# Physics 121
# Classical and Modern Physics I
# *"How to Think As a Physicist"*

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Office Hours: Frank 234B (x2162), TF 11:30-12:30, T 15:30-17:30, R 14:30-16:30
http://www.guilford.edu/physics/121

## 1 Course Outline and Philosophy

*Books on Physics are full of complicated mathematical formulae. But thought and ideas, not formulae, are the beginning of every physical theory.*
*– Albert Einstein and Leopold Infeld*

This is the first course of a three-semester sequence of introductory physics for physics majors. It is not a survey course in physics, but an introduction to the thinking process and techniques that physicists use to describe and understand the real world. It is a way of thinking that recognizes the provisional nature of all scientific knowledge, that looks at interacting through the world through model building, empirical testing of hypotheses, and proficiently applying quantitative estimations of physical quantities. A physicist is not satisfied with received wisdom, but always asks "why?" A physicist takes things apart to see how they work. If you embrace the goal of this course, it will open your eyes to entirely different world going on all around you and give you skills that you can apply in any career path you pursue.

Physics is not a spectator sport. It is vitally important that you engage with the material and with the instructor and your classmates. Questioning is encouraged. If you don't speak up, I will have to conclude that you think you understand the material. If you don't come get help, I must conclude you do not wish help. Please do not struggle alone and in silence. Talk to your peers; talk to more advanced students; talk to me. We will be happy to assist you. A good rule of thumb is that if you spend 15 minutes on a problem and have not yet figured out *how* to solve it, for goodness' sake, STOP and get help! It may take you longer than 15 minutes to actually *do* it, but you should be able to see *how* to do it in that time.

Please note that despite the quote that begins this section, this course does assume a familiarity with the basic principles of calculus. If you have not had calculus before now, you must take Calculus at the same time as Physics 121. You should also be familiar with trigonometric functions, logarithms, and matrix multiplication. If you need extra help with these topics, please make an effort to seek tutors in the learning commons, meet with me, or with the course teaching assistant.

The best way to contact me is to show up at my office hours or via e-mail. I don't respond well to telephone calls. If you cannot make it to my office hours, you may make an appointment to meet me during some time when I don't already have something scheduled. My schedule is available through my web site, which is linked from the course web page. Please suggest a time when we might meet when you contact me. If you just ask to make an appointment, I will ask you when you would like to meet, so you might as well save the extra step and pick a time that's free on my schedule as a starting suggestion. If I can't make that time, I'll make an alternative suggestion.

We will be using a course pack of readings from textbooks, papers, and essays as the text for this course (see section 2). Although the text will (I hope) be helpful in supporting your efforts to understand, the most important material will be dealt with in class. It is important that when reading is assigned, you do the reading before we engage with the material in class. Your in-class time will be much more interesting and productive if you have already given the book a cursory read before we meet to discuss that material. In class, we will do much, much more than simply go over what the text says, so IT IS VERY IMPORTANT THAT YOU ATTEND CLASS EVERY DAY. The text will be used as a reference and as a source of homework problems. Other textbooks are available for perusal in the Data Reduction Laboratory.

We will be using Matlab as the programming language for this course. It has both numerical and algebraic modes. We will spend some class time learning how to use this program. Where appropriate, I will expect that you use this program while solving problems. Matlab is available on the Mac computers in the physics department.

The most crucial skill a physicist can develop is the ability to ask questions. We will therefore encourage the asking of questions in this class. Although we will follow a tentative schedule (see section 8), your curiosity may take us in unplanned directions. It is very important to understand that the planned schedule is tentative. This course is *skills*-oriented, not content oriented, so it's more important that we delve into topics you find interesting than that we cover some pre-arranged set of topics.

This course rests firmly on the Guilford College honor code. As in professional scientific work, if you present work with your name on it that you did not figure out yourself, that is plagiarism, and it incurs severe penalties. You should give credit for ideas and help received from others. On the parts that are to be your own work, you should write the honor pledge (or the word pledged) and sign your name. If you do not credit others with helping you, it will be assumed that you are claiming the work as your own. Violations of the honor code will be forwarded to the judicial board. See section 10.3 for more details.

*You cannot teach a man anything; you can only help him discover it in himself.*
*– Galileo Galilei*

# 2 Textbooks

The primary text for this course will be a collection of readings that have been assembled into a course pack that is available through the bookstore. This is the same course pack that has been used for the last three years, so you may have luck finding a student from a previous year

Table 1: Rubric for Grading Homework Problems

| Score | Description |
|---|---|
| 10 | Setup and work are clear, answer is correct, with sanity checks and comments |
| 9 | Answer is wrong due to minor mistakes, but everything else is present and clear |
| 8 | Answer is wrong due to major mistakes, or comments missing |
| 7 | Setup is weak or absent, or there are major mistakes, but main ideas are there |
| 6 | Adequate understanding but not mastery of the topic. Work is not clear. |
| 5 | About half the problem is missing. Partial understanding. |
| 4 | Articulation is unclear, work is missing, little thought shown about work. |
| 3 | Poor understanding and/or articulation. Set up is adequate, but nothing after. |
| 2 | Good faith effort, but flailing wildly about with no idea what to do. |
| 1 | A correct answer only |
| 0 | Nothing at all |

who would be willing to sell or loan you their course pack. This course pack will be used in both Physics 121 this semester and Physics 122 next semester. The course pack contains both chapters from an introductory textbook as well as supplementary essays on specific topics and a few classic papers of great historical interest.

As a supplemental text, to help you further your journey towards thinking like a physicist, I've assigned a book of essays by science journalist K. C. Cole, "First You Build a Cloud" (Harcourt Brace, New York, 1999, ISBN 0-15-600646-4). These are essays for the general public about advanced physics topics, and more importantly, about the ways physics changes your understanding of the world around you. We will be reading them out of order, at various points throughout the semester and discussing the ideas in class.

Finally, for the students taking this course as an Honors class, we may be reading and discussing the selections in "What's the Matter?" (Great Books Foundation, Chicago, 2007, ISBN 1-880323-91-5) This is an anthology of physics-related writings assembled by the Great Books Foundation. It includes essays by Newton, Aristotle, Feynman, Einstein, and Hawking, among others. Some are presentations of physics concepts, and others are essays about the philosophy of physics and its implications for how we live our lives. The emphasis of the honors section will be determined by the interests of the students who register for it.

*You can know the name of a bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird... So let's look at the bird and see what it's doing – that's what counts. I learned very early the difference between knowing the name of something and knowing something.*

*– Richard Feynman*

# 3 Pre-flight Quizzes

Assigned readings will be accompanied by "preflight quizzes." These quizzes will be made available by links from the 121 home page. Given the flexible nature of the course, the exact due dates will change as we move through the course, but you will always have at least a week's notice. Keep a close eye on the the course web page for updates.

The quizzes must be completed by 1 am the morning the readings are due (that is, the night before), but they may be completed at any time before then. Correct answers are not required; your grade will only consist of "completed" or "not completed", not correct or incorrect.

These quizzes serve two purposes: they help you stay on-task in completing the readings on time, and they help me assess where you are in your understanding of the material in the readings. If I can enter class knowing something already about what you understand and what you don't understand, I can shape the in-class activities to more efficiently match what you need.

Because of how IT&S has structured the campus network, the preflight quizzes will only be accessible via the on-campus computer network. If you wish to complete them from off-campus, you will need to install a "Virtual Private Network" (VPN). See the IT&S help facilities for instructions and assistance with this installation. If you do not wish to use a VPN, you will have to use on-campus computers to complete the quizzes, but any computer on-campus will suffice. You will be given a login/password in class.

# 4 Homework

You will be asked to write solutions to at least one (sometimes two) homework set every week. These sets will likely be different than physics homework sets you may have seen in the past in other courses, as they are intended to help you train your brain to *think* as well as familiarize yourself with the relevant concepts from that week's classes and readings.

Communication is a vitally important skill for scientists. Therefore I will emphasize in grading the homework not only whether or not you understand a problem, but how well you explain that problem to me, the reader. Do not hand in a rough draft of your worked homework problems. Scribbled and difficult to follow work will simply be given a zero. It is your responsibility to explain yourself clearly; it is not the reader's responsibility to figure out what you really meant. Make sure that the presentation is neat and readable.

Writing is to thinking what lifting weights is to muscle strength. The more you write, the more clearly you will come to think about the problems you attempt to solve. Remember that I am not the only reader here – you will someday want to reread these solutions yourself. Perhaps when studying for an exam. You will not remember in three or thirteen weeks what you were thinking when you scribbled out a few equations, but you can recapture your thoughts when you read a well-written explanation of your process.

Each solution to a homework problem must contain four parts: (1) a setup in which you explain the problem and what your goal is, in your own words. That is, an explanation of the method you will use to solve the problem, (2) a clear presentation and explanation of your work that leads to (3) an answer, and (4) testing of that answer and some exploration of its

implications. It is NOT sufficient to simply get an answer. You MUST think about what that answer MEANS. Mastery of these steps is essential to achieve the goal of thinking like a physicist.

A rubric for how I grade homework problems is presented in Table 1. This table is meant to be an approximate framework, not a rigid formula, but it gives you an idea of my priorities and what I look for in a solutions set. Roughly speaking, the setup is usually worth about 3 points, the work is worth 4 points, the answer is worth 1 point, and your comments on the answer are worth 2 points. Some problems will have different emphases, which may shift these percentages in either direction. These criteria do not apply to homework problems that are short answer questions or that ask you to explain or discuss a concept. If we have a teaching assistant who is willing to grade them, you may rewrite homework assignments to gain up to half the points you missed. That is, if you earned a 6 on your first submission, a perfect re-write may earn up to an 8. If we do them, rewrites will be due one week from the day you received your graded first submissions, at a time and place to be decided by the TA.

Homework assignments and exams come with associated due dates and times. I do not accept late work. You should plan your time accordingly. Just because an assignment is due at 5:00 pm does not mean you must turn it in at 4:59 pm. You can turn it in *any* time before 5:00 pm, even days early. Remember that the printer is *always* out of ink or paper, and that there is *always* bad traffic on the way to campus. Allow for problems and delays in your planning. Furthermore, it is the time on *my* clock that matters, not yours. To compensate for my strict deadlines, as life is not always cooperative with even the best planning, I tend to be very generous with extensions. If there is any danger of your not turning in an assignment on time, make sure you ask for an extension. Extensions must be requested *before* the due date/time. Once the deadline is past, nothing can be done. Do not assume that you will be granted an extension – there may be other circumstances that make an extension untenable. You should plan as if you won't get an extension, and then ask if you must.

# 5 Laboratory Experiments

*It is a capital mistake to theorize before one has data.*
*– Sir Arthur Conan Doyle*

The laboratory part of the course will centered about the microcomputer (MacIntosh) based laboratory equipment in the department. You will learn how to use computer driven lab equipment, how to analyze the data using a spread sheet type program and then incorporate the results into a document typesetting program (LaTeX).

Professor Rex Adelberger will be teaching the two laboratory sections for this course. He will explain his procedures and criteria for grading to you in a separate document. He will assign a grade for your laboratory work, which will be incorporated into your final grade according to the procedure described in section 9.

# 6 Exams

There will be two exams for this course: one mid-semester exam and one cumulative final exam at the end of the semester. These will be take-home exams, but they are not to be collaborations with other students. Each exam will come in an envelope or be uploaded to Moodle, with a set duration for your work (to be determined later). You choose when to start the clock by opening the envelope or printing the file from Moodle. Once you open the envelope or look at the printout, you may not discuss the exam with anyone except the instructor until after the deadline. The exams will cover material from both lecture and laboratory, and they may even introduce new material that you can tackle with the tools you have learned in class. Please make an effort to keep yourself from a situation where you see another student's work or show your work to another student.

# 7 Class Participation

In order to learn to think like a physicist, you must actively engage your mind with the class activities. A physicist asks questions. A physicist kicks the tires (a physicist asks "Why do we kick the tires, anyway?"). A physicist peels back the surface and demands to know what's going on underneath. You cannot sit back and watch and learn to think like a physicist. Therefore, a significant portion of your grade (10%) is based on your participation in class. An A student will regularly contribute to class discussion, ask insightful questions, and make connections between course material and the world outside the classroom. A student who never speaks or takes initiative will get an F in this aspect of the course, even if he or she is present at every single class session.

# 8 Schedule

*The cure for boredom is curiosity. There is no cure for curiosity.*
*– Dorothy Parker*

This course is designed to give you the tools to think like a physicist. To that end, we will begin the term by laying the hermeneutical, philosophical and structural foundation for participation in the intellectual enterprise we call physics. We will learn about physical laws, units, operational definitions, and the importance of uncertainty.

Then we will begin constructing models of the world around us and exploring how we can test those models. We will see how the process of building and testing models has led physicists to construct the standard model of particle physics: the basis for our modern understanding for what the universe is made of and how the pieces interact. We will explore the importance of conservation laws and symmetry in our understanding of the universe. Finally, we will close the semester by exploring the theory of Special Relativity, which will change the way you think about space and time. At the end of this semester, if you have understood this material, you will look at the world around you in completely different ways.

Table 2: Tentative Schedule of Readings and Topics

| Week | Topic | Reading |
|---|---|---|
| 1 | Foundations | |
| 2 | Units, Estimation, and Uncertainty | Ford 1, Cole 2 |
| 3 | Operational Definitions & Conservation Laws | Ford 2 |
| 4 | Into the Atom | Ford 3, Cole 3 |
| 5 | Binding Energy & Half-lives | Ford 4.1-5 |
| 6 | Particles | Ford 4.6-8, Cole 4 |
| 7 | Quarks | Allday 1,5 & 7 |
| 8 | Symmetry | Cole 1, 5 & 6 |
| 9 | Relativity Foundations | Adelberger 1 |
| 10 | Space-time | Adelberger 2, Cole 13 |
| 11 | Lorentz Transformations | Adelberger 3 |
| 12 | Simultenaity | Adelberger 4, Cole 8 |
| 13 | Velocity | Adelberger 5 |
| 14/15 | Momentum & Energy | Adelberger 6 & 7 |

A tentative schedule of topics is given in Table 2. Since we will also be exploring your questions, the actual development of the course will likely deviate from this schedule. A more up-to-date schedule of readings and pre-flight quizzes will be kept on the course web page. Please monitor this page on a regular basis.

# 9 Grading Policy

Physics, as an enterprise, is a creative balance between collaborative work and individual insight. I therefore encourage you to consult with each other, to ask questions and try to puzzle out the solutions together. However, unless explicitly stated otherwise, all submitted work must be your own individual work. That means when you work together, you figure out how a problem may be solved, but when you sit down to actually write out what you will hand in, you do it alone. You may not copy what someone else has written, nor may you cut-and-paste out of someone else's files. It is very important that you find a study group with whom to work, discuss, and hash out problems, but it is just as important that you try to do the homework yourself before you meet with your peers. If you don't, the danger is too great that you will allow yourself to simply be told what the answer is without trying to figure it out yourself.

Your contributions to this class will be graded in the following manner: Homework = 25%, Pre-flight quizzes = 5%, Mid-term exam = 15%, Final Exam = 15%, Labs = 30%, and Class Participation = 10%. I see grades purely as an assessment tool. They are not motivations nor are they punishments. I want the grades to be completely transparent. I do not *give* you grades. You *earn* them. If you are confused as to how your work on a particular assignment matches the rubrics described here, please come talk to me.

# 10 Course Policies

## 10.1 Credit Hours

This course is worth five credits, although we will only spend about five hours in official class contact per week. For a five-credit course, it is expected that you spend on average fifteen hours a week on the course. This expectation is based on the faculty-approved standard that students are awarded one credit for every three hours they spend on course work. I will expect you to spend at least an average of an hour a day on your homework assignments, and you should be prepared to spend an average of four or five hours on the lab. Very few students can excel in this class with only fifteen hours of work per week.

## 10.2 Attendance Policy

Attendance will not be taken as a daily policy. However, this class is heavily based in the participation in group discussions, and therefore chronic absence will interfere with your ability to learn what the class has to offer. As one of my colleagues says, "Attendance is optional. Passing is also optional." That said, I expect respectful, mature behavior as the default state for participation in class activities. Chronic tardiness is disruptive and disrespectful. Be aware that if you arrive late to class, you may find the door locked against you, or it may count as an absence. Guilford's policy for classes that meet three times a week is that nine absences are allowed. If you know of an impending situation that will require your absence from class, you must contact me in advance. Rex will have his own attendance policy for the laboratory sessions.

## 10.3 Honor Code

I am a firm believer in acting with integrity and performing at least to the standard of the Guilford Honor code. The work you submit is understood to be claimed by you to be your work. If others helped you, or if you got ideas from other sources, you must credit them appropriately. I have a zero-tolerance policy for plagiarism. If I am convinced you have violated the Guilford Honor Code, you will fail this course, and the case will be referred to the Dean's office for the possibility of other consequences. According to the college catalog, the statement, "I have been honest and have not observed any dishonesty," gives testament to the honor system and should be pledged in writing on all academic work. Compliance is assumed even if the statement does not appear on college work. The word "pledged" may substitute for the longer statement. Assignments without the honor code pledge may not be graded.

## 10.4 Accommodations

Guilford complies with the Americans with Disabilities Act by providing a process for disclosing disabilities and arranging for reasonable accommodations. The policy may be found online[1]. Students who require accommodations must complete a disabilities disclosure form and submit

[1] http://www.guilford.edu/about guilford/values/handbook/ada.html

it to the Disability Services Coordinator, located in the Learning Commons (x2253), along with the appropriate documentation. It is the students choice to disclose difference/disability information to individual instructors. However, only students who provide their instructors with a 504 Accommodations Agreement may receive accommodations. All disability information is treated confidentially and is not a part of your academic record.

*The most exciting phrase to hear in science, the one that heralds new discoveries, is not "Eureka!" ("I found it!") but rather "hmm....that's funny..."*

*– Isaac Asimov*