Engineering Physics Strand: Physics I&II with Calculus

Engineering Physics Strand – Governor's School for Science and Technology

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1. Course Text: Physics for Scientists and Engineers (4th edition) by Randall D. Knight

2. What is Physics (and this course)

"*The whole of science is nothing more than a refinement of everyday thinking*." (Einstein)

Physics is the study of nature – it is a *living* discipline, not a collection of facts. It is the science of daily existence and is something you know a great deal about. You have direct experience with the nature of forces, how things respond to those forces, the conservation of mass, energy, momentum, and some aspects of gravity. The formal study of physics should guide and clarify your understanding to build a consistent basis of fundamentals that allow you to build models for describing the physical behavior of unfamiliar or complex systems. Physics is about reasoning, making connections, and understanding what will happen in a situation, and why it happens.

In order to do physics in a genuine sense, it is necessary to be able to apply the skills used within the discipline to new situations. When dealing with new situations, we use mathematical models to describe them – and applying these models often requires simplifications or assumptions about the physical situation. It is necessary to become proficient with the use of models, their applicability, when they are not appropriate (and why), and to be able to analyze situations multiple ways. My goal is for you to be able to leave the course with a set of skills and tools that you can use to analyze any basic system, and to understand what the next step would need to be to address a more complex aspect of that system.

My job is therefore not to tell you information - my job is to help you make sense of the information and help you develop the tools and skills needed to model and understand the physical world... i.e., not to just know ABOUT physics but to be able to DO physics.

This course is not only about physics but also about applications of physics in the field of engineering. This makes learning physics purposeful and applies your creativity, while developing skills to be productive in a teamwork, and communication skills that are so important for your future life and career.

3. **Course Specific Requirements/Student Responsibilities:**
   Prerequisites/Corequisite: Calculus I
   Required Materials:
   - Notebook (3-ring binder preferred) – Students will be expected to keep a binder or section exclusively for use in this class. The binder should be a comprehensive, well-organized record of your work in physics.
   - Composition Lab notebook (graph ruled preferred)
   - Pencil(s) (with eraser), loose-leaf paper
   - Scientific Calculator (*e.g*. TI-30, Casio fx-300, or better)

Effective organization is important in a student's success in physics. Consistent organization can make a difficult course manageable and raise a marginal grade to an excellent grade.

Classroom Expectations:
- <u>Be On-Time:</u> Students are expected to be in the room and seated when the bell rings.
- <u>Be Ready to Learn:</u> Bring ALL required materials to class.
- <u>Be Respectful:</u> Take RESPONSIBILITY for your own actions and THINK before you ACT.
- <u>Show Effort:</u> Do your homework and adequately prepare for all tests and quizzes.
- <u>Ask for Help:</u> Ask questions when needed and/or arrange for a time to come and see instructor.

4. **Academic Integrity:** Any cheating on any exams or quizzes will result in a grade of "0" for that test. Cheating is defined as either the giving or the receiving of unauthorized help. Any indication of cheating will result in a grade of zero for the exam; **a second violation and there will be conferencing with the director**. A one-sided 3x5 NOTE CARD WILL SOMETIMES BE PERMITTED.

5. **Grading:** Each semester will consist of classwork and labs, homework, exams and quizzes, as well as a project. Students will be evaluated on the following scale. The cumulative semester exam shall be worth 20% of their grade. The rest of the grade will be calculated using the following weights. All assessments will be timed to correspond to nationally normed standardized testing. Grading is done via the point system. Points are assigned for each given assignment, quiz, or test etc… All points will be pooled by category. The category weights of for the points are listed in the next section.
   A special note about grades: Although I know that your grade is important to you, I have found that focusing on your grade is actually counter-productive. I have found that if you focus on mastering physics then the grade <u>**always**</u> takes care of itself. So the next time you find yourself worried about your grade in my class, ask yourself instead what do you need to learn or master and you will be on the right path.

   Final course grades will be assigned using the following scale as a guide:

   90-100 A
   80-89 B
   70-79 C
   60-69 D
   0-59 F

6. **Evaluation:**

   a. 50% Exams and quizzes

b. 20% Lab
c. 15% Homework
d. Project(s) 10%
e. 5% Classroom Participation and work

7. Course Outline

Physics I: Mechanics

Unit 1: Kinematics (Ch. 1-4) 4 weeks
1. Concepts of motion
2. One-dimensional motion
3. Free falling particles
4. Two-dimensional motion

Unit 2: Newton's Laws of Motion (Ch. 5-8) 4-5 weeks
1. Force and motion
2. Static and dynamic equilibrium
3. Newton's Law
4. Acceleration of systems of particles

Unit 3: Work, Energy and Power (Ch. 9-10) 2-3 weeks
1. Work done by constant and changing forces
2. Conservation Laws
3. Hooke's Law
4. Work Energy Theorem
5. Power and Cost

Unit 4: Systems of particles and Linear momentum (Ch. 11-12) 1-2 weeks
1. System of particles
2. Center of mass
3. Momentum and Impulse
4. Conservation of Momentum

Unit 5: Rotation (Ch. 12) 1-2 weeks
1. Uniform Circular Motion
2. Rotational Dynamics
3. Torque
4. Conservation of Angular Momentum

Unit 6: Simple Harmonic Oscillators (Ch. 14) 1-2 weeks
1. Pendulums
2. Oscillating system of masses
3. Beats, Frequencies, and Period

Unit 7: Gravity and Kepler's Laws (Ch. 13) 1 week
1. Newton's Law of Gravity

Unit 8: Potpourri of chapters in Mechanics (if time permits)
1. Fluid mechanics

2. Elasticity
3. Waves

Physics II: Electricity and Magnetism

Unit 1: Electric Field and Gauss' Law (Ch. 22-24) 2-3 weeks
1. Coulomb's Law
2. Field Distributions of Systems of Particles
3. Electric Flux
4. Gauss' Law and various charge distributions

Unit 2: Electric Potential (Ch. 25-26) 2-3 weeks
1. Potential difference
2. Potential difference in Electric Fields
3. Potential difference of systems of particles (discrete and continuous)
4. Capacitance

Unit 3: Current, Resistance, and DC Circuits (Ch. 27-28) 2-3 weeks
1. Ohm's Law
2. Kirchhoff's Law
3. EMF and internal resistance

Unit 4: Magnetic Fields and Inductance (Ch. 29-30) 3-4 weeks
1. Hall Effect
2. Ampere's Law
3. Electromagnetic Induction
4. Faraday and Lenz's Law
5. Inductors
6. RLC Circuits

Unit 5: Optics (Ch. 31, 33-34) 3 weeks
1. Geometric Optics
2. Optical Instruments
3. Wave Optics

8. Labs

Labs are an essential portion of the course and will require 20%- 25% of the course time. Labs are crucial in making connections between real world applications, the vocabulary of physics, curricular learning, and problem-solving skills learned in class. All labs are designed to be guided inquiry. These hands-on investigations allow students the chance to practice critical thinking skills that are crucial to learning to be a scientist. Students will play a role in developing the experimental question and shaping or modifying the experimental design or procedure. A variety of lab tools and techniques such as video analysis, data logging equipment, motion sensors, and electronic apparatus will be introduced.

Many units begin with a laboratory investigation preceding any other instruction. The subject of the lab is designed to introduce one or more concepts important in the unit. These labs begin with a demonstration for the students to discuss. In the discussion they are prompted to brainstorm variables that might be reasonably presumed to govern the behavior of the demonstration apparatus. They then design and investigate to find relationships between the variables. A class discussion follows in which the class describes models for the behavior observed. Afterwards the model becomes explanatory and can be invoked in explaining concepts and solving problems.

Other labs are presented as open-ended lab problems where students can use the equipment available to them and design experimental procedures to find relevant relationships between variables and are guided to see the underlying physical principles. A few labs are virtual simulations that allow for review and reinforcement of concepts learned in class*. These virtual labs are listed for completeness but are not included in the lab time estimation. All labs will require written work both in keeping a lab notebook as well as some full laboratory write-ups.

*denoted by asterisk below

<u>Lab Listing</u>

Mechanics

Unit 1: Kinematics (Ch. 1-4) 4 weeks

1. Constant Velocity Cars: Students are asked to make motion diagrams and make predictions from data. A review of velocity, vectors, and experimental design
2. Describing Motion: Graphical analysis of 1-dimensional motion. Students use motion detectors or video analysis to collect motion graphs or mimic given graphs. Students will apply the derivative and integral to their models to derive kinematics equations.
3. Galileo's Experiment: Students find g on an inclined plane.
4. Thrown Objects: Students use video analysis to analyze projectile motion, confirm g, and analyze motion with non-constant acceleration. Calculus will be used for data analysis.

Unit 2: Newton's Law (Ch. 5-8) 4-5 weeks

1. Newton's Second Law: Students design an experiment to verify Newton's Second Law.
2. Sliding Friction: Students determine the coefficient of friction of a sliding and rolling object.
3. Drag: Students find a model for drag force using coffee filters and a motion detector.
4. Atwood Machine.

Unit 3: Work, Energy and Power (Ch. 9-10) 2-3 weeks

1. Elastic Energy: Students analyze the energy of bouncing objects and objects rolling on a track.
2. Hooke's Law

Unit 4: Systems of Particles and Linear Momentum (Ch. 11-12) 1-2 weeks

1. Center of Mass: Students find the balanced point distributed objects.
2. Impulse: Students collect force time data of a chain falling into a cup and compare it to the change in momentum.
3. Collisions: Students determine the mass of an unknown object by analyzing the motion of colliding carts.

Unit 5: Rotations (Ch. 12) 1-2 weeks

1. Flying Cow: Students compare the linear and rotational motion of an object
2. Rotational Inertia: Students compare the motion of various rotating objects and find the rotational inertia of the objects.
3. Angular Momentum: Students compare the linear and angular momentum using a ballistic pendulum.
4. Rotational Energy: Students reanalyze the energy of an object rolling down/around a track.

Unit 6: Simple Harmonic Oscillators (Ch. 14) 1-2 weeks

1. Spring-mass system: Students analyze the motion of an object hanging from a vertical and horizontal spring.

2. Pendulums: Students analyze the motion of a physical pendulum using video analysis.

Unit 7: Gravity and Kepler's Laws (Ch. 13) 1 week

1. Virtual Solar System: Students model circular and eccentric orbits using PhET simulation.

Engineering Projects of the first semester:

1. 3-D printing: Desk Organizer
2. Inverse Design: Mechanical Pencil
3. Bridge Contest

Electricity and Magnetism

Unit 1: Electric Field and Gauss' Law (Ch. 22-24) 2-3 weeks

1. Introduction to Charge: Students are challenged to explain the behavior of charged rods, pith balls, fun fly stick, and electroscopes.
2. Van de Graff: Students observe several Van de Graff demonstrations and explain and sketch the behavior to build their model of charge carriers.
3. E Field Mapping: Students map and explain the electric field and equipotential surfaces of several metal objects in a pan of water.

Unit 2: Electric Potential (Ch. 25-26) 2-3 weeks

1. *Virtual Electric Potential: Students use a PhET simulation to compare a topographical map to electric potential.
2. Capacitor Network: Students explore the behavior of systems of capacitors in series and parallel.

Unit 3: Current, Resistance, and DC Circuits (Ch. 27-28) 2-3 weeks

1. Resistivity: Students measure resistance as a function of length and area for conductor paper
2. Ohm's Law: Students analyze voltage versus current for various substances.
3. DC Circuit: Students build series, parallel, and combination circuits while predicting and measuring the voltage and current in different parts of the circuit.
4. RC Circuit: Students measure charge and discharge curves for an RC circuit.

Unit 4: Magnetic Fields and Inductance (Ch. 29-30) 3 weeks

1. Magnetic Field Investigation: Students investigate the magnetic force/field by investigating magnets, levitating objects over current loops, and iron filings.
2. Helmholtz Coil: Students measure the deflection of a beam of electrons passing through a Helmholtz coil to understand the Lenz Law and build on their understanding of the Lorentz Force.
3. *Virtual Faraday's Law: Students investigate induction using a PhET simulation.
4. *Virtual LR and RC circuits: Students use a PhET simulation to review RC circuits and extend their understandings of LR/LC circuits.

Electromagnetic Fields and Wave Optics (Ch. 31, 33-35) 2 weeks

1. *Single and Double Slit Simulation: Students analyze the behavior of waves when passing through a single or double slit using a simulation.
2. Thin Lens: Students build systems of lens and measure and predict images size and magnification.

Engineering Projects of the second semester:

1. Mini Van-der-Graaf Generator
2. Electromagnetic Motor
3. Telescope

Times and Subjects are subject to change, updated schedules will be announced and posted online.