Foundations of Physics II

Spring 2021 Block D | Physics 200 | PEngel 173

Instructor:

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Informal Office Hours: 7:30 A.M. – 5:00 P.M.

Texts:

- *University Physics* by Hugh Young & Roger Freedman (Pearson, 2019 15^{th} edition)
  Chapters: 21–32
- *Laboratory Manual for Foundations of Physics II*
- `http://www.physics.csbsju.edu/200/`

Grading:

Your grade will be determined by averaging six scores: overall homework score, lab score, two exam scores, and the final exam score (which is double-counted). Homework is assigned via Mastering Physics The hour exams include both multiple choice and numerical problems (see examples online). You may use a single-sided $8\frac{1}{2}$" $\times 11$" formula sheet to assist you on the exam. The formula sheet should be limited to formulas and definitions—no worked examples. Exam dates are: April 27 (Tuesday), May 7 (Friday), and May 14 (Friday).

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. 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 132/6) 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 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 invisible 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 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; the acceleration can be calculated from the sum of forces. 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) 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. While the ultimate source of the heat is the external blowtorch, the effect inside the block is not some sort of 'action at a distance' but rather determined the temperature of *neighboring* points. 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 (along with the qualitative notions of Faraday).

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. In a different context Famous Dead Physicist 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 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 Kurt Vonnegut, Jr: "freshman physics is invariably the most satisfying course offered by any American university." I hope you enjoy it!

Catalog Course Description

Electric and magnetic fields and their sources, electric potential and electro-magnetic induction. DC and AC circuit elements and circuits. Electromagnetic waves. Emphasis on problem solving. A laboratory is included. Prerequisites: 191, concurrent registration in MATH 120. Spring.

Student learning outcomes

After successful completion of this course, students will be able to

- solve numerical problems involving electricity and magnetism;
- understand the related physical concepts: fields, potentials, sources and their connections via Maxwell's Equations;
- analyze and interpret data from simple physics experiments and operate common electronic equipment: DMM and oscilloscope.

Class		Date	Text	Topics	Labs
1	T	Apr 20	21.1–21.3 21.4–21.6 21.5–21.7	Electric Charges, Coulomb Electric Fields $\vec{\mathbf{E}}$ by integration, dipoles	
2	R	Apr 22	22.1–22.2 22.3 22.4–22.5	Electric Flux Gauss' Law Applying Gauss' Law	Field Superposition
3	F	Apr 23	23.1–23.2 23.2–23.3 23.4–23.5	Electric Potential V by integration Equipotentials, $\vec{\boldsymbol{\nabla}}$	
4	M	Apr 26	24.1–24.3 24.3–24.4 24.4–24.6	Capacitance Stored energy & dielectrics Dielectrics	Equipotentials
5	T	Apr 27	21 – 24	Catch up, review **Test 1**	
6	R	Apr 29	25.1–25.3 25.4–25.5 25.6	Current, Current Density, Ω Simple Circuit, power Metalic conduction	Digital Oscilloscope
7	F	Apr 30	26.1–26.3 26.3–26.5 26.4–26.5	Kirchhoff's Rules Electrical Measurements RC Circuits	
8	M	May 3	27.1–27.3 27.3–27.6 27.7–27.9	Magnetic Field $Id\vec{\boldsymbol{\ell}} \times \vec{\mathbf{B}}$ loops: force & torque	DC Circuits
9	T	May 4	28.1–28.4 28.5–28.7 28.5–28.8	Biot-Savart Ampere's Law More $\vec{\mathbf{B}}$	
10	R	May 6	29.1–29.4 29.5–29.8 29.5–29.8	Induction emf Maxwell	Electron e/m
11	F	May 7	25–29	Catch up, review **Test 2**	
12	M	May 10	30.1–30.3 30.2–30.4 30.4–30.6	Inductors Magnetic Energy & RL circuit LC. LRC circuits	Helmholtz Coils
13	T	May 11	31.1–31.3 31.4–31.6 31.4–31.6	Phasors, reactance: X_L, X_C LRC circuit Resonance, Transformer	
14	R	May 13	32.1–32.3 32.4–32.5	Electromagnetic Waves EM energy & momentum	AC Circuits
15	F	May 14	all	**Final Exam**	

Links to Institutional Policies:

- Course Attendance policy
  `www.csbsju.edu/academics/catalog/academic-policies-and-regulations/courses/class-attendance`
- Statement on accommodations for students with disabilities
  `www.csbsju.edu/student-accessibility-services/information-for-faculty/syllabus-statement`
- Academic Misconduct and Plagiarism
  `www.csbsju.edu/academics/catalog/academic-policies-and-regulations/rights/academic-misconduct`
- Sexual Misconduct
  `www.csbsju.edu/human-rights/sexual-misconduct/sexual-misconduct-policy`
- Title IX policy
  `www.csbsju.edu/joint-student-development/title-ix`
- Institutional Statement on Diversity
  `www.csbsju.edu/joint-student-development/institutional-statement-on-diversity`