

Honors Physics Course Syllabus

Course Goals

This course adheres to the objectives outlined in the *Science Content Standards for California Public Schools*, plus many of the objectives of *Physics B* from the AP College Board and essential developments in the process of understanding physics as developed by the Physical Science Study Committee (PSSC). The course is intended to be the equivalent of a one semester, introductory college course in Fundamental Physics. The aim of the Honors Physics course is to provide students with the scientific principles, skills, concepts and methodologies required of a person who has completed a college level course in physics. The goals include mastery of standard mathematical and physics content and skills allowing the students to identify and analyze how the physical world works and to be able to describe the process of our having developed the current state of knowledge.

This course is designed to assist students master the major skills of classical and modern physics with a strong emphasis on how each set of principles, laws, understandings were developed by “standing on the heads of giants”. The scientific method is used to analyze and understand the inter-relationships between the components of the natural physical world. The course covers the following main topics:

- 1) Motion in a single direction: Aristotle to Newton
- 2) Measurement, accuracy
- 3) Relationship between forces, motion and acceleration
- 4) Gravitational motion / acceleration
- 5) Two dimensional motion and vectors
- 6) Forces, acceleration, momentum
- 7) Momentum, collisions
- 8) Work and energy
- 9) Rotational equilibrium and dynamics
- 10) Center of Gravity
- 11) Fluid mechanics
- 12) Property of gases
- 13) Thermodynamics
- 14) Waves and wave motion
- 15) Sound
- 16) Polarization and color
- 17) Light reflection and refraction
- 18) Interference and diffraction
- 19) Electric force and fields
- 20) Electrical energy and capacitance
- 21) Current, resistance and power
- 22) Circuits
- 23) Magnetism and forces

- 24) Induction and alternating current
- 25) Semiconductors and circuits
- 26) Development of atomic physics, radioactivity
- 27) Introduction to quantum, light
- 28) Subatomic physics
- 29) Relativity

Laboratory and field study are an essential component to this course. There is a total of 15 major laboratory exercises and 8 micro-labs in the two-semester course.

The goal is for students to master the scientific techniques and methodologies that will enable them to become independent learners, capable of gathering and evaluating information and making rational and informed judgments that they will be able to communicate to others. This will enable them to function effectively as competent science investigators in whatever field they ultimately choose.

Upon completion of this course, the student will:

- Be able to solve honors level problems from each content area in classical and modern physics
- Be able to explain the way various principles interact to produce observable phenomenon in mechanics, thermodynamics, light, sound, and modern physics
- Be able to express physics concepts in mathematical terms and use math expressions to solve problems as well as to derive relationships
- Be able to identify the ways new theories are based on previous theoretical and experimental work
- Be able to conduct careful detailed reproducible investigations
- Be able to write cogent meaningful reports on experimental work
- Be able to propose possibilities when confronted with unexpected results and follow with defining experimental ideas for ruling hypotheses out or in
- Be able to answer specific questions aimed at determining mastery of conceptual and problem solving skills

Course Prerequisites

The Honors Physics course places significant emphasis on laboratory and field work, including mathematical calculations and statistical analyses. To succeed in this course, students must have taken a minimum of two years of lab science, including chemistry) and completed of algebra 2. These pre-requisite course requirements are strictly adhered to.

Methods

As this is a college-level class, students are expected to participate fully in all aspects of the course. Through hands-on laboratory and field exercises, frequent class discussions of issues, and extensive readings, students take an active role in learning, appreciating, and explaining the various physics laws and their mathematical versions, as well as developing their critical thinking and problem solving skills.

To address the variety of learning styles in the classroom, several approaches to topics are incorporated into each unit. Lectures are minimal and generally presented as group problem solving or conceptual development exercises based on observing and interacting with a physical demonstration of a physical phenomenon. There is a strong reliance on in-class activities and group discussions, hands-on and virtual laboratories, field investigations, and field trips. In addition to lectures, other methods of instructional delivery for the course include videos, interactive websites, software programs, group activities, and guest speakers.

The course places considerable emphasis on theoretical and laboratory work with a minimum of two class hours per week devoted to investigation. For many labs, students are given a pre-lab description, appropriate references, text content citations, and a lab introduction. On lab days, students are expected to have read the pre-lab, answered the questions posed, prepared any necessary data collection forms, and be completely prepared to perform the lab or field work required. Some labs are more involved, and in these cases students are expected set up their own experiments, and monitor their experiments as needed. Additionally, students are expected to share and collaborate with one another, including exploring the theoretical base, brainstorming for possible ways to test theories, and peer reviewing. All lab and field work exercises require a written report.

Communicating ideas and concepts is an essential component of this course. Students are expected to investigate an essential topic then express their ideas by making presentations for the class once each quarter.

The majority of homework for the course consists of the study questions and “critical thinking issues” assignment at the end of each chapter in the textbooks. The homework provides students with the vocabulary, the scientific principles and concepts, and the methodologies required to become familiar with the physics theories, methods and ways of solving problems. These assignments are due daily and are graded for thoroughness, a clear understanding and application of the material, incorporation of relevant knowledge beyond that presented in the chapter, and clarity of thought.

Quizzes exploring student mastery of homework, readings and videos are administered throughout each unit.

At the conclusion of each unit, a unit test is administered. Unit tests typically consist of short answer and essay questions focused on the chapters, problems, labs and field activities from the unit. The intent of these tests is to evaluate depth and breadth of knowledge, and critical thinking skills.

The semester final exams are comprehensive and are similar in scope to standard college or AP tests, consisting of multiple choice, short answer and free-response sections. The second semester final examines mastery of the whole course content. There is also a lab component to the exam, requiring the students to identify a problem, propose a hypothesis, use materials provided to develop an experiment, perform the experiment, evaluate their hypothesis and then interpret and present their information. Students are challenged to use the lab skills, methodologies, and mathematics they have been learning through the course, as well as their powers of observation and interpretation.

To facilitate time-management for the students, a complete syllabus for the course is handed out at the beginning of each semester detailing the topics to be covered in the class, the laboratory and field exercises to be conducted, the daily readings, the weekly assignments, and the dates of all major unit tests.

Textbooks

Primary text for course: *Holt Physics*, by Serway and Faughn, 2000 (Holt Rinehart and Winston Inc.)

Supplemental text: *Conceptual Physics*, 3rd Ed., by Hewett, 1997 (Addison Wesley)

Supplemental Reader: Selected essays, articles, and other writings from various authors, including Physical Science Study Committee,

Additional Support:

Scientist Interviews: John Muster, 1979: A series of audio tape interviews with twenty mid 20th century Nobel prize winners concerning how they did what they did, including: Heisenberg, Frisch, Chamberlain, Fowler, Segre, and Mendelsohn.

Internet resources including: go.hrw.com www.scilinks.org www.si.edu/hrw

Course Outline

UNIT 1 Classical Motion

Key Themes:

- Our understanding of motion evolved from the ancients through the classical Greeks to Newton and pre-relativists through a mixture of profound theoretical thought followed by detailed experimental work. Our current physics is the result of a mixture of mathematical and experimental advances coupled with the ability to communicate results to others.
- Many mathematical descriptions of how force and motion and mass are related can be employed to solve a wide variety of interesting and complex problems.
- Fundamental concepts (no free lunch, mass is the constant that relates force and acceleration, significance in measurement) are essential to developing the conceptual and mathematical skills required of physics.

Content and Structure:

1) Motion in a single direction ConPh: 10-24, Holt: 38-76

By exploring constant speed motion, the relationships between rate of change, time and graphing the data to reveal distance are clear. The shift from scalar to vector is then a reasonable step.

- a. Aristotle to Newton, force and speed
- b. Speed, distance (air track demo)
- c. Velocity, displacement
- d. Graphing velocity, time, displacement

Mini-lab 1: Constant speed, velocity, time, displacement. Students will determine speed of car from photos, measure their own velocity in the halls and measure air-track velocities.

2) Measurement, accuracy Holt:10-24

Based on students' experience measuring speed, velocity time and distance in the first Mini-lab, this section explores details of measurement and accuracy in terms of:

- a. Significant figures
- b. Statistics
- c. Measurement
- d. Units

- e. Estimating
- f. Metric system

Mini-lab 2: Measurement of volume of blocks and room using meter sticks and meter tapes with different accuracies.

3) Relationship between forces, motion and acceleration ConPh: 43-58

Although forces were used previously to set objects in motion, this section follow Newton's work leading to the proportionality constant between force and acceleration, mass.

- a. $F=ma$

LAB 1: Force and acceleration: Determining relationship between force and acceleration using a constant mass with varying forces. CBL and sensors will allow for reasonably accurate data collection. They will record data, create graphs, interpret and write up results.

4) Gravitational motion / acceleration PSSC:

This section is a thorough examination of the relationships among gravitational force, acceleration, instantaneous velocity, average velocity, displacement, followed by examining the information available from graphing each set of data.

- a. Acceleration
- b. Average speed, unit displacement
- c. Graphing: time, gravitational acceleration, displacement, applied force

LAB 2: Acceleration due to Gravitational Force

This lab has students measure g in a series of free fall experiments using crude and then advanced time and distance measurement equipment.

Major Test 1

5) Two-dimensional motion and vectors ConPh: 28-39 Holt: 82-120

- a. Vectors

Mini-lab 3: Resolving force vectors

- b. Projectiles
- c. Satellite forces and mechanics
 - i. Tape of interview with NASA scientist on space physics
- d. Changes in motion

- e. Graphing acceleration, velocity, displacement and forces of projectile motion through time

LAB 3: Projectile Motion

Lab consists of launching a metal ball down an incline and then into the air until it strikes carbon paper. Students determine components of motion.

- 6) Forces, acceleration, momentum ConPh: 43-85 Holt: 122-164

A central aspect of classical physics is resolving net forces and the net force's impact on an object. This section fully explores Newton's conclusion and the advances he made by carefully exploring forces.

- a. Net forces
- b. Force diagrams
- c. Newton's laws
- d. Friction

Major Test 2

UNIT 2 Energy and its Transfer

Key Themes: Conservation laws are clearly seen in the potential, kinetic energy, work, and momentum interactions, both in linear and rotational motions. Conservation laws permit calculations of the effects of forces and collisions on masses.

- 7) Momentum, collisions ConPh: 86-98 Holt: 208-229

The joining of concepts of mass and velocity into momentum allows for investigation of many phenomenon and produces ways of solving complex problems.

LAB 4: Conservation of Momentum

Students will employ recording timers to measure velocity of a cart before and after collision, repeating the experience with an air track.

- 8) Work and energy ConPh: 103-121 Holt: 168-190 PSSC: 94-109

Exploring the result of applying a force through a distance to an object and how it relates to mechanical, kinetic and potential energy produces a series of mathematical and theoretical tools for solving important problems and for relating powerful additional concepts including efficiency and machines.

LAB 5: Conservation of Mechanical Energy

Students will employ simple harmonic motion with a weight on a spring, measuring velocity, force exerted.

- 9) Rotational Equilibrium and dynamics ConPh: 122-135 Holt: 278-313

A special aspect of motion, energy, work and momentum is the physics of rotating bodies. This set of constructs allows students to explore a more complex environment by applying tools from the simpler linear motion environment.

LAB 6: Rotational Energy

In this lab, a stopper is swung in circular motion, and the velocity sensors determine instantaneous velocity. The radius is held constant, but the force varies.

- 10) Center of Gravity ConPh: 136-146 Holt: 243-298

Many problems of statics and motion are only solvable with ease by assuming all the mass of an object is concentrated at a point and performing calculations from that view. Gravitational effects at a distance, angular speed and displacement, satellite mechanics and universal gravitation are structures that can be examined and produce important results.

Mini-lab 4: Center of Gravity

A feather and a weight are balanced on a beam, a cut-out of California is used to determine the center of mass of the state.

Major Test 3

UNIT 3 Fluids and Heat

Key Themes: Fluids because of their physical properties, fluids make it possible to explore forces as they are distributed throughout a medium or as they interact with non-liquid objects. Density, liquid pressure, gas pressure, the relationship between pressure,

temperature and volume all are essential to understanding / acting on our current state of knowledge and engineering. The force on a object floating in a liquid is equal to the weight of the displaced liquid, which is in turn related to the density of the liquid and the object.

11) Fluid mechanics ConPh: 273-284 Holt: 317-334

Central issues include exploring the differences between a liquid and gas, density, how liquids produce buoyant actions on objects, how pressure relates to depth and hydraulics.

Mini-lab 4 on buoyancy

A steel boat is placed in water and the water level determined. The boat is filled with water to the same level, the water weighed. The boat is weighed and comparisons made.

12) Properties of Gases ConPh 290-300 Holt: 338-386

How gases behave include issues of pressure, volume and temperature, state changes, and the ideal gas law.

13) Thermodynamics ConPh: 307-365 Holt: 402-437

Heat is a form of energy and is conserved. Kinetic energy is changed to heat when there is friction. When heat is added to a system, the total energy (internal energy + external work done by the system) remains constant. Heat flows from hotter to colder objects. All such phenomenon can be explained through exploration of the kinetic energy of the gas molecules.

LAB 7: Boyle's Law

Gas in a syringe is measured for volume. Pressure is applied and the gas is compressed. Measurements of V and P are made for several weights on the syringe.

Major Test 4

First Semester Final Examination (Cumulative of first semester)

UNIT 4 **Waves and Light**

Key Themes:

Vibrations in a medium can be a form of energy transfer. Wave behavior and characteristics including amplitude, wavelength and frequency are essential concepts and can be described mathematically.

14) Waves and wave motion ConPh: 372-386 Holt: 437-466

By employing a series of mini-labs and demonstrations with a wave table, wave bar, tuning forks, films, and oscilloscope the various properties of waves are examined in detail. Spring and pendulum simple harmonic motion are also explored and related to wave issues.

Mini-lab 5 Waves in Water

The wave table is employed to demonstrate transmission, amplitude, interference, constructive and destructive interaction.

15) Sound ConPh: 390-396 Holt: 479-510

Sound production is moving air produced by a moving object that creates compression and rarefaction in a longitudinal wave. Issues of pitch, quality, harmonics, volume, propagation, Doppler effect, pipes, and resonance are explored as physical phenomenon.

16) Polarization and Color ConPh: 414-441 Holt: 543-548

Pigment and light color effects are demonstrated followed by polarization as it demonstrated wave properties of light.

Mini-lab 6: on polarized light

Polarized lenses are employed to demonstrate the way light interact with the “gate”. Likewise a picket fence is used.

17) Light reflection and refraction ConPh: 442-477 Holt: 419-542, 561-585

Reflection and refraction of light and other electromagnetic radiation are explored both from a ray description as well as from the electromagnetic description. Wave fronts, square of distance impact on intensity, impact on images through flat and curved surface reflection and need for parabolic mirrors in telescopes are central to the theoretical and laboratory work. Lenses and prisms are used to demonstrate and calculate properties of light when refraction takes place. The

human eye and the impact of glasses is also explored. This section concludes with snell's law, total internal reflection and critical angles.

LAB 8: Ray optics in reflection and refraction

The standard set of reflection, refraction by lenses, prisms, through plane glass or plastic are demonstrated and measurements of focal length, etc completed.

18) Interference and diffraction ConPh: Holt: 397-400, 480-496, 597-617

When light passes through thin-films, two point sources, or a thin slit the wave characteristics of light are most obvious as interference and diffraction take place much like the same phenomenon in a water wave table. CD's, interferometers, diffraction gratings are carefully examined and mathematical analysis of the various phenomenon are examined in detail.

LAB 9: Light as a wave

A diffraction grating is employed to measure the wavelength of light and to observe the spectrum. Students try different diffraction gratings with different numbers of lines.

Major Test 5

UNIT 5 Electric Effects

Key Themes:

Electric charge was a puzzle until the 1700's when great advances were made concerning how charges are created, stored, discharged, and measured. Soon the impact of charges were measured in force fields and when controlled, as currents, energy and capacitance. These topics plus the interaction with magnetic fields, circuits, induction and alternating current are examined in detail from an electron behavior standpoint and by employing mathematical analysis leading to precision in describing the phenomenon.

19) Electric force and fields ConPh: 500-522 Holt: 628-633, 643-652

Collecting a large number of electrons in one place produces a large negative charge. Taking them away from an object produces a positive charge. Both have direction and are vectors. This process allows us to quantify electric charge, measure charge. Electric fields are measured, compared with gravitational field strength, and employed in calculations of force.

Lab 10: electrostatics

Students will charge small balls and measure the repulsive force when both are charged the same. Likewise charges are used to move a rod.

20) Electrical energy and capacitance ConPh: 523-529 Holt: 665-680

Electrical potential energy is a form of mechanical energy and can be used to calculate effects. Potential differences in an electric field are used to examine possible work that can be done.

Lab 11: Electrical Energy

A capacitor is charged then discharged with the heat generated measured. Calculation of the energy in heat and electrical are completed.

21) Current, resistance and power ConPh: 531-542 Holt: 693-716

The objective of modern electrical power distribution is to control the current flow to accomplish work with out destruction or death. How much current flows is determined by the voltage applied and the internal resistance of the object. The amount of work that it can do is determined by the voltage and the number of electrons flowing (current)

Lab 12: Current and Resistance

The resistance in a coil is measured, as is the voltage of a source. An ammeter is included in the circuit so the actual current flow can be measured and compared to the theoretical $E=IR$

Major Test 6

22) Circuits ConPh: 542-558 Holt: 729-750

Series and parallel resistance in circuits, potential differences and circuits in house wiring, and energy distribution, including calculating efficiency, work are explored in this short section.

Mini-lab 7: standard circuits

The voltages in the circuit breaker box will be measured by the teacher. Students will wire a 3 way light, circuit and a lamp.

23) Magnetism and forces ConPh: 562-575 Holt: 765-780

Another essential component of physics understanding is magnetism and how charged particles interact with magnetic fields. Field strength, the right-hand rule, resulting forces are all examined from a theoretical and mathematical view.

Lab 13: Magnetic fields of a conducting wire

Lab consists of exploring the magnetic field around a current carrying wire, coupled with building a simple battery motor.

24) Induction and alternating current ConPh: 577-591 Holt: 793-826

The interaction between magnetic fields and charges is particularly important as the current alternates direction of flow. Fields are built up and collapse, currents are induced. Generators and motors are constructed and calculations of power consumption or generation, work consumed or output are measured.

25) Semiconductors and circuits Holt: 865-891

A brief exploration of semi-conductors and semi-conductor circuitry is included because of the pervasive nature of the technology.

Mini-lab 8: resistors and diodes

Major Test 7

UNIT 6 Modern Physics

Key Themes:

The twentieth century produced some of the most remarkable advances in understanding in history: nature of light, photoelectric effect, relativity, atomic physics, tunneling, quantum, radioactivity, general relativity, semiconductors, near absolute zero phenomenon, subatomic physics, sense-making of solar energy generation, life of stars, quasars, and black holes.

26) Development of atomic physics, radioactivity ConPh: 609-635, Scientist tapes of Otto Frisch, Chamberlain. Data from collision work at LBL.

Lab 14: half life

Employing the safest measures, class will demonstrate the half-life of Barium in 10 second intervals using a nuclear station.

27) Introduction to quantum, light ConPh: 596-606 Holt: 714-15, 830-853

This introduction to quantum physics, blackbody radiation, electron tunneling, KE of electrons, photoelectric effect and evidence for supporting the photon theory of light are central to this investigation.

Lab 15: photoelectric effect

We will use a series of filmed data concerning light of various intensities being shown on a plate to demonstrate that the energy of the photon, not the length of time the plate is exposed, causes the current to flow.

28) Subatomic physics Holt: 840-932

The development of our understanding of the nature of the atom is a wonderful investigation into how physics works. This section examines the process of standing on each other's shoulders, the impact of experimentation, brilliant theoretical work: from Greeks, to Rutherford, spectra, Bohr, atomic levels of excitement, fission, fusion.

29) Relativity ConPh: 636-642

The logic and implications of the special theory are examined with an eye towards experimental results predicted and observed.

Major Test 8

Final Comprehensive 3 hour exam

Second Semester Project Assignment: Mini-research project with lab: This project is designed to further develop skills in research, experiment design, field work, lab work, report writing, and mathematical analysis. As a group, the class decides on a few major themes for the project (such as "spectroscopy," "sub-atomic" or "alternative energy"). Once the themes are chosen, each student identifies a topic within the theme that they would like to pursue. Students conduct background research into their topic, then from their insights they formulate testable hypotheses. Each student next designs a controlled

experiment to test their hypothesis and conducts further research into their topic, sometimes relying on available data. Once their concepts and designs pass instructor approval, the students perform their experiments, collect observations and data, prepare charts and graphs where needed, perform mathematical analyses of data, and report findings, all in lab report format. Acceptable experiments shall involve extensive field lab work, and shall be challenging in nature. At regular intervals through the semester, drafts of work are peer reviewed, evaluated and discussed by the class. A comprehensive, “journal-ready” lab report is due by end of the semester.