SUBJECT MATTER

Physics is the study of the fundamental laws of nature that underlie all of science. Physics is an experimental science in that the laws of nature were deduced from experimental observations. The goal of P114 is to provide the biological sciences and medicine majors with a basic understanding of the physics and the technology that underlie their majors. P114 should provide you with an understanding of the basic laws of nature, as well as the principles of measurement, that are required of science that you intend to pursue. Most scientific topics and technology used in the life and physical sciences evolved from basic studies by physicists, such as studies of electricity and magnetism, optics, as well as molecular, atomic, and nuclear quantal systems.

The beauty of physics is that, for each branch of physics, the laws of nature can be condensed into just a few fundamental concepts or laws. Once you have mastered these basic concepts you will have a valuable insight into even the most complicated applications. Therefore P114 will emphasize the underlying physical principles rather than rote memorization of a mass of facts and formulae. It is important that you first understand the basic laws and then learn how to apply them.

A roadmap of the topics to be discussed in P114 are shown schematically in figure 1 and described below.

1; Electricity and magnetism

Electricity and magnetism will be the topic discussed during the first part of this course and will underlie much of this course. The fascination and beauty of this subject is that the behavior of electricity and magnetism is unified into a one topic, called electromagnetism, and this large subject can be condensed in four laws of nature, the Maxwell Equations. Electricity and magnetism has a profound influence on your life. You are familiar with the role of electromagnetism in providing electric power, electronics, computers, radio, television, automobiles, electromagnetic waves such as light, radio waves, X-ray, gamma rays, etc. Electromagnetism plays a key role in life, it is electromagnetic radiation that transmits, from the sun, energy needed to support life on earth. It is electrical forces that bind together atoms, molecules and matter. Nerve cells, the senses of smell, touch, vision all ultimately are electromagnetic in nature. Electromagnetism, as epitomized by Maxwell’s equations, led to the theory of relativity, the understanding of optics, as well as binding of atoms, molecules and matter that underlies most of the life sciences.

2; Optics

The discussion of electromagnetic waves, as manifest by light, leads to an introduction to wave aspects, geometrical optics, and optical instruments. Optics features prominently in the study of the life sciences.

3; Modern physics

The remarkable scientific developments during the twentieth century will be introduced, namely, Einstein’s Theory of Relativity and the development of quantum physics. The introduction of wave-particle duality and the wave equation has had profound implications on all sciences as will be discussed for atoms, molecules, and nuclei. The understanding of quantum physics is crucial in the understanding of atomic and molecular binding which underlies all of biology. The course will end with a discussion of the unity of physics ranging from the fundamental building blocks and forces to cosmology and the origin of the universe.
ORGANIZATION:

The course comprises three equally important components that operate in parallel.

1) Lectures that cover the conceptual aspects of the material.

2) Workshop sections that are devoted to applications of the concepts, questions and problem solving.

3) Laboratory work that emphasizes the principles of measurement using experiments designed to demonstrate topics discussed in the lectures.

Lectures will be given on Tuesday and Thursday 1230 - 1350 hours in Hoyt Hall commencing Thursday 16 January. Lecture notes will be provided prior to each lecture to allow prestudy. It is suggested that you print a copy of the lecture notes that you take to the corresponding lecture so that you can annotate them. This will minimize note taking and enhance the learning experience during class. Demonstrations will be given in class. Attendance of lectures is required since there is considerable experience that shows that the most successful students are those with the best course attendance records. In addition, there is quantitative evidence that students who sit at the front of class are more successful than those who sit at the rear. If any student is unable to attend a lecture they should contact the instructor to ensure that the missed material is covered.

Workshops will be an integral part of this course, similar to P113. You will meet once per week, for two hours, with a group of about fourteen other students plus a leader. The basic idea of the workshop concept is to institutionalize the study group with the addition of some leadership and supervision. At the workshop sessions, students will work through sample questions and conceptual exercises designed to elucidate the material taught in class. The purpose of the workshop leader is to facilitate the discussions rather than lecture or provide answers. The workshop leaders will record your attendance and level of participation at workshop sessions and this will count towards 3% of the final course grade. Workshops will commence on Tuesday January 21. The workshop assignments will be posted on the Workshop module web page link of the P114 website.

Problem sets will be assigned weekly to illustrate and enhance the understanding of material taught in class. Lectures will emphasize concepts while the problem sets and workshops will emphasize quantitative problems. Only two questions of each homework problem set will be graded because of manpower limitations; it is felt that instructor time is better spent providing guidance during workshops rather than grading homework. Students will be given one point for each question answered plus up to 5 points each for the two questions that are fully graded. The assignments will be posted on the P114 homework web page, available via the P114 web page, 10 days prior to the deadline. The solutions will be posted on the homework solutions webpage 5 days after the deadline. Note that examinations will emphasize quantitative problems, thus it is crucial that you take the time to learn to solve the assigned problems every week, prior to looking at the solutions. You will seriously reduce the chances of a high grade in this course if you do not expend the consistent effort needed to learn how to solve quantitative problems. In contrast to P113, the physics concepts introduced in P114 will be novel and new to you, and thus your intuition, derived from common experience, will be less useful. It takes time learning to understand and apply these new concepts, so do not fool yourself into thinking that you can cram the material just before examinations.

Class Quizzes: Weekly 5-minute multiple choice class quizzes will be given, they will be based on material presented during prior lectures. The grades on these class quizzes will count 10% towards your course grade. Evidence shows that repeated class tests provide the stimulus to work consistently and keep up with the material. Each lecture builds on material discussed in prior lectures, so you must keep up with the course; it is difficult to recover if you fall behind.

Reading Assignments will include the lecture notes provided prior to each lecture. The knowledge gained from this pre-lecture reading should enable you to extract more from each lecture.

Laboratory work is required for P114. You already have signed up for the Physics 114 laboratory course. You MUST perform the experiments and hand in satisfactory lab reports to pass the P114 course. Laboratory work comprises five 3-hour laboratory experiments scheduled every other week in B&L 206. The laboratory component of the course is run independently of the lectures by Professor Bodek. Contact The Laboratory Administrator on matters pertaining to the Laboratory. The e-mail address is; physicslabs@pas.rochester.edu. Laboratory sessions will start January 28.

Office Hours. Contact your workshop leader directly whenever you need help and arrange mutually convenient times to meet. Office hours will be posted on the P114 web page. Students should take advantage of the office hours and other help provided by the workshop instructors.

COURSE INSTRUCTOR:

Prof. Douglas Cline
Office: B&L 203D
Tel: 275-4934
Email: Cline@pas.rochester.edu
Office hours: Tuesdays & Thursdays at 1400-1500 hours, or by appointment, in B&L 203D.
WORKSHOP LEADERS:

Levi Neukirch  
Office: Wilmot 215  
Email: lneuk@pas.rochester.edu

Lucian Lo  
Office: B&L 373  
E-mail: lucien1011@gmail.com

Ryan Waldman  
Office: B&L 304  
E-mail: rwaldman@pas.rochester.edu

Runyu Bi  
Office: POA Library  
E-mail: rbi2@u.rochester.edu

Selin Haci  
Office: POA Library  
E-mail: shaci@u.rochester.edu

James Maslek  
Office: POA Library  
E-mail: jmaslek@u.rochester.edu

Ian Pershing  
Office: POA Library  
E-mail: ipershlin@u.rochester.edu

Kevin Silverstein  
Office: POA Library  
E-mail: ksilver2@u.rochester.edu

Steven Torrisi  
Office: POA Library  
E-mail: storrisi@u.rochester.edu

STUDENT-INSTRUCTOR INTERACTION:

I am a strong believer in the importance of frequent student-instructor interaction when learning physics and thus typically I arrange one-on-one meetings with my students. Unfortunately this is not feasible in P114 because of the large class size, ≈ 220 students. Therefore it is necessary to delegate student-instructor interactions to the workshop leaders. Each student will be assigned one workshop leader and this workshop leader assumes responsibility for providing the student with guidance, grading, recording of the grade records, and will participate in assigning the final course grade for the student. Thus it is important that you and your workshop instructor get to know each other. Your workshop leader is the one assigned to teach the workshop section that you selected when registering for workshop sessions. Unfortunately I have no flexibility to move students between workshop sections because most workshop sections are already at the maximum size of 15 students. If you wish to switch to another workshop instructor you must first locate a student in your preferred workshop sessions who is willing to swap sections with you, and then the two of you must come to my office at the same time so that I can check that the proposed swap is mutually agreeable to both students. All 9 workshop leaders will hold office hours and students are allowed to interact with any of the 9 workshop leaders to have questions answered.

COMMUNICATION

Both email and a web page will be used for communication.

Email: Email is a more direct, confidential, and personal communication approach than is the web page. Therefore you will receive personal email messages, roughly every week, that will list the current status of all of your grades for P114 as well as to provide quick dissemination of other information pertinent to P114. Grades will be distributed only by email so it is important that you have an active email address.

Web: http://www.pas.rochester.edu/~cline/P114.html. The P114 webpage lists the general information for the course, such as schedules, instructor information, and links to other P114 web pages. The homework and the workshop problem sets as well as solutions to the problem sets and mid-term tests will be posted on the P114 web page.

ASSIGNMENTS

Homework: Weekly problem sets will be assigned to elucidate the material covered in lectures and teach you how to solve problems. The homework should be handed in to the P114 locker assigned to your workshop leader prior to the deadline. These boxes are at the bottom of the main staircase on the first floor of B&L. The assignments will be posted on the P114 homework web page 10 days prior to the deadline. The solutions will be posted on the same homework solutions webpage 5 days after the deadline. It is crucial that you work through these problem sets or you will have serious problems with the examinations.

Class Quizzes: Five-minute multiple-choice quizzes will be given every week.

Reading Assignments: A reading assignment will be given each lecture outlining material to be read prior to the next lecture. The class quizzes may include a question taken from the reading assignment due that day, to help encourage you to do the pre-lecture reading.

Examinations: Two 90-minute examinations will be given during Common Examination Times. The first test is scheduled for Tuesday February 18 between 8:00 am - 9:30am. The second test is scheduled for Tuesday March 25 between 8:00 am - 9:30am. (Note that the MCAT exams are March 22, April 5,
The final examination is scheduled for Wednesday May 7 at 1915 - 2215 hours.

**Laboratory:** Independently written reports are required for each of the five laboratory experiments.

### GRADING

The final grade will be based on the following percentages:

- Class tests: 34%
- Homework: 10%
- Workshop participation: 3%
- Class quizzes: 10%
- Laboratory: 10%
- Final Exam: 33%

*A passing grade in the laboratory course is required in order to pass P114.* Attendance at lectures and workshop sessions is required. Your active participation in the lectures and workshops will be assessed and are included in your grade. No make-up exams will be given except for cases documented by medical certification. Such exams may be orals. All suspected cases of cheating or plagiarism will be reported to the Board on Academic Honesty. To defuse problems associated with the competition for grades, final letter grades will be based on the absolute total score for the course, rather than using a grading curve. Thus in principle, you all could get high grades. Your grade record will be sent to you regularly by email. You are responsible for checking that your record is correct and for informing your workshop teaching assistant of errors.

### DIFFICULTY

Physics has an undeserving reputation, among life scientists, of being a difficult subject. Physics is a logical and deductive science where each discussion builds upon earlier discussions. Each new concept or derivation is not implicitly difficult, but it is crucial that the student not get behind in the work. This is the reason for weekly problem sets, quizzes and frequent tests. The laws of nature are best expressed in the form of mathematical equations, thus any serious study of physics requires a minimum level of mathematics. The discussion of electromagnetism and quantum physics requires use of vectors and basic elements of both differential and integral calculus. This will include simple differential equations, and line, surface and volume integrals. To minimize the mathematics the simpler integral calculus approach will be used when discussing electromagnetism rather than the powerful differential vector-calculus approach. In addition, a list of required integrals will be provided on tests.

### UNITS

As in all fields of measurement, one is free to choose a system of units. The furlong-fortnight-stone system of units may be a convenient system of units for horse racing, but it is inconvenient for scientific measurements. The meter-kilogram-second system of units (M.K.S.) is the system that has been adopted worldwide as the international system of units. The United States is one of the few countries that has not committed itself to this system. The rationalized MKS system of units will be used in P114. Some older but excellent textbooks, such as the Berkeley Physics Course Vol 2 (McGraw-Hill), by Purcell, use the centimeter-gram-second system.

### TEXT BOOKS

**Class textbook:** Douglas Giancoli, *Physics for Scientists and Engineers*, Volumes 2 & 3, 4rd edition (2006), Prentice-Hall. This text has been chosen for continuity with P113.

**Library reserve:** In addition to the class text, the following other books are on reserve in the Physics Library.

1. "University Physics Volume 2 and 3" by Young and Freedman. Volumes 2 and 3 are required for P114. This excellent textbook has been used as the P114 text in prior years.
2. "Physics for Scientists and Engineers 4 Edition" by Tipler. This is an excellent book that is biased more towards the physical scientists. It covers the material at the correct mathematical level and often best matches the lectures.
3. "General Physics" (second edition) by Sternheim and Kane published by Wiley. This book focuses on life-science applications of the physics under discussion. However, the superficial discussion of some aspects frustrates many students.
4. "The Mechanical Universe" by Olenick, Apostol and Goodstein, Cambridge. This book covers the required material at the correct mathematical level. It is biased towards the physicist and astrophysicist rather than the life scientist.
5. "Physics" (Second edition) by Ohanian, Norton. This text covers the required material at a slightly higher mathematical level than required for P114, it is aimed at the physical scientist.

The **P114 Lecture Notes**, will supplement the textbook. The lectures will cover the material slightly differently than the way it is given in the textbooks. Professor Cline believes that you will understand the material better by presenting it from a slightly different perspective than that presented in the book. It is recommended that you study the book in parallel with the lecture notes provided.
SYLLABUS

1 ELECTROSTATICS
   Introduction, Experimental facts, Coulomb’s Law, Units, Principle of Superposition, Force Field, Concept of Electric Field, Representation of an E field.

2 THE ELECTRIC FIELD
   Introduction, Discrete charges: Electric dipole, Continuous charge distributions, Flux, Gauss’ Law.

3 GAUSS’S LAW
   Introduction, Flux of vector field, Gauss’ Law, Symmetry, Spherical symmetry, Cylindrical symmetry, Plane symmetry, Motion of point charges in electric fields.

4 ELECTRIC POTENTIAL
   Introduction, Electric potential energy, Electric potential, V for a system of point charges, V for a continuous charge distribution, Determination of E field from electric potential, Circulation of a static electric field, Maxwell’s equations for electrostatics.

5 CONDUCTORS IN ELECTRIC FIELDS

6 ELECTRIC FIELDS IN DIELECTRICS
   Introduction, The electric dipole, Dielectric polarization, Electric field in dielectrics, Boundary conditions, Capacitance and dielectrics, Energy density in matter.

7 ELECTRIC CURRENT
   Introduction, Electric current, Charge conservation, Electric conductivity, Microscopic picture, Electric power, Electromotive force, Kirchhoff’s rules.

8 MAGNETISM
   Introduction, Electromagnetism, The Lorentz force, Units, Motion of point charges in uniform magnetic fields, Magnetic forces on electric currents, Force on a current loop.

9 SOURCES OF MAGNETIC FIELD
   Introduction, Magnetic field due to a moving point charge, Units, Biot-Savart Law, Forces between circuits.

10 AMPERE’S LAW
   Introduction, Gauss’s Law for magnetism, Ampere’s Law, Applications of Ampere’s Law.

11 MAGNETISM IN MATTER
   Introduction, Magnetic dipole, Microscopic magnetism in matter, Magnetic behavior of matter, Boundary conditions, Electromagnet, Magnetic energy density.

12 MAGNETIC INDUCTION

13 INDUCTANCE
   Introduction, Self inductance, Mutual inductance, Transformer, LR circuits, RLC circuits, Applications, Magnetic energy.

14 MAXWELL’S EQUATIONS
   Introduction, Electrodynamics before Maxwell, Displacement current, Maxwell’s equations.

15 ELECTROMAGNETIC WAVES IN VACUUM
   Introduction, Mathematics of waves, Maxwell equations for vacuum, Transverse plane wave, Relation of E and B fields, Wave equation, Generation of electromagnetic waves.

16 ELECTROMAGNETIC WAVES IN MATTER
   Introduction, Electromagnetic spectrum, Energy and momentum in electromagnetic waves, Electromagnetic waves in matter, EM waves at boundaries.

17 WAVE PHENOMENA
   Introduction, Coherence, Division of amplitude interference, Division of wavefront interference, Diffraction, Summary.

18 GEOMETRICAL OPTICS
   Introduction, Reflection and refraction at boundaries, Reflection at a single surface, Refraction at a single boundary, Thin lenses, Double-lens systems, Dispersion, Aberrations.

19 OPTICAL INSTRUMENTS
   Introduction, Camera, Human eye, Compound microscope.

20 EINSTEIN’S UNIVERSE
   Introduction, Inertial frames, Special theory of relativity, Behavior of clocks and rules in motion, Electromagnetism, Relativistic energy and momentum, General relativity.

21 ORIGIN OF QUANTUM MECHANICS
   Introduction, X rays, Radioactivity, Discovery of the electron, The atomic nucleus, Origin of the quantum constant, The photon hypothesis, Quantization of atomic energies, Bohr model of the atom, Summary of old quantum theory.

22 QUANTUM WAVE THEORY

23 WAVE EQUATION
   Introduction, Wave-particle duality, Quantized modes, Schrodinger equation, One-dimensional solutions, Three-dimensional solutions, Conclusions.

24 QUANTUM THEORY OF ATOM
   Introduction, Hydrogen atom, Exclusion Principle, Symmetry in nature, Multi-electron atoms, Dirac wave equation.

25 THE NUCLEUS
   Introduction, Nuclear structure, Quantum tunneling, Nuclear fission, Nuclear fusion, Detection of radiation. Radiation dosage. Applications to the life sciences.

26 UNITY OF PHYSICS
   Introduction, Fundamental particles, The four forces in nature, Cosmology and the Big Bang, Unity of physics.
### SCHEDULE

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<td>23 Jan</td>
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<td>13 Feb</td>
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<td>Ampere’s Law, forces between circuits</td>
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<td><strong>First Class Test.</strong> Lectures 1-7</td>
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