Foundations of Physics II

Spring 2009 | Physics 200 | PEngel 173

Instructor:

Dr. Tom Kirkman PEngel 111
tkirkman@unix.csbsju.edu 363–3811
Informal Office Hours: 7:30 A.M. – 5:00 P.M.

Texts:

- *University Physics* by Hugh Young & Roger Freedman (Pearson, 2008 12^{th} edition) Chapters: 21–32
- *Laboratory Manual for Foundations of Physics II*
- *An Introduction to Error Analysis* by J.R. Taylor (recommended for lab)
- http://www.physics.csbsju.edu/200/

Grading:

Your grade will be determined by averaging seven scores: total quiz/homework score, total lab score, three exam scores, and the final exam score (which is double-counted). Homework is assigned daily and is listed in the class web site; it is due at the beginning of the following class period. Late homework is generally not accepted. The hour exams include both multiple choice and numerical problems. You may use a single-sided $8\frac{1}{2}$" × 11" "formula sheet" to assist you on the exam. The formula sheet should be limited to formulas and definitions—no worked examples. Exam dates are: February 5 (Thursday), February 27 (Friday), and April 20 (Monday, beware!). If informed in advance, I may be able to accommodate exam conflicts. The final exam will be comprehensive and have a structure similar to the other exams, but proportionally longer. The final exam has not yet been scheduled by the registrar.

Lab:

Time in lab is limited so prepare for each lab by reading the lab manual *before* lab. Pre-lab exercises and short pre-lab quizzes must be turned in at the beginning of lab. Your completed lab report must be turned in at the end of the lab. You will need three lab notebooks with quad ruled paper and a sewn binding (e.g., Ampad #26–251). Used notebooks from 191 are fine. Read the INTRODUCTION to the *Laboratory Manual* ASAP for further information on the lab.

Questions:

There is no such thing as a dumb question. Questions during lecture do not "interrupt" the lecture, rather they indicate your interests or misunderstandings. I'd much rather clear up a misunderstanding or discuss a topic of interest than continue a dull lecture.

Remember: you are almost never alone in your interests, your misunderstandings, or your problems. Please help yourself and your classmates by asking any question vaguely related to physics. If you don't want to ask your question during class, that's fine too: I can be found almost any time in my office (PEngel 111) or the nearby labs. Drop in any time!

Topics:

The central aim of this course is to introduce the discoveries of James Clerk Maxwell (1831–1879) which are the foundation of modern physics and the basis our electronic technology. As Albert Einstein put it: "One scientific epoch ended and another began with James Clerk Maxwell." Maxwell's discovery[1] was that the forces of nature do not act directly on distant objects ('action at a distance'), instead forces act indirectly through 'fields' that pervade all of space (even in the absence of objects the forces could act on: in a vacuum). It was a bit of a challenge for Maxwell's colleagues to believe in the existence of mathematical force fields in the absence of obvious effects (forces on objects), so Maxwell's work was largely unheralded until 1887 when Heinrich Hertz produced and detected the radio waves (a type of light) predicted by Maxwell's theory. Thus Maxwell's *Dynamical Theory of the Electromagnetic Field* (which was produced

[1] Maxwell clearly 'stood on the shoulders' of Michael Faraday (1791–1867) in making this discovery.

during our Civil War), was considered state-of-the-art when Einstein was in school.

The key concept in Newton's mechanics is the ordinary differential equation. The location of an object can be thought of as the result of zillions of tiny displacements. The velocity during those displacements is changing due to forces which are the cause of acceleration. Typically we calculate the trajectory—the position as a function of time, e.g., $x(t)$—from the sum (integral) of infinitesimal displacements.

The key concept in Maxwell's electrodynamics is the partial differential equation. The difference between the force field at neighboring locations is infinitesimal, but determined by locally present sources of the force. Typically we calculate the force *field*—for example, the electric field as a function of position: $\vec{\mathbf{E}}(x)$—from the sum (integral) of infinitesimal field contributions. Do note the change in domain: in 191 we were interested in the position as a function of time; in 200 we'll seek the field as a function of position.

Partial differential equations are probably a couple of years beyond your current mathematical studies (they are touched on in MATH 305: Multivariable Calculus, and MATH 341: Fourier Series and Boundary Valued Problems) but the idea is simple enough that I can explain it now. Think about what happens when a blowtorch is applied to the outside of a big block of metal. Initially the temperature as a function of position ($T(\vec{\mathbf{r}})$) inside the block is uniform at room temperature. As heat flows into the block, temperatures will rise at a rate determined by the temperature of neighboring points. The direction and magnitude of the heat flow is directly determined not by the blow torch at the surface, but by the local temperature differences (the temperature gradient). The temperature as a function of position and time ($T(\vec{\mathbf{r}}, t)$) could be called the temperature *field*. Indeed it was the analogy between heat flow and the electric field that started Maxwell on the path toward his theory.

There are a couple of aspects of this course that make it particularly difficult. First, since the universe follows mathematical laws, you must be able to *do* mathematics to do physics. In this course we will use 110% of the mathematics you've learned over your lifetime: arithmetic, geometry, trigonometry, algebra, and calculus. Trying to recall the mathematics you learned a couple of years ago and apply it in new situations is challenging. The best tonics for this problem are to ask lots of questions and work lots of problems. (Yes, work problems that are not assigned.) In addition carefully study the book's "Problem-Solving Strategies" and read the advice recorded on the class web page. Perhaps the single most important suggestion I can make is to read listed sections of the textbook *before* they are covered in lecture. Additional advice is collected on the class web page.

Second, this course deals with phenomena removed from everyday experience: invisible force fields and their sources. Intuition will be of little help, and the danger is to substitute formula plug-and-chug for developing an understanding. In a different context FDP[2] P.A.M. Dirac wrote

> The new theories, if one looks apart from their mathematical setting, are built up from physical concepts which cannot be explained in terms of things previously known to the student, which cannot even be explained adequately in words at all. Like the fundamental concepts (e.g., proximity, identity) which every one must learn on his arrival into the world, the newer concepts of physics can be mastered only by long familiarity with their properties and uses.

Thus you want to think hard[3] every day about your physics problems, and you will—like a baby learning about his new world— come to understand it. The famous Einstein quote: "The most incomprehensible thing about the universe is that it is comprehensible." Einstein might have been a bit over-confidant, but while the universe might not be comprehensible in one gulp, it seems there is a step-by-step approach you can follow to understand it: physics.

I'll finish this quote fest with one from a famous dead author[4] Kurt Vonnegut, Jr: "freshman physics is invariably the most satisfying course offered by any American university." I hope you enjoy it!

[2]Famous Dead Physicist

[3]Famous living physicist Murray Gell-Mann reported that the key step in FDP Richard Feynman's problem solving technique was: "think[ing] very hard." If it worked for Feynman, it may work for you!

[4]It's hard to pick his best novel, but I'll recommend *Cat's Cradle*, *Player Piano* and *Slaughterhouse-Five*, three books that are tough on science, and hence good for scientists to read.

Schedule

Day		Date	Text	Topics	Exams	Labs (Days: 4–6)
1/1	M	Jan 12	21.1–21.3	Electric Charges		
1/3	W	Jan 15	21.4–21.6	Electric Fields		
1/5	F	Jan 17	21.5–21.6	$\vec{\mathbf{E}}$ by integration		
2/1	T	Jan 20	21.5–21.7	$\vec{\mathbf{E}}$ by integration, dipoles		
2/3	R	Jan 22	22.1–22.3	Gauss' Law		
2/5	M	Jan 26	22.1–22.5	Applying Gauss' Law		Field Superposition
3/1	W	Jan 28	23.1–23.3	Electric Potential		
3/3	F	Jan 30	23.3–23.5	V by integration, $\vec{\boldsymbol{\nabla}}$		
3/5	T	Feb 3	21.1–23.5	Review		Equipotentials
4/1	R	Feb 5	21.1–23.5	**Electricity**	**Exam 1**	
4/3	M	Feb 9	24.1–24.3	Capacitance		
4/5	W	Feb 11	24.4–24.6	Dielectrics		Digital Oscilloscope
5/1	F	Feb 13	25.1–25.3	Current Density, Ω		
5/3	T	Feb 17	25.4–25.6	Simple Circuit		
5/5	R	Feb 19	26.1–26.3	Kirchhoff's Rules		Electrical Circuits
6/1	M	Feb 23	26.4–26.5	*RC* Circuits		
6/3	W	Feb 25	24.1–26.5	Review		
6/5	F	Feb 27	24.1–26.5	$\boldsymbol{V, I, R, C}$	**Exam 2**	*RC* Circuits

Spring Break: Week of Mar 1

Day		Date	Text	Topics	Exams	Labs
7/1	T	Mar 10	27.1–27.3	Magnetic Field		
7/3	R	Mar 12	27.3–27.6	$Id\vec{\boldsymbol{\ell}} \times \vec{\mathbf{B}}$		
7/5	M	Mar 16	27.7–27.9	loops: force & torque		Ohmic & Non-Ohmic
8/1	W	Mar 18	28.1–28.4	Biot-Savart		
8/3	F	Mar 20	28.5–28.7	Ampere's Law		
8/5	T	Mar 24	28.5–28.8	More $\vec{\mathbf{B}}$		Electron e/m
9/1	R	Mar 26	29.1–29.4	Induction		
9/3	M	Mar 30	29.5–29.8	emf + Maxwell		
9/5	W	Apr 1	30.1–30.3	Inductors		Helmholtz Coils
10/1	F	Apr 3	30.4–30.6	*LRC* circuit		
10/3	T	Apr 7	31.1–31.3	AC Circuits: *LRC*		

Easter Break: Thursday–Monday

Day		Date	Text	Topics	Exams	Labs
10/5	T	Apr 14	31.4–31.6	Resonance, Transformer		AC Circuits
11/1	R	Apr 16	27.1–31.6	Review		
11/3	M	Apr 20	27.1–31.6	$\vec{\mathbf{B}}$ **& AC Circuits**	**Exam 3**	
11/5	R	Apr 23	27.9,28.8,29.8	materials + Maxwell		
12/1	M	Apr 27	32.1–32.3	Electromagnetic Waves		
12/3	W	Apr 29	32.4–32.5	Electromagnetic Waves		
12/5	F	May 1	21.1–32.5	Review		
		May ?	21.1–33.7	Everything!	**Final Exam**	