PHYS 114: Physics for the Life Sciences I
University of North Carolina at Chapel Hill

Lead Instructor: **Email Address:**
Office: **Office Phone:**
Office Hours:
Studio Coordinator: **Email Address:**
Office: **Office Phone:**
Office Hours:

PREREQUISITE: MATH 231 or equivalent

COURSE DESCRIPTION
Basic principles of physics including forces, energy, oscillations, sound, diffusion, heat transfer and random processes, and how to apply these concepts to understand biological systems and processes. This course is intended to meet the needs of, but is not restricted to, students majoring in the life sciences. Students who have taken PHYS 104 or 116 may not receive credit for PHYS 114.

COURSE GOALS
1. To gain a fundamental understanding of matter and its interactions
2. To be able to apply that fundamental understanding to analyze biological systems and processes
3. To enhance skills in quantitative analysis of physical systems and phenomena

Through this course you will have the opportunity to analyze the physical world around you and improve your critical thinking skills. The instruction for this course places significant emphasis on qualitative physical reasoning as an important foundation to quantitative problem solving.

COURSE FORMAT AND PHILOSOPHY
The instruction in this course focuses on student-centered learning and involves active participation from the students. The instructors will act more as "coaches" who facilitate student learning, as opposed to a pure "lecturers" who transmit knowledge without necessarily requiring thought or action on the part of the student. Since the instructional focus is on learning rather than teaching, students are expected to take more responsibility for their own learning than might be required in a more traditional lecture-only format. At the same time, frequent course assignments are designed to keep students "on track" through the learning process. To the extent possible, the instruction is aimed to meet a variety of learning styles. You are encouraged to spend a few minutes examining your own learning style using the on-line Index of Learning Styles survey (http://www4.ncsu.edu/unity/lockers/users/f/felder/public/ILSpage.html).

You will not be required to memorize lots of physics equations, but you will be required to comprehend and apply physics concepts to a variety of situations, especially (though not

exclusively) those that arise in living systems. The reason that many students find physics difficult is that it goes beyond memorization by requiring higher-level thinking skills (levels 4 through 6 below). Learning physics is also like learning a foreign language since new words and symbols must be understood and applied correctly within the context of various physical situations.

Bloom's Taxonomy of the Cognitive Domain:

1. **Knowledge** - memorization of facts, words, and symbols
2. **Comprehension** - understanding the meaning of knowledge
3. **Application** - applying concepts to various situations
4. **Analysis** - breaking apart complex ideas
5. **Synthesis** - putting individual ideas together to form a complete explanation
6. **Evaluation** - judging the merits of individual ideas and making decisions

The course will be conducted in "Lecture/Studio" format. Each unit will consist of a 50-min. lecture meeting and a 110-min. studio session, so that most weeks will contain two units. A topic will typically span more than one unit. Each topic will begin with a lecture introducing the biological "driving question" for the topic and the physics concepts relevant to the question. During class you will spend most of your time performing hands-on, minds-on experiments, working with computers and computer simulations, and discussing ideas with your classmates. The basic aim of this format is to allow you to take charge of your own learning, with the curriculum materials and your instructor as guides.

ACTIVITIES

Physics Education Research has shown that students actively involved in their learning of the subject will gain a greater understanding of physics than those students who are passive. Active learning, therefore, is a general term which refers to the active involvement of students in the classroom rather than passive involvement. As mentioned above, instead of only listening to lectures and watching demonstrations, on any given day students might be answering questions, working in groups, performing activities, and/or discussing concepts. To this end, a variety of teaching techniques will be used throughout the semester. These may include (but are not limited to) the following.

Pseudo-Socratic dialog Student questions are not answered directly. Instead, the professor will ask students leading questions to facilitate the students to answer the questions themselves.

Peer Instruction Lectures consist of short presentations on key points. Students are then asked a conceptual question related to the topic at hand. They are given time to think about it and then to discuss it with their neighbors. Answers are then given and discussed as a class.

Cooperative Group Problem Solving A supportive environment is fostered in which students can practice using problem-solving strategies within the classroom setting.

Science is a group activity, carried out in collaboration in research groups. Working in groups will help you develop skills that will benefit you throughout life. In addition, group work will

help you learn physics. By discussing the concepts and problems with others you will discover alternative ideas and solutions. You will also have the opportunity to teach others what you have learned (i.e. peer instruction). Nothing tests your understanding of an idea better than trying to explain it clearly to someone else.

All students are expected to engage in learning activities in all class meetings. In lecture meetings students will respond to questions asked by the instructor, using an electronic personal response system; these responses may be preceded by discussions with other students (peer instruction). In studio meetings activities will include laboratory exercises, simulation exercises, and cooperative problem-solving, all carried out in small groups. All activities will be aimed at enhancing your grasp of the physics concepts and how they can be applied to understand biological systems. Graded work associated with the activities will include (but is not limited to) group worksheets, problem solutions and calculations, and individual or group mini-reports summarizing the findings of a laboratory or simulation exercise. There will be no make-ups for missed activities, but students who are granted an excused absence will have the weighting of the activity scores adjusted accordingly. Only the lead instructor or the studio coordinator can grant excused absences for activities.

WARM-UPS

Before the beginning of each unit each student must complete a warm-up assignment. The assignment may include reading, viewing a video, or other preparation for the unit's activities. Each student must also complete a short quiz based on the assignment before attending the first class meeting of the unit. All warm-up assignments and their due dates will be available via the class Sakai site or the *MasteringPhysics* site (see below).

HOMEWORK

Each unit will have an associated set of exercises to be completed individually outside of class. We will use the *Mastering Physics* online homework system for this purpose. Assignments and their due dates will be posted on the Sakai site and on the *Mastering Physics* site. Students are encouraged to discuss the exercises with one another, but must submit individual responses to the questions.

EXAMINATIONS

There will be quizzes given throughout the semester; each quiz will contain a problem or question similar to ones that might appear on a midterm or final exam. There will be two midterm exams and a final exam, all closed-book. The midterm exams will take place in the evening on dates to be posted on the class Sakai site. There will be one make-up exam given for each midterm, only for those students who have been granted an excused absence for the original date. Any student who is granted an excused absence for the original date but is also unable to attend on the make-up date will have the weighting of his/her exam scores adjusted accordingly in the calculation of his/her final grade. Only the lead instructor or the studio coordinator can grant excused absences for exams. There will also be a practicum exam based on the laboratory exercises conducted in studio meetings. The course final exam will be given in compliance with UNC final exam regulations and according to the UNC Final Exam calendar.

GRADING
Warm-up assignments 5%
Personal responses in lecture 5%
Homework exercises 10%
Studio assignments 25%
Practicum exam 5%
Quizzes 5%
Midterms 10% each
Final Exam 25%

Late Policy: Unless you have made arrangements with the instructors prior to the due date or have an official University excused absence, you will lose 10 percentage points per day on late assignments.

Attendance Policy: Students are expected to attend all class meetings and participate in all activities in lecture and studio meetings. Excused absences can be granted only by the lead instructor or the studio coordinator, one of whom must be informed in advance of the date of the absence except in cases of sudden illness or other emergency.

Honor Code Policy: The Honor code and the Campus Code, embodying the ideals of academic honesty, integrity and responsible citizenship, have for over 100 years governed the performance of all academic work and student conduct at the University. Acceptance by a student of enrollment in the University presupposes a commitment to the principles embodied in these codes and a respect for this significant University tradition. Your participation in this course is with the expectation that your work will be completed in full observance of the Honor Code.

Academic dishonesty in any form is unacceptable, because any breach in academic integrity, however small, strikes destructively at the University's life and work. If you have any questions about the Honor Code, please consult with someone in the Office of the Student Attorney General or the Office of the Dean of Students.

Students are expected to abide by the Honor Code in all classroom activities. Collaboration is explicitly allowed on assignments that are designated as group submissions. Discussion with other students prior to submitting an individual answer is also permitted on personal response activities in lecture and on homework exercises, as described above. All other graded assignments (warm-ups, individual studio assignments, quizzes and exams) must be submitted without any aid not explicitly authorized by the instructors.

Syllabus changes: The lead instructor and studio coordinator reserve the right to make changes to the syllabus, including due dates and test dates. These changes will be announced as early as possible.

Physics 114 Topic Schedule

Topic 1 Physics, biology, and scaling

- Introduction to the course: The physical nature of life
- Similarities and differences between the two disciplines
  Provide some examples to set the stage
- Scaling
  Orders of magnitude & scientific notation: *Powers of Ten* video
  Dimension
  Estimation
  Scaling laws
  Ratio reasoning

Online assignment for Topic 1: Trigonometry and calculus review

Topic 2 Kinematics

- How do we describe motion?
  Magnitude and direction: the displacement vector
  Net displacement
  Where do we start and which way are we going? Coordinate systems
  Vector addition in steady motion and random walk
  Position versus time graphs: motor protein on a microtubule
  Vector components
  Multiplying vectors by scalars
- Rates of change and velocity (instantaneous and average)
- Acceleration
- Velocity versus time graphs
  Using graphs to determine accelerations and changes in position
  Connections to calculus
- Acceleration versus time graphs
- Non-linear velocities and accelerations
- Authentic examples e.g., cheetah and antelope
- Modeling
- Contrast with "massless" systems—Brownian motion (more on this later)

Topic 3 Forces I: Newton's laws

- Quantifying forces
  Contact and non-contact forces and examples of each
- Newton's 1st Law
  Free-body diagrams
  Passive and active forces
- Newton's 2nd Law

$$\vec{F}_{net} = \frac{d\vec{p}}{dt}$$

  Detailed analysis of systems versus point-like objects
- Newton's 3rd Law
- Centripetal forces

Topic 4 Forces II: Stress and Strain

- Hooke's law
- Stress and strain
- Material stiffness
  Young's modulus
- Stress, scaling, and the shapes of living things
- Shear and pressure
  Limitations of the linear stress-strain model
  Plastic deformation and rupture
  Non-linear materials: polymer
- Viscoelasticity and DNA

Topic 5 Forces III: Torque and Rotation

- Non-point masses
- Torque and vectors
- Locomotion and torque

Topic 6 Work and Energy

- Work and the energy of motion
  Work and changes in kinetic energy contrasted to impulse and changes in momentum
- Calculating work and determining changes in energy
- Work-energy theorem
  Constant forces applied to objects traveling in straight lines
  Non-constant forces applied to objects traveling in straight lines
  Power

Topic 7 Energy conservation

- Gravitational potential energy
  Path independence
  Accounting for gravitational work
  Location of PE: Systems including and not including the Earth
- Elastic potential energy and deformation
  Linear materials
  Non-linear materials
  Stored energy and fractures

Topic 8 Energy conversion and efficiency

- Frictional forces as a means of energy conversion
  Sticking versus slipping: static and kinetic friction
- Adhesion and surface roughness
- Moving through air and water: viscosity and drag
- Chemical and thermal energy; conversion among forms of energy
- Efficiency: motor protein vs. automobile

Topic 9 Energy at the atomic level: heat and thermal motion

- Energy contained in a material: temperature and thermal energy
- Statistical physics
  Predictable outcomes from random motion
  Irreversibility and chance
- Entropy and statistics

Topic 10 Diffusion

- Diffusion: random motion
  Particle size and mean free path
  The diffusion coefficient and time scales
  Reptation
- Breathing and the transfer of oxygen to cells
- Diffusion across membranes and osmosis vs. active transport
- Diffusion of energy: thermal transport

Topic 11 Heat transfer

- Temperature and thermal expansion
- Heat capacity
  Predicting molar heat capacities
  Diatomic gases
  Solids and more complex materials (including animals)
- Changes of state
- Heat transfer
  Conduction
  Convection
  Radiation
  Evaporation
- Thermoregulation
  Thermoregulation on land
  Thermoregulation in water

Topic 12 Oscillations A mix of kinetic and potential energy

- Harmonic motion
  Oscillations about equilibrium
  Simple harmonic motion: mass on a linear spring
  Natural frequencies
  An oscillating rod: hair cells in the ear
- Energy in harmonic motion
  An example: intermolecular bonds
- Damped harmonic motion
  Weak damping
  Overdamped motion—the normal biological state
  Chromatin vs. microtubules
- Driven oscillations

Topic 13 Sound

- Wave motion
- Intensity of sound
- Superposition of sound waves
- Producing sound
- The human ear: physiology and function
- The Doppler effect
- Ultrasound
- Guided waves: singing whales

Topic 14 Special relativity: Life in the fast lane

- Relativity of space and time; Einstein's trains
- Mass-energy and dynamics: $E=mc^2$