and *wholes*, not sequential relations between the parts. It isn't intentional – we can't "make" our right brains figure something out, it is often the other way around! Working hard on a problem, then "sleeping on it" is actually a *great* way to develop "insight" that lets you solve it *without really working terribly hard* after a few tries. It also utilizes more of your brain – left and right brain, sequential reasoning and insight, and if you articulate it, or use it, or make something with your hands, then it exercises these parts of your brain as well, strengthening the memory and your understanding still more. The learning that is associated with this process, and the problem solving power of the method, is *much greater* than just working on a problem linearly the night before it is due until you hack your way through it using information pulled a part at a time from the book and then forgotten just as quickly.

The information above is provided to help you figure out how to learn as effectively as possible with a limited amount of time to study. All of the above is compressed into the following "method of three passes" for doing your physics homework. What is that?

I'm glad you asked....

The Method of Three Passes

Pass 1 Three or more nights before recitation (or when the homework is due), make a *fast* pass through all problems. Plan to spend 1-1.5 hours on this pass. With roughly 10-12 problems, this gives you around 6-8 minutes per problem. Spend *no more* than this much time *per problem* and if you can solve them in this much time fine, otherwise move on to the next. Try to do this the last thing before bed at night (seriously) and *then go to sleep*.

Pass 2 After at least one night's sleep, make a *medium speed* pass through all problems. Plan to spend 1-1.5 hours on this pass as well. Some of the problems will already be solved from the first pass or nearly so. *Quickly* review their solution and then move on to concentrate on the still unsolved problems. If you solved 1/4 to 1/3 of the problems in the first pass, you should be able to spend 10 minutes or so per problem in the second pass. Again, do this right before bed if possible and then go immediately to sleep.

Pass 3 After at least one night's sleep, make a *final* pass through all the problems. Begin as before by quickly reviewing all the problems you solved in the previous two passes. Then spend fifteen minutes or more (as needed) to solve the remaining unsolved problems. Leave any "impossible" problems for recitation – there should be no more than three from any given assignment, as a general rule. Go immediately to bed.

This is an *extremely powerful* prescription for deeply learning nearly *anything*. Here is the motivation. Memory is formed by repetition, and this obviously contains a lot of that. Permanent (long term) memory is actually formed in your sleep, and studies have shown that whatever you study right before sleep is most likely to be retained. Physics is actually a "whole brain" subject – it requires a synthesis of both right brain visualization and conceptualization and left brain verbal/analytical processing – both geometry and algebra, if you like, and you'll often find that problems that stumped you the night before just solve themselves "like magic" on the second or third pass if you work hard on them for a short, intense, session and then sleep on it. This is your right (nonverbal) brain participating as it develops intuition to guide your left brain algebraic engine.

Other suggestions to improve learning include working in a study group for that third pass (the first one or two are best done alone to "prepare" for the third pass). Teaching is one of the best ways to learn, and by working in a group you'll have opportunities to both teach and learn more deeply than you would otherwise as you have to articulate your solutions.

Make the learning *fun* – the *right* brain is the key to forming long term memory and it is the seat of your *emotions*. If you are happy studying and make it a positive experience, you will increase retention, it is that simple. Order pizza, play music, make it a "physics homework party night".

Use your *whole brain* on the problems – draw lots of pictures and figures (right brain) to go with the algebra (left brain). Listen to quiet music (right brain) while thinking through the sequences of events in the problem (left brain). Build little "demos" of problems where possible – even using your hands in this way helps strengthen memory.

Avoid "memorization". You will learn physics far better if you learn to *solve* problems and *understand* the concepts rather than attempt to *memorize* the umpty-zillion formulas, factoids, and specific problems or examples covered at one time or another in the class. Memory is transient; understanding is not.

Be sure to review the problems one last time when you get your graded homework back. Learn from your mistakes or you will, as they say, be doomed to repeat them.

If you follow this prescription, you will have seen *every assigned homework problem* a minimum of five or six times – three original passes, recitation itself, a final write up pass after recitation, and a review pass when you get it back. At least three of these should occur after you have solved *all* of the problems correctly, since recitation is devoted to ensuring this. When the time comes to study for exams, it should really be (for once) a *review* process, not a cram. Every problem will be like an old friend, and a very brief review will form a *seventh* pass for the hour exam or *eighth* pass for the final through the assigned homework.

With this methodology (enhanced as required by the instructor(s) and e.g. tutors) there is no reason for you do poorly in the course and every reason to expect that you will do well, perhaps very well indeed! And you'll *still* be spending only the 3-6 hours/week on homework that is *expected* of you in any course of this level of difficulty!

Syllabus and Tentative Schedule

The following is a *tentative* schedule for the semester. It probably will not survive intact, as I tend to slow down where people have trouble and speed up where it is smooth sailing. But it is *a* schedule that will carry us through the material in a timely way, and complete all the required work in the allotted time.

Note that this has all the assignments for the semester, at least as of now. As we go, I will review the homework assignments in terms of difficulty and feasibility and may adjust them, but for now, do all the unstarred problems.

Day	Chapter	Assignment
August 25-27	Course Intro, Week 1/Tipler21)	Week 1 HW (Due 09/02)
September 1-3	Week 2/Tipler 22	Week 2 HW (due 09/09)
September 8-10	Week 3/Tipler 23	Week 3 HW (due 09/16)
September 15-17	Week 4/Tipler 24/25	Week 4 HW (due 09/23)
September 22-24	Week 5/Tipler 26	Week 5 HW (due 10/7)
September 29-October 1	Week 6/Tipler 27	Study for 1st Exam
October 1-2	Hour Exam 1 (Weeks 1-4)	In Lab or by arrangement
October 6	Fall Break (no class)	
October 8	Week 6/Tipler 27	Week 6 HW (due 10/14)
October 13-15	Week 7/Tipler 28	Week 7 HW (due 10/21)
October 20-22	Week 8/Tipler 29	Week 8 HW (due 10/28)
October 27-29	Week 9/Tipler 30	Week 9 HW (due 11/4)
November 3-5	Week 10/Tipler 31	Week 10 HW (due 11/11)
November 6	Hour Exam 2 (Weeks 5-8)	In Lab or by arrangement
November 10-12	Week 11/Tipler 32	Week 11 HW (due 11/18)
November 17-19	Week 12/Tipler 33	Week 12 HW (due 12/2)
November 24-26	Thanksgiving	No additional work
December 1-3	Complete Week 12, makeup, review	
December 4	Hour Exam 3	In Lab or by arrangement
December 9	Final Exam, 2:00-5:00 p.m.	Room 130