PHYSICS 211—— GENERAL INFORMATION —— FALL 2015

Instructor Office Phone E-mail Office Hours
Timothy Good Masters 103 x6024 goodt@gettysburg.edu MWF 3-4 pm, and by appointment

About the course: Physics 111, 112, and 211 comprise a three-semester calculus-based introduction to physics. This non-traditional course is based on a model curriculum developed at Pomona College for the Introductory University Physics Project (IUPP), a national project funded by the National Science Foundation and the American Institute of Physics. This syllabus is closely modeled after the example provided by Dr. Thomas Moore, at Pomona College.

Texts: Six Ideas That Shaped Physics, Unit E: Electric and Magnetic Fields Are Unified, 3rd Edition (Draft), Thomas A. Moore
An Introduction to Error Analysis, the Study of Uncertainties in Physical Measurements, 2nd Edition, John R. Taylor

Other supplies you will need:
(1) A good scientific calculator.
(2) An 8" x 10" quadrille-ruled lab notebook.

Students with Disability: Any student in this course who has a disability that may prevent him/her from fully demonstrating his/her academic potential should contact me as soon as possible so that we can discuss accommodations necessary to insure full participation in this class and to facilitate the learning process.

LEARNING OUTCOMES:

- Students will investigate fundamental properties of static electric charge: that it exists in two kinds, it is quantized, it is conserved, and that it interacts via the Coulomb force law.

- Students will learn to employ classical field theories, in which we imagine that the space around a charged particle is filled with an electric field and we describe such a field mathematically by assigning some kind of numerical quantity to every point in space. The field model is extended to the electrostatic potential field and to the magnetic field. Like a particle, a field is more than a mental construct, it is a real thing that has energy, carries momentum, and obeys equations of motion that describe how it evolves with time in response to its surroundings.

- Students will learn to exploit models for sources that create electromagnetic fields: charge distributions ranging from the discrete point charge and dipole, to continuous distributions on the surfaces of sheets, spheres and cylinders, and current distributions ranging from the infinitesimal wire segment to current loops, as well as continuous surface and volume current distributions of charges in motion inside conductors.

- Students will determine the relationship between electric fields and electrostatic potential, while connecting the quantities that describe the electrostatic interactions among charged objects: force, fields, and energy.

- Students will develop hands-on laboratory skills with simple electric circuits and the instruments used to measure circuit parameters.

- Students will utilize mathematical methods from introductory calculus and will learn to integrate mathematical reasoning and models of physical science through analytical applications of electromagnetic theory expressed in Gauss’s and Ampere’s Laws.

- Students will develop an appreciation for the power and elegance of symmetry in the unified electromagnetic theory expressed by Maxwell’s Equations.

- The overarching goal of this course is for students to gain awareness of the logical and sequential development of electromagnetic field theory spanning from Coulomb’s law to electromagnetic waves. It is our goal to appreciate why electricity and magnetism must be unified if their field theories are to make sense in the context of relativity.
**A Metaphor:** Research has shown that learning to do physics has more in common with learning to play a sport or musical instrument than it does with memorizing a body of information. This course is structured to fit this metaphor. This means that you should consider class sessions to be *practice*, quizzes and exams to be *league games or recitals*, and your instructor and PLA to be *coaches*. You will receive credit for both practice and performance.

**Flip teaching** (or flipped classroom) is a form of blended learning in which students learn new content online by watching video lectures, usually at home, and what used to be homework (assigned problems) is now done in class with the teacher offering more personalized guidance and interaction with students, instead of lecturing. This is also known as *backwards classroom, reverse instruction, flipping the classroom* and *reverse teaching*.

The traditional pattern of teaching has been to assign students to read textbooks and work on problem sets out of class, while listening to lectures and taking tests in class. In flip teaching, the students first read the text to study the topic by themselves, and then, typically using video lessons prepared by the teacher or third parties such as the MIT Open Courseware site, [http://ocw.mit.edu/courses/physics/8-02-electricity-and-magnetism-spring-2002/video-lectures/](http://ocw.mit.edu/courses/physics/8-02-electricity-and-magnetism-spring-2002/video-lectures/). Classroom time is for the students to apply their knowledge by solving problems and doing practical work. The teacher tutors the students when they become stuck, rather than imparting the initial lesson.

**Preparing for Class:** Class sessions will primarily involve interactive exercises where you *practice* using the concepts you have read about in the text and watched in the video lecture. You will get the full benefit of these activities only if you are prepared to participate.

To prepare for each class, you should:

1. **Read the assigned reading** for the day (shown in bold type on the syllabus), *work* through the exercises in the text, and
2. **View the on-line lecture or film, writing a brief reflection where assigned.**
3. **Read** the problems to be solved in the next class and *contemplate* their solutions.

**Problem Solving In Class – In Search of Robust Learning:**

We will practice peer learning in the classroom as students form problem solving teams of four individuals. Each team will solve one of the four daily problems at the black or white boards. Each team will have a **Reader**, a **Conceiver**, a **Presenter**, and a **Scribe**. At the outset, the Reader will pose the problem to the team and then the Conceiver will lead a brief discussion to identify in words the key concepts underlying the problem. After about 25 minutes used to solve the problem, the Reader will recite the question and the Presenter will orally explain the group concepts and solution to the class. It is the duty of the Scribe to document the solution presented at the board, and to write up a complete version for submission to our course Moodle site at some time that same day (or evening). A quality submission by each Scribe is important since the repository of solutions on Moodle will provide a student resource for quiz and exam preparation. For full participation credit, each student will serve as Presenter, Scribe and Conceiver eight times during the semester. Periodically student participation in group work will be evaluated by peers to assess the qualities of contributing, listening, and leading.
Collaborative-Learning (CL) Problems: A more challenging R-level homework problem will also be assigned almost every week: these problems appear underlined on the syllabus. (Note that these problems are usually due on Monday.) These problems are designed to be worked in groups of three or four students during our Thursday class session. Collaborative learning sessions are scheduled for our Thursday flex period to work this problem under the eye of your instructor who can answer questions and help you when you are stuck. These problems are also where you demonstrate to me that you can write a complete and coherent problem solution using good English prose. Therefore, while you can (and probably should) work these problems in groups, your final solution must be in your own words.

Laboratory Policy: Physics 211 is considered and counted as a "lecture/lab" course. Therefore, every student must engage in the laboratory part of the course consisting of twelve weekly laboratory exercises. Students are encouraged to complete all twelve exercises to receive the full benefits of laboratory instruction and to maximize the impact on the course grade. The laboratory sessions will culminate in a formal lab report, as in Physics 112.

Students who do not complete all twelve exercises will be assessed a penalty in the course grade:

<table>
<thead>
<tr>
<th>Missed Work</th>
<th>Penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>One incomplete lab</td>
<td>Zero for that laboratory report grade</td>
</tr>
<tr>
<td>Two incomplete labs</td>
<td>Zero for the laboratory component of the course</td>
</tr>
<tr>
<td>Three or more incomplete labs</td>
<td>Failure for the entire course</td>
</tr>
</tbody>
</table>

Grading scale: All grades in this class will be based on a fixed scale, so that you do not need to compete with each other. If average class performance for any item is particularly low (indicating that the item was unusually difficult) I may adjust grades to be higher than this average would indicate, but I will never adjust your grade to be lower.

<table>
<thead>
<tr>
<th>EVALUATION</th>
<th>FINAL GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Participation</td>
<td>15%</td>
</tr>
<tr>
<td>Problem quizzes</td>
<td>10%</td>
</tr>
<tr>
<td>Homework</td>
<td>10%</td>
</tr>
<tr>
<td>Laboratory</td>
<td>25%</td>
</tr>
<tr>
<td>Three exams - 10% each</td>
<td>30%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>10%</td>
</tr>
</tbody>
</table>

Flexibility: Any aspects of the course, schedule, or basis for evaluation may be changed by the instructor if such a change would appear to contribute better to the accomplishment of the objectives of the course for the particular students enrolled. Students will be appropriately notified of changes. Laboratory assignments and necessary reference materials will be provided in a timely fashion.
HOMEWORK STANDARDS — PHYSICS 211

General Comments: This course is designed to help you develop more sophisticated physical reasoning skills than you may have had to use before in more elementary science and math courses. As a result, the homework problems serve a somewhat different purpose here. This document is intended to clarify what I want to see in a solution to a homework problem. These guidelines express what years of experience as a teacher and problem solver have shown me to be the most effective and (ultimately) efficient way to handle sophisticated, realistic problems.

Solution Tasks: Solving a challenging physics problem almost always requires four steps.

(1) You have to **TRANSLATE** the problem into mathematical language. This *always* involves defining a set of symbols that you will use to mathematically represent quantities of interest, and *almost always* involves drawing a picture of the situation described in the problem and setting up some kind of coordinate system. You can usually save a *lot of time* by using your drawing to define the symbols instead of defining them in words.

(2) You have to build a **MODEL** of the situation by deciding what basic physical principles apply and by making simplifying assumptions and/or approximations to match the realistic situation to a set of equations you can solve. From my perspective, the answer (to a problem) is the model: the rest of the solution, including the final numerical answer (if there is one), is mechanical detail that simply expresses the consequences of the model.

(3) You then apply the basic equations suggested by your model and **SOLVE** them algebraically. While this is pretty mechanical, most beginners make their task much more difficult by plugging in numbers too soon, which take more time to write than symbols and make it much harder to track down errors. My rule is that if a quantity has associated units, one should usually wait until the very last step before substituting a symbol’s numerical value.

(4) You then need to **EVALUATE** your final result. Does it make sense? Does it have the right units? Does it have a believable magnitude? Experienced problem-solvers evaluate even intermediate results this way. In the past, the science “problems” you have been asked to solve have probably been so simple that you can do steps 1 and 2 in your head and go right to step 3. Most S and R-level problems in this text, like the problems you are likely to encounter in real life, generally require that you *consciously* work through all these steps.

Standards for Completeness: A solution will not be considered “complete” if you do not show:

**Translation:** Define all symbols and coordinate directions used in the solution (usually using a picture)

**Model:** Briefly describe the fundamental principle(s) and important approximations/assumptions used

**Solution:** Work the algebra *symbolically* as far as possible and keep track of units when you do use numbers

**Evaluation:** Check the units, sign, magnitude, and/or plausibility of any final results. (The text will describe additional items that should be included in the model section for specific kinds of problems.) You do not actually *have* to write anything for the evaluation part, but if your final result is clearly absurd and you don’t note that in your solution, it will cost you completeness as well as correctness points.

In Class Problem Solving: On problems worked in class, definitions and descriptions can be very brief (even telegraphically abbreviated) as long as all necessary items are present and the class can decipher them. A problem’s solution should fit nicely into the four steps described above.

**CL Problem Standards:** However, I would like your solutions to CL problems to show me that you *can* write a logically coherent and readable problem solution using good English prose (with complete sentences). The example problem solution on the back of this page illustrates the problem-solving style I am looking for from your CL solutions. Your solutions obviously don’t have to be beautifully typeset and can probably be up to 30% shorter than mine, but you should strive for the same level of readability and completeness. Poor English will lead to deductions in your score. Note that the model step counts most: this is the step I am most interested in. Your evaluation step is “complete” if your result is plausible even if wrong.
EXAMPLE PROBLEM SOLUTION

C1R.1 Model and Translation: One way to estimate the total mass $M$ of the earth’s oceans is to multiply the density $\rho$ of water by the volume $V$ of the oceans. To estimate this volume, we can estimate the percentage of the earth covered by water, multiply this by the earth’s total surface area and then multiply this by a plausible estimate of the average depth of the water. Let’s guess that about 70% of the earth’s surface is covered by ocean, and that (since the maximum ocean depth is 11 km) the average ocean depth is $d \approx 5$ km. The volume of the earth’s ocean is $V \approx 0.7Ad$, where $A$ is the earth’s surface area. Since the earth is approximately a sphere, we can approximate this area by $A = 4\pi R^2$, where $R$ is the earth’s radius, which (according to the inside of the front cover of the text) is $\approx 6380$ km.

Solution: The total volume of the earth’s ocean is thus very roughly:

$$V \approx 0.7A d \approx (0.7) (4\pi) (6.38 \times 10^6 \text{ m})^2 (5 \times 10^3 \text{ m}) = 1.8 \times 10^{18} \text{ m}^3.$$  

(1) If the average depth is closer to 3 km, this volume is closer to $1.1 \times 10^{18} \text{ m}^3$; if the average depth is closer to 7 km, the volume is closer to $2.5 \times 10^{18} \text{ m}^3$. Since I don’t think that it is very plausible that the average depth of the ocean lies outside this range, we can be fairly confident that the volume is within about ±40% of $1.8 \times 10^{18} \text{ m}^3$.

Model II: The density of fresh water is $\rho \approx 1000 \text{ kg/m}^3$. Ocean water (because of the dissolved salt) is somewhat more dense, but 1000 kg/m$^3$ is a reasonable estimate considering the accuracy of the approximations we have made so far!

Solution II: So multiplying our estimate of the density of ocean water by our estimate of the volume gives us an estimate of the mass of the water in the earth’s ocean:

$$M = \rho V \approx (1000 \text{ kg/m}^3)(1.8\times 10^{18} \text{ m}^3) = 1.8 \times 10^{21} \text{ kg}$$

Evaluation: The final result has the right units for mass. It is hard to know what is a “reasonable” magnitude here (the answer is very large!), but it is comforting to note that the earth’s total mass is $5.98 \times 10^{24} \text{ kg}$, which is more than 300 times larger. (One would expect the ocean’s mass to be small compared to the entire earth.)

(Note: According to the Encyclopedia Britannica, oceans cover a bit less than 71% of the earth’s surface area; estimates between 60% and 80% are plausible. The same source states that the average depth of the ocean is 3.7 km; estimates between 3 km and 7 km are acceptable. The more exact figures imply that a better estimate of the mass of the ocean would be about $1.4 \times 10^{21} \text{ kg}$. Note that even crude, common sense estimates give an answer that is easily within a factor of 2 of this result!)