Physics 33-122.
Physics II for Biological Sciences and Chemistry Students
Spring Semester 2023

Lectures:	10:00–10:50	Mondays and Wednesdays in Gates-Hillman Centre 4215
Section A:	9:00–9:50	Tuesdays and Thursdays in Doherty Hall A325
Section B:	10:00–10:50	Tuesdays and Thursdays in Doherty Hall A325
Help Sessions:	6:50–8:50	Wednesdays (Wean 7423) and Thursdays (Wean 8325)

Instructor: Hael Collins, Wean Hall Room 7414, hcollins@andrew.cmu.edu
Office hours: Feel free to come by at any time (afternoons and evenings are the best)

Assistants: Andy Park, chanhyup@andrew.cmu.edu, recitations
Office hours: 4:30 pm–5:30 pm, Wednesdays, Wean Hall 8324

Todd Cheng, taocheng@andrew.cmu.edu, grading
Office hours: 4:00 pm–5:00 pm, Thursdays, Wean Hall 6303

Textbook: Sternheim and Kane, *General Physics* (2nd edition), Wiley, 1991.
The course will cover material in chapters 16–21, 23–24
Electromagnetism and Optics, 2023.
This booklet is a set of lectures notes prepared for the course

Course work: The purpose of this course is to help you to become more familiar with some of the basic properties of electromagnetism, waves, and optics. You are probably taking this course, as opposed to 142 or 152, because you are interested in using physics to provide deeper insight into your own field; so the emphasis will be a bit less abstract with more examples from chemistry or biology. The list of topics that you will learn appears on the last page.

During most weeks of the semester you will be given several problems to solve. Some will be quite simple, while others will be much more challenging. The trickier problems will help you to learn to think more creatively and abstractly, which is one of the most valuable skills that you will learn from studying physics.

You are free to consult with your colleagues while you are working on the problem sets, but you must figure out the solutions for yourself, and never just copy another student's work. **You must show <u>all</u> of the necessary steps for each solution.** Writing just the answer is not enough.

I am very eager for you to learn this subject well. You are always welcome to visit my office or send me a message if you have any questions or if something is not clear.

Tests: We shall have two subject examinations:

Examination I	Chapter 16	23 February	7:00–8:00 pm
Examination II	Chapters 19–21	6 April	7:00–8:00 pm

The examinations will be tentatively held in Doherty 1212. You should bring a scientific calculator to all the tests.

LECTURES AND RECITATIONS

Because we have at most only two lectures each week, the course is structured as follows:

- **Lectures** will present ideas, definitions, and derivations.
- **Recitations** will present detailed examples and worked applications.

You will learn better and find the course most fulfilling the more fully that you are engaged with it. One of the ways to do so is to remove any distractions during the lectures and recitations, and to concentrate on the material presented, asking questions when confused and taking very good notes. You will also understand the lectures better if you have read about the ideas in advance. So to help you to keep engaged and focused, here are a few suggestions for the course:

1. You are expected to attend all of the lectures and recitations.
2. **Please put away all telephones, tablets, and computers during the lectures and recitations, unless you are using them for taking notes.** They can be pernicious distractions.
3. Please bring a scientific calculator to the recitations and the tests.
4. You should not record or photograph the lectures in any way.
5. You are strongly encouraged to ask questions whenever anything is confusing.
6. I shall be periodically asking you for your feedback, to help improve the lectures and to clarify any of the topics in the course. You are also welcome to send me a message if you have any questions about the material in the course.
7. As mentioned, since there are only two lectures each week, the lectures will focus on the **concepts** and **ideas** of electromagnetism, while the recitations will provide you with the opportunity to see specific **examples** presented in detail.

PROBLEM SETS

Here are a few more general rules for the problem sets.

8. The problem sets are due by **3:00 pm on Fridays**, at my office, Wean Hall 7414. If I happen not to be in my office, you can put your set beneath the door.
9. It is a good habit to study your problem sets even after they have been graded. Points might be subtracted if you do not pick up your problem sets.
10. **None of the grades for the problem sets or tests will be dropped.** If you do anticipate that you will not be able to complete a problem set on time, please contact me.
11. **You must staple your problem sets.** This is meant to be kind to the grader.
12. The edges of the problem sets cannot be ragged—please do not just tear the pages out of a notebook. This is also meant to help the grader.

QUIZZES

At most lectures there will be a short attendance quiz based on the current lecture material and readings.

GRADES

Grading:

3%	Recitations	30%	Three Subject Examinations
3%	Attendance quizzes	28%	Final Examination
36%	Problem Sets		

WEEK I — 16 to 20 January

Monday	**No lecture**
Tuesday	**Lecture 1. Coulomb's law and charge** Sternheim and Kane: sections 16.1-16.2, sections 5.5–5.6 Notes: chapter I.1-I.5
Wednesday	**Lecture 2. The electric field** Sternheim and Kane: sections 2.1
Thursday	**Recitation 1. Coulomb's law and vectors**
Friday	Problem set 1 due

WEEK II — 23 to 27 January

Monday	**Lecture 3. Distribution of charge** Sternheim and Kane: sections 16.3-16.4 Notes: chapter I.6-I.8
Tuesday	**Recitation 2. Distributions of charge**
Wednesday	**Lecture 4. The electrostatic potential** Sternheim and Kane: sections 16.5-16.6 Notes: chapter II
Thursday	**Recitation 3.The electrostatic potential**
Friday	Problem set 2 due

WEEK III — 30 January to 3 February

Monday	**Lecture 5. Dipoles** Sternheim and Kane: section 16.7 Notes: chapter III.1-III.4
Tuesday	**Recitation 4. Electric dipoles**
Wednesday	**Lecture 6. Capacitors** Sternheim and Kane: sections 16.9-16.11 Notes: chapter III.5-III.9
Thursday	**Recitation 5. Capacitors**
Friday	Problem set 3 due

WEEK IV — 6 to 10 February

Monday	**Lecture 7. Symmetries** Notes: chapter IV
Tuesday	**Recitation 6. Symmetries**
Wednesday	**Lecture 8. Gauss's law** Sternheim and Kane: sections 16.12-16.13 Notes: chapter V
Thursday	**Recitation 7. Gauss's law**
Friday	Problem set 4 due

WEEK V — 13 to 17 February

Monday	**Lecture 9. Currents, Ohm's law, and power** Sternheim and Kane: sections 17.1-17.4, 17.9 Notes: chapter VI.1-VI.6
Tuesday	**Recitation 8. Currents and ressitance**
Wednesday	**Lecture 10. Kirchhoff's rules and *RC* circuits** Sternheim and Kane: sections 17.5-17.7 Notes: chapter VI.7-VI.11
Thursday	**Recitation 9. Kirchhoff's rules and *RC* circuits**
Friday	Problem set 5 due

WEEK VI — 20 to 24 February

Monday	**Lecture 11. A circuit model of an axon** Sternheim and Kane: sections 18.1-18.3 Notes: chapter VII.1-VII.2
Tuesday	**Recitation 10. More on circuits**
Wednesday	**Lecture 12. A circuit model of an axon** Sternheim and Kane: sections 18.4-18.5 Notes: chapter VII.3-VII.5
Thursday	**Recitation 11. Nerves** **EXAMINATION I** Material covered: chapter 16
Friday	———

WEEK VII — 27 February to 3 March

Monday	**Lecture 13. Magnetic fields and magnetic forces** Sternheim and Kane: sections 19.1-19.4 Notes: chapter VIII.1, VIII.3-VIII.4
Tuesday	**Recitation 12. Magnetic fields and Lorentz force law**
Wednesday	**Lecture 15. Ions, isotopes, and particles** Sternheim and Kane: sections 19.9-19.10 Notes: chapter VIII.2
Thursday	**Recitation 13. Electric and magnetic forces**
Friday	Problem set 6 due

SPRING BREAK — 6 to 10 March

WEEK VIII — 13 to 17 March

Monday	**Lecture 15. Magnetic dipoles** Sternheim and Kane: sections 19.5 Notes: chapter IX
Tuesday	**Recitation 14. Magnetic dipoles**
Wednesday	**Lecture 16. The Biot-Savart law** Sternheim and Kane: sections 19.7-19.8 Notes: chapter X
Thursday	**Recitation 15. The Biot-Savart law**
Friday	Problem set 7 due

WEEK IX — 20 to 24 March

Monday	**Lecture 17. Ampère's law** Sternheim and Kane: sections 19.12 Notes: chapter XI
Tuesday	**Recitation 16. Ampère's law**
Wednesday	**Lecture 18. Faraday's law** Sternheim and Kane: sections 20.1-20.3 Notes: chapter XII.1-XII.4
Thursday	**Recitation 17. Magnetic flux and Faraday's law**
Friday	Problem set 8 due

WEEK X — 27 to 31 March

Monday	**Lecture 19. Alternating currents** Sternheim and Kane: sections 20.3-20-4 Notes: chapter XII.5-XII.7
Tuesday	**Recitation 18. Generators, transformers, and AC currents**
Wednesday	**Lecture 20. Inductance and magnetic materials** Sternheim and Kane: sections 20.6-20.8 Notes: chapter XIII
Thursday	**Recitation 19. Inductors and inductance**
Friday	Problem set 9 due

WEEK XI — 3 to 7 April

Monday	**Lecture 21. Waves and their basic features** Sternheim and Kane: sections 21.1-21.3 Notes: chapter XV.1-XV.3
Tuesday	**Recitation 20. Maxwell's equations**
Wednesday	**Lecture 22. Standing and travelling waves, interference** Sternheim and Kane: sections 21.4, 21.7 Notes: chapter XV.4
Thursday	**Recitation 21. Properties of waves** **EXAMINATION I** Material covered: chapters 17–19
Friday	———

WEEK XII — 10 to 14 April

Monday	**Lecture 23. Boundary conditions** Sternheim and Kane: sections 21.5-21.6 Notes: chapter XVI
Tuesday	**Recitation 22. Resonant standing waves**
Wednesday	**Lecture 24. Energy, momentum, polarisation, reflection** Sternheim and Kane: sections 21.5-21.6, 23.1-23.3 Notes: chapter XVII
Thursday	**No lecture**
Friday	**No lecture**

WEEK XIII — 17 to 21 April

Monday	**Lecture 25. Refraction, interference, and diffraction** Sternheim and Kane: sections 23.4-23.8 Notes: chapter XVIII.1-XVIII.4
Tuesday	**Recitation 23. Polarisation and diffraction**
Wednesday	**Lecture 26. Single-slit diffraction, mirrors, and lenses** Sternheim and Kane: sections 23.9, 24.1-24.2 Notes: chapter XVIII.5, XIX.1-XIX.2
Thursday	**Recitation 24. Diffraction and mirrors**
Friday	Problem set 10 due

WEEK XIV — 24 to 28 April

Monday	**Lecture 27. Forming images with lenses** Sternheim and Kane: section 24.3 Notes: chapter XIX.3-XIX.4
Tuesday	**Recitation 25. Lenses**
Wednesday	**Lecture 28. Magnification and magnifying glasses** Sternheim and Kane: sections 24.4-24.5 Notes: chapter XIX.5-XIX.6
Thursday	**Recitation 26. Forming images through lenses**
Friday	Problem set 11 due

An Outline of the Topics for Electromagnetism and Light

I. Electrostatics
Coulomb's law, electric fields, electric field diagrams, determining the electric field for a collection of charges, special configurations: spheres, wires, and planes, the electrostatic potential, equipotential surfaces, electric dipoles, capacitance, dielectrics, energy in a capacitor, Gauss's law, conductors

II. Direct currents
Electric currents, resistance, the atomic theory of resistance, Ohm's law, energy in circuits, power in circuits, Kirchhoff's rules, resistors in parallel and in series, capacitors in parallel and in series, RC circuits

Extra Topic: Nerves

III. Magnetism
Magnetic fields, the force on a moving charge, magnetic forces on wires, magnetic dipoles, magnetic fields generated by currents, charge to mass ratio, mass spectrometers, the Biot-Savart law, Ampère's law, solenoids

IV. Time-dependent electromagnetic fields
Magnetic flux, Faraday's law, Lenz's law, induced fields, inductance and self-inductance, energy in an inductor, generators, transformers, AC circuits, power, root-mean-square current, ferromagnets, Maxwell's laws

Extra Topic: Magnetic resonance imaging (omitted this semester)

V. Waves
Sinusoidal waves, a mathematical description of waves, speed of waves, travelling waves and standing waves, boundary conditions, interference, complicated waves, beats, energy and momentum in a wave, polarisation of a wave

VI. Optics
Index of refraction, Huygen's principle, reflection and refraction, total internal reflection, the double-slit experiment, coherence, diffraction gratings, diffraction, polarisation of light

VII. Mirrors and lenses
Mirrors, lenses, images and objects, power of lenses, aberrations, simple magnifiers