Honors Physics Class Information and Syllabus: 2021-2022

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Conference period: 1st

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Syllabus: Honors Physics
Instructor: *Dr. Qing Jie*

Overview

In general, physics is the scientific study of the properties and interactions of matter and energy. Physics has qualitative, quantitative, empirical, and theoretical aspects and relies upon mathematical descriptions of nature. In this course, we will emphasize organized and logical approaches to problem solving, and direct observation, analysis, and interpretation of natural physical phenomena through laboratory studies. Whenever possible this course will make connections to other scientific disciplines such as biology, geology, astronomy, and chemistry. This course will also explore the significance of scientific methods and physical principles to technology and engineering, daily life, the economy, and ultimately, our civilization.

Course Objectives and Instructor Philosophy

Although knowledge of specific facts and concepts is important, science education must focus primarily on developing logical, systematic, and rigorous approaches to inquiry and problem solving. In this course, I will place emphasis upon learning to think scientifically—namely, developing a questioning habit of mind, and learning to formulate hypotheses and devising appropriate tests for these hypotheses. Instruction will include direct instruction (lecture), Socratic methods (leading questions), inquiry (e.g., laboratory investigations), and design-a-lab investigations that require physical intuition, creativity, and independent application of broad scientific concepts to solve challenging problems. Course topics will generally be taught in a historical way. We will see how great physicists of the past addressed outstanding scientific questions of their times. In this way, we will gain an understanding of a broad range of scientific methodologies from pure description to thought experimentation and experimental laboratory methods.

Mathematical Considerations

In general, Honors Physics is an algebra-based investigation of elementary physics concepts. However, from time to time the methodologies of calculus and vector analysis are so powerful and illuminating that I use them in solving physics problems—many in the class will have a working knowledge of these concepts (especially those in Calculus class!). Students in the Honors course may rest assured, however, that I will explain any unfamiliar mathematics used, and that I will not hold them accountable for advanced or exotic mathematical concepts beyond the level of ordinary algebra and trigonometry.

Topical Course Outline (with approximate timeline)
Fall Semester
Week 1

I. Introduction
A. General expectations for student performance during the course
B. Readiness assessment
C. Measurement, uncertainty, and analysis (e.g., SI units, dimensional analysis, significant figures and absolute precision)
D. Scientific methods
    A. What is science?
    B. Qualitative, quantitative, and empirical methods
    C. Falsifiability: hypotheses, theories, and scientific laws

Week 2-3

III. Newtonian (Classical) mechanics
    A. Kinematics
        1. Motion in one dimension
            a. Distance and displacement
            b. Speed and velocity
            c. Acceleration

        d. Position function and equations of motion
        e. Relative motion
    2. Motion in two dimensions, including projectiles

Week 4-6

B. Dynamics and Newton's laws of motion
- 1. Static equilibrium and the law of inertia (1st law)
- 2. Dynamics of a single particle: **F** =m**a** (2nd law)
- 3. Action-reaction principle/systems of two or more objects (3rd law)
- 4. Types of forces
    - a. Fundamental forces (field forces)
    - b. Mechanical forces (e.g., Hooke's law)
    - c. Conservative versus non-conservative (e.g., frictional) forces

Week 7-8

C. Work, energy, power
- 1. Work-energy theorem
- 2. Potential energy
- 3. Kinetic energy
- 4. Mechanical energy
- 5. Conservation of energy
- 6. Power
- 7. Review of simple machines

Week 9

D. Systems of particles and linear momentum
- 1. Center of mass
- 2. Impulse (and impulse-momentum theorem)
- 3. Elastic and inelastic collisions
- 4. Conservation of linear momentum

Week 10-11

E. Circular motion and rotation
- 1. Uniform circular motion: centripetal acceleration and force ("force that maintains circulation")
- 2. Rotational kinematics
    - a. Angular displacement
    - b. Angular speed and velocity
    - c. Angular acceleration
    - d. Position function and equations of rotational motion
- 3. Rotational dynamics
    - a. Moment of inertia
    - b. Torque and rotational equilibrium
    - c. Newton's laws for rotation
    - d. Angular momentum and its conservation

Week 12-13

F. Gravitation
- 1. Kepler's laws of planetary motion and the conic sections
- 2. Newton's law of universal gravitation

G. Oscillations and simple harmonic motion (dynamics and energy relationships)
- 1. Mass on a spring
- 2. Pendulum and other oscillators

Week 14-17

V. Thermal Physics

A. Temperature and heat
- 1. Mechanical equivalent of heat
- 2. Heat transfer methods and thermal expansion

B. Kinetic theory and thermodynamics
- 1. Ideal gases

a. Kinetic model
b. rms speed of gas molecules
c. Avogadro's number and Boltzmann's constant
d. Ideal gas law

2. Thermodynamic processes and the four laws of thermodynamics
    a. Thermal equilibrium (0^{th} law)
    b. Isovolumetric, isothermal, isobaric, and adiabatic processes
    c. First law (with pressure-volume phase diagrams)
    d. Entropy principle and the Second law the (with heat engines and the Carnot cycle)

Week 18: Semester review/finals

Spring Semester
Week 1-4

VI. Waves and Optics

- A. Wave motion
    1. Traveling waves
        a. Anatomy of waves: amplitude, wavelength, etc.
        b. Doppler effect
    2. Wave propagation
        a. Wave types: longitudinal (e.g., sound) and transverse (e.g., light)
        b. Intensity
        c. Polarization
    3. Standing waves
        a. Harmonics
        b. Resonance
    4. Superposition principle
- B. Physical optics
    1. Interference: constructive and destructive
        a. Single slit
        b. Double slit
        c. Interferometers and the Michelson-Morley experiment
        d. Thin films
    2. Diffraction
    3. Dispersion
    4. Electromagnetic spectrum
- C. Geometric optics and ray diagrams
    1. Reflection
        a. Plane mirror
        b. Spherical and other mirrors
        c. Law of reflection
        d. Image types, magnification
    2. Refraction
        a. Snell's law
        b. Lenses
            1. Concave
            2. Convex
    3. Thin lens/mirror equation with sign conventions

Week 5-7

VII. Electricity and magnetism

- A. Electrostatics
    1. Electric charge and Coulomb's law
    2. Conductors and insulators
    3. Electric fields, potentials, and potential energy (around point charges and other objects)

4. Gauss's law

B. Capacitors

1. Capacitance
2. Parallel plate and other geometries (cylindrical, etc.)
3. Dielectrics

Week 8-9

C. Electric circuits

1. Electric battery
2. Direct current, resistance (and resistivity), and voltage: Ohm's law and electric power
3. Direct series circuits (batteries and resistors only)
4. Direct parallel circuits (batteries and resistors only)
5. Direct combination circuits (batteries and resistors only)
6. RC circuits
   a. Steady state
   b. Charging and discharging (transients)

D. Magnetic fields

1. Magnetic polarity and field geometry
2. Gauss's law for magnetic fields

Week 10-13

E. Electromagnetism

1. Magnetic fields around wires with current: Ampere's law (and the Biot-Savart law)
2. Lorentz force (forces on charges moving through space and through wires)
3. Electromagnetic induction (Faraday's and Lenz's laws): electric generators and motors and ac currents
4. Coils and inductance
5. Synthesis: Maxwell's equations
   a) Gauss's law for electric fields
   b) Gauss's law for magnetic fields
   c) Faraday's law of electromagnetic induction
   d) Ampere-Maxwell law (with displacement currents)
   e) Maxwell's concept of the electromagnetic wave

Week 14-17

VIII. Nuclear physics

1. Nuclear forces (strong and weak forces)
2. Nuclear reactions: modes of radioactive decay; fission and fusion

VIII. Project on Modern Physics

Week 18: semester review/finals

Laboratories

The laboratory component of this course contains three "levels." Instructor demonstrations include the electrostatics of materials (fur, plastics, etc.), Van de Graaff generator, discharge tubes, standing sound waves in a pipe, longitudinal and transverse wave in a spring, angular momentum conservation on a turntable, etc. Hands-on student-conducted labs include more or less classic "cook book" labs with procedures and expectations clearly indicated and a strong instructor presence and *design-a-labs*, which require creativity and physical intuition to solve difficult problems.

Design-a-labs require students to design procedures to measure physical quantities, conduct experiments using their own procedures, compare their experimental values with accepted ones, identify sources of error, and suggest modifications to their experimental designs in order to improve results.

During all laboratory work students are strongly encouraged to work together, discuss, and debate hypotheses, approaches to problem solving, and theory. Laboratory write-ups will normally include an identification of the problem; formulation of a hypothesis; procedures, data, theory and calculations, conclusion, and sources of error.

Students will often be encouraged to share their ideas/results with the class. Students must keep a lab notebook to document their work.

Materials Needed to Be Successful:

- Textbook: OpenStax College Physics
    - Can be accessed using the link: https://openstax.org/books/college-physics-ap-courses/pages/preface
- Scientific Calculator, every day (*preferably* NO Casio models!)
    - WABBIT must be downloaded to your laptop and will allow you to perform all the calculations necessary for this course.
    - Cell phones, tablets, or IPods are not acceptable for use as a ‘calculator’.
- Single subject notebook (required)
- Ruler and plastic protractor
- Pens, pencils and erasers
- Other supplies necessary for projects will be announced as the year proceed

Grading and Related Policies:

- 70% Major Grades (Tests and Projects)
- 30% Minor Grades
  - Class work/homework, weighted x1
  - Labs & quizzes, weighted x2
  - "Check" grades *(see policy below)*

Tests: Since Major grades are 70% of your class average, your six weeks grade will strongly reflect how you perform on tests. Notice for tests will always be posted at least a week in advance. For the third and sixth cycles a project will be launched and will be considered as a major grade.

Test Re-Takes: Any student scoring *below 75* on a test may attend the test retake. Always attempt to do your best the on the original test; the maximum grade that will be entered into the gradebook for a retake is a 75. There are no retakes offered for projects. Dates, times, prerequisites and location for test retakes will be posted.

Classwork / Homework: Tasks such as daily work, homework, participation, lab cleanup, etc. may be check graded. Assignments may be graded based on the number of questions you get correct (traditional grading), *or* as a check grade (completion grading). You may not know in advance what type of grade will be assigned so always complete all assignments to the best of your ability.

Late Work: Assignments have due dates and each assignment is planned with a specific timeline in mind to help you to acquire the learning necessary to demonstrate mastery on assessments. It is important that you exert deliberate effort to stay on track with the due dates for your work. Late work will only be accepted as long as the answers have not been posted, or if the assignment has not been graded and passed back. Late work will receive a 10 point reduction if received after the time that it was due, with an additional 10 points deducted for each day that follows.

Make-up Work: It is very helpful to communicate with me via email or telephone if/when you know that you will be absent. You are responsible for getting and turning in *YOUR OWN* make-up work. Find the appropriate folder for the day(s) that you missed on The Hub, and also in the classroom. You are allowed the same number of days missed to turn in makeup work. Missed tests must be made up before they are unlocked on the HUB; if you fail to meet this requirement, you must follow the appropriate steps for retakes.