Course Syllabus – AP Physics 1
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I. Course Description

AP Physics 1 is an algebra-based, introductory college-level physics course (roughly equivalent to PH-101 at the University of Alabama) intended to cultivate student understanding of Physics through inquiry-based investigations of various Physics topics.

Students should be concurrently enrolled in or have already completed Algebra II with Trigonometry. Introductory differential and integral calculus are not expected to be part of AP Physics 1, but a basic primer will be given and its understanding will simplify some aspects of this course. You might find this free online course to be a helpful resource: https://www.coursera.org/learn/calculus1

The Physics topics included in this course are one and two dimensional kinematics (with some basic introduction to three-dimensional kinematics), Newton's laws of motion, work, energy, and power, systems of particles and linear momentum, circular motion and rotation, mechanical waves and sound, simple circuits, and various others as time permits.

These topics are condensed into a series of six "Big Ideas" to be covered throughout this course – see pages 7 and 8 of this syllabus for a list of these "Big Ideas" and the "Enduring Understandings" associated with them. These "Big Ideas" will henceforth be denoted with "[Big Idea #]" e.g. "[Big Idea 5]" and/or "[Big Ideas 1, 3, 5]" within this document while the "Enduring Understandings" will be denoted with "[EU #.L]" e.g. "[EU 5.B]."

This course has a set of non-negotiable "Curricular Requirements" imposed by the AP College Board and "Science Practices" which students should master. See page 9 of this syllabus for these "Curricular Requirements" and pages 10 and 11 for the "Science Practices." These "Curricular Requirements" will be denoted with "[CR #]" e.g. "[CR3]" and the "Science Practices" will be denoted with "[SP #]" e.g. "[SP 1]" within this document.

II. Class Schedule

The course will meet every day from 1049 to 1242 for lecture and discussion. Two or three days of each two-week period (approximately 25-30% of the course) **[CR5]** will be spent doing hands-on inquiry-based laboratory activities. The intent is for students to *discover* physical relationships rather than being *told* about said relationships.

III. Course Expectations

Lecture and discussion will require students to ask questions and be personally involved in the learning process; the goal is to develop a deep understanding of physics concepts. Students will be working in small groups on a regular basis to solve problems and then present their research methods, data, and conclusions on whiteboards. The class will then engage in peer critique of each group's results as well as discuss strategies to reduce/eliminate errors and suggest additional research/investigations, and lively debate is encouraged. **[CR8]**

III. Course Expectations (continued)

Laboratory activities will require students to ask questions, make observations and predictions, design and carry out experiments, analyze data, construct arguments, and defend their results in a collaborative setting. The first few lab activities will have a fair amount of guidance from the instructor, but the eventual goal as we progress through the course is for students to be given only a problem to solve/research and then determine how to proceed on their own. Each student is expected to complete a lab notebook. Lab notebooks will include pre-lab discussions, hypothesis/question being explored, experimental procedure, collected data, graphs, data analysis, conclusions reached, discussion of error sources and analysis thereof, and any other information deemed pertinent and/or useful by students and/or instructor. This will often require time outside class, so be prepared for that. Examinations often include scenarios similar to those researched during laboratory activities, so it is imperative for you to participate and be attentive to detail in your work there. **[CR7]**

IV. Grading Procedures

This course is divided into two components: *AP Physics 1* (one credit) and *Research and Writing* (one credit). Classwork, homework, quizzes, and exams will count toward the *AP Physics 1* component, while laboratory activities (your lab notebooks), research papers, and other activities which have a substantial writing component will count toward the *Research and Writing* component.

In each of the components, a points system is used to determine student average at any given time. For example, if you have earned 450 points of 570 possible points, your average at that time will be 78.9%.

V. Materials and Text

Text: Physics: Principles With Applications (Pearson/Prentice Hall, 2014) by Giancoli **[CR1]**
Text: College Physics for AP Courses (OpenStax College, 2015) * PDF provided * **[CR1]**
TIPERs: Sensemaking Tasks for Introductory Physics (Pearson, 2015)
Composition book with graph paper (for lab notebooks) * provided *
Three ring binder
Loose leaf paper (college-ruled)
Pens (black ink, water-resistant preferred) and #2 pencils
Scientific Calculator
Various ASIM (Alabama Science in Motion) and APEX (Alabama Physics Excellence) labs
Science computer lab and associated equipment
Physics lab and associated equipment

VI. Supplemental Resources

Dan Fullerton's "AP Physics 1" video series on YouTube:
    https://www.youtube.com/playlist?list=PLd2HWlWc-MsysWuL9ksneEM8cl5bk3bHH
Bozeman Science's "AP Physics 1 & 2" video series:
    http://www.bozemanscience.com/ap-physics
The Physics Classroom: http://www.physicsclassroom.com/

VII. Course Outline – 1st semester [CR6a, CR6b]

Week 1: Introduction to Graphical Analysis and Basic Calculus

Lab – Guided inquiry: Given an unknown length of wire, students will use graphical analysis of the relationship between mass and length to determine the unknown length. **(SP 2,4,5,7)**

Lab – Guided inquiry: Given containers with various numbers of flat washers inside as well as some with unknown numbers, students will use graphical analysis of the relationship between mass of container+objects and number of things inside to determine the mass of a single thing, mass of the container (y-intercept), and number of things inside the unknown containers. **(SP 2,4,5,7)**

Week 2: SI Units and Dimensional Analysis

Lab – Structured: – given cut pieces of PVC pipe, students will use graphical analysis of the relationship between circumference and diameter to experimentally determine the value of pi. This activity will serve as the basis for classroom exploration of "big things are made of smaller things," from points → lines → squares → cubes, which leads to (hopeful) review of area and volume, which leads to an intro to basic integration and differentiation. **(SP 2,4,5,7)**

Weeks 3 and 4: One Dimensional Kinematics **[CR2a] [Big Ideas 2,3,4]**

Lab – Structured: constant velocity; graphical analysis (APEX lab) – students will measure the displacement of a constant velocity cart over some defined time intervals and graph the results **(SP 2,5)**

Lab – Minimally Structured: motion with constant acceleration (adapted from APEX lab) – students determine the acceleration of a cart on an inclined track **(SP 2,3,4,5)**

Lab – Open Inquiry: students determine acceleration due to gravity **(SP 2,4,5)**

Lab – Open Inquiry: reaction time – students must independently design and carry out an experiment to determine their individual reaction times **(SP 2,3,4,5,7)**

Weeks 5 and 6: Two Dimensional Kinematics (linear) **[CR2a] [Big Ideas 2,3,4]**

Lab – Open Inquiry: students determine muzzle velocity of projectile launched horizontally (ASIM lab) **(SP 2,4,5)**

Lab – Guided Inquiry: students explore the relationship between range of a launched projectile and the angle of launch, the goal is for them to discover that range versus launch angle is a sine function rather than a parabola **(SP 1,2,4,5,7)**

Weeks 7 and 8: Force and Newton's Laws of Motion **[CR2b] Big Ideas 1,2,3,4**

* approaching this backwards with respect to Newton's Laws (3rd → 2nd → 1st)

Lab – Guided Inquiry: Force pairs – students use standard bathroom scales to discover that forces act in pairs and on different objects **(SP 1,3,6)**

Lab – Open Inquiry: Students explore the effect of varying the force on constant mass **(SP 1,2,3,4,5)**

Lab – Open Inquiry: Students explore the effect of varying mass subjected to constant force **(SP 1,2,3,4,5)**

Lab – Minimally Structured: Students use an Atwood's machine setup to test their discoveries in the two prior labs **(SP 1,2,3,4,5,6,7)**

Lab – Guided Inquiry: Friction blocks on horizontal surface (students discover μ) **(SP 2,3,4,5)**

Lab – Guided Inquiry: Friction blocks on inclined surface (students discover that things aren't exactly as thought to be from the prior lab) **(SP 2,3,4,5)**

Weeks 9, 10, and 11: Circular Motion, Centripetal Force, Kepler's Laws, and Gravitation **[CR2b, CR2c] [Big Ideas 1,2,3,4]**

- *Lab – Open Inquiry*: students determine relationships among centripetal force, mass, and radius (adapted from APEX lab) **(SP 1,2,3,4,5,6)**
- *Lab – Guided Inquiry:* students determine Kepler's Laws by researching and analyzing actual data from various exoplanets **(SP 1,2,3,4,5,6,7)**
- *Lab – Open Inquiry*: students determine tension in the string connecting a "flying pig" to the ceiling and the centripetal force on the pig **(SP 1,2,3,4,5,6,7)**

Weeks 12, 13, and 14: Work, Energy, and Power **[CR2f] [Big Ideas 3,4,5]**

- *Lab – Guided Inquiry*: students determine using a force versus distance graph the work done by stretching a spring **(SP 1,2,3,4,5,6,7)**
- *Lab – Structured*: Conservation of Energy – students will use a steel ball on the "Energy Track" to test whether total energy of the system appears to be a conserved quantity **(SP 1,2,3,4,5,6,7)**
- *Lab – Structured*: students determine their work done and power output while climbing a flight of stairs **(SP 1,2,4,5,6,7)**

Weeks 15 and 16: Impulse, Momentum, and Collisions **[CR2e, CR2f] [Big Ideas 3,4,5]**

- *Lab – Open Inquiry*: students will measure the changes in momentum of two dynamics carts colliding in various fashions to determine whether total momentum of a system is conserved **(SP 1,2,3,4,5,6,7)**
- *Lab – Guided Inquiry:* students will measure a dynamics cart's change in momentum and compare it to the impulse on the cart using a force versus time graph. As an extension, students will test various "bumper" materials and compare the forces exerted by each on the cart **(SP 1,2,3,4,5,6,7)**
- *Lab – Guided Inquiry:* Students explore energy and momentum conservation principles using a ballistic pendulum to determine the type of collision **(SP 1,2,3,4,5,6,7)**

Week 17: Review and Practice / Flex Week

Week 18: Mid-term Exam (mock AP exam)

VIII. Course Outline – 2nd Semester [CR6a, CR6b]

Weeks 19, 20, and 21: Rotational Kinematics, Dynamics, Equilibrium, and Energy **[CR2g] [Big Ideas 3,4,5]**

- *Lab – Structured*: Moment of Inertia with various rolling cylinders on incline – students determine how the type of cylinder affects the time required to roll down an incline; this will be used to introduce rotational kinetic energy **(SP 1,3,4,5,6)**
- *Lab – Open Inquiry*: Torque – students determine what factors affect the rotational motion of an object **(SP 1,2,3,4,5,6)**
- *Lab – Structured*: Conservation of Angular Momentum – PhET simulation
- *Lab – Structured*: Conservation of Angular Momentum – Bicycle wheel and rotating platform
- *Lab – Guided Inquiry*: Rotational Equilibrium with suspended beam and various masses; students experiment to find how much mass to add and in what location to make net torque equal to zero, and along the way discover that this is related to finding center of mass **(SP 1,2,3,4,5,6,7)**

Weeks 22 and 23: Simple Harmonic Motion **[CR2d] [Big Ideas 3,4,5]**

Lab – Open Inquiry: students determine what factors affect the period of a pendulum **(SP 1,2,3,4,5,6,7)**

Lab – Open Inquiry: Hooke's Law – students rediscover F = -kx (Adapted ASIM) **(SP 1,2,3,4,5,6,7)**

Lab – Structured: Pendulum Lab (PhET Simulation)

Weeks 24 and 25: Waves and Sound **[CR2j] [Big Idea 6]**

Lab – Guided Inquiry: students use a string vibrator to determine the relationship between frequency and wavelength given constant wave speed **(SP 1,2,3,4,5,6)**

Lab – Guided Inquiry: students use a string vibrator to determine relationships among frequency, wavelength, period, wave speed, and wave amplitude. As an extension, students will explore beats and standing waves **(SP 1,2,3,4,5,6,7)**

Lab – Minimally Structured: students determine the speed of sound using two way radios and megaphone over large distance (Adapted ASIM) **(SP 2,3,4,5,7)**

Lab – Guided Inquiry: students determine (well, given the prior lab, verify) the speed of sound using resonance inside cardboard shipping tubes **(SP 1,2,3,4,5,6,7)**

Weeks 26 and 27: Electrostatics **[CR2h] [Big Ideas 1,3,5]**

Lab – Guided Inquiry: students explore the interactions of various charged and uncharged objects **(SP 1,3,4,5,6,7)**

Lab – Guided Inquiry: Where does charge originate?
* students discover the Law of Conservation of Charge

Lab – Open Inquiry: students determine the type of charge on an object **(SP 3,4,5,6,7)**

Lab – Guided Inquiry: Coulomb's Law – students determine the relationship among force, charge, and distance between charges **(SP 1,2,3,4,5,6,7)**

Weeks 28, 29, and 30: Simple DC Circuits **[CR2i] [Big Ideas 1,3,5]**

Lab – Open Inquiry: Students are given a battery, a bulb, and one piece of wire and must find a way to light up the bulb **(SP 1,3,6,7)**

Lab – Guided Inquiry: Discovery of Ohm's Law in series circuits – students explore voltage and current relationships in simple series circuits **(SP 1,2,3,4,5,6,7)**

Lab – Guided Inquiry: Discovery of Ohm's Law in parallel circuits – students explore voltage and current relationships in simple parallel circuits **(SP 1,2,3,4,5,6,7)**

Lab – Guided Inquiry: Kirchhoff's Laws (APEX/CASTLE) – students explore various circuits to discover Kirchhoff's Current Law and Voltage Law **(SP 1,3,4,5,6)**

Lab – Open Inquiry: students determine resistance of an unknown resistor in a parallel branch (Adapted APEX) **(SP 1,2,3,4,5,6,7)**

Lab – Open Inquiry: Students design and build a "hallway switch" (three-way switch) **(SP 1,2,3,4,5,6,7) (CR4)**

Week 31: Flex Week – Tie up Loose Ends, Etcetera

Weeks 32 and 33: Review for AP Exam (mock tests, more TBD labs, etcetera)

Week 34: AP Exam

Weeks 35 and 36: TBD, likely magnetism, electric motors and generators, AC circuits

IX: Outside the Classroom Lab Experience [CR3, CR4]

After the AP Exam (early May), each student will be required to conduct some independent research and work out of class.

You will be tasked with designing, building, and testing some sort of structure (typically a bridge, but external factors, e.g. current events, may influence my decision on structure type). There will be rules and limitations with respect to materials used, sizes of finished products, etcetera, similar to what one would experience in a Science Olympiad event. There will be an opportunity to test and (if necessary) make revisions to projects, after which the finished projects will be presented and put to the test in a friendly competition.
[Learning Objectives 1.C.1.1, 3.A.3.3, 3.B.1.2]

X: Real World Physics Experience [CR4]

For our annual pilgrimage to Six Flags Over Georgia, each student will pick one of the “thriller” rides to research (both during and after the trip as needed). Each student will then make a presentation to the class (approximately 5-10 minutes) about the ride’s safety features, why they are necessary, and whether they are too lenient or too restrictive along with supporting evidence.

Big Ideas and Enduring Understandings in AP Physics 1

Big Idea 1: **Objects and systems have properties such as mass and charge. Systems may have internal structure.**

- *EU 1A*: The internal structure of a system determines many properties of the system.
- *EU 1B*: Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.
- *EU 1C*: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.
- *EU 1D*: Classical mechanics cannot describe all properties of objects.
- *EU 1E*: Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.

Big Idea 2: **Fields existing in space can be used to explain interactions.**

- *EU 2A*: A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.
- *EU 2B*: A gravitational field is caused by an object with mass.
- *EU 2C*: An electric field is caused by an object with electric charge.
- *EU 2D*: A magnetic field is caused by a magnet or a moving electrically charged object. Magnetic fields observed in nature always seem to be produced either by moving charged objects or by magnetic dipoles or by combinations of dipoles and never by single poles.
- *EU 2E*: Physicists often construct a map of isolines connecting points of equal value for some quantity related to a field and use these maps to help visualize the field.

Big Idea 3: **The interactions of an object with other objects can be described by forces.**

- *EU 3A*: All forces share certain common characteristics when considered by observers in an inertial reference frame.
- *EU 3B*: Classically, the acceleration of an object interacting with other objects can be predicted by using $a=F/m$
- *EU 3C*: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
- *EU 3D*: A force exerted on an object can change the momentum of the object.
- *EU 3E*: A force exerted on an object can change the kinetic energy of the object.
- *EU 3F*: A force exerted on an object can cause a torque on that object.
- *EU 3G*: Certain types of forces are considered fundamental.

Big Idea 4: Interactions between systems can be result in changes in those systems.

- *EU 4A*: The acceleration of the center of mass of a system is related to the net force exerted on the system, where $a=F/m$
- *EU 4B*: Interactions with other objects or systems can change the total linear momentum of a system.
- *EU 4C*: Interactions with other objects or systems can change the total energy of a system.
- *EU 4D*: A net torque exerted on a system by other objects or systems will change the angular momentum of the system.
- *EU 4E*: The electric and magnetic properties of a system can change in response to the presence of or changes in other objects or systems.

Big Ideas and Enduring Understandings in AP Physics 1 (continued)

Big Idea 5: Changes that occur as result of interactions are constrained by conservation laws.

EU 5A: Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.
EU 5B: The energy of a system is conserved.
EU 5C: The electric charge of a system is conserved.
EU 5D: The linear momentum of a system is conserved.
EU 5E: The angular momentum of a system is conserved.
EU 5F: Classically, the mass of a system is conserved.

Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

EU 6A: A wave is a traveling disturbance that transfer energy and momentum.
EU 6B: A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.
EU 6C: Only waves exhibit interference and diffraction.
EU 6D: Interference and superposition lead to standing waves and beats.
EU 6E: The direction propagation of a wave such as light may be changed when the wave encounters an interference between two media.
EU 6F: Electromagnetic radiation can be modeled as waves or as fundamental particles.
EU 6G: All matters can be modeled as waves or as particles.

Curricular Requirements for AP Physics 1

CR1: Students and teachers have access to college-level resources including college-level textbooks and reference materials in print or electronic format.

CR2*: The course design provides opportunities for students to develop understanding of the foundational principles of kinematics (**CR2a**), dynamics (**CR2b**), gravitation and circular motion (**CR2c**), simple harmonic motion (**CR2d**), linear momentum (**CR2e**), energy (**CR2f**), rotational motion (**CR2g**), electrostatics (**CR2h**), electric circuits (**CR2i**), and mechanical waves (**CR2j**) in the context of the big ideas that organize the curriculum framework.

CR3: Students have opportunities to apply AP Physics 1 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.

CR4: The course provides students with opportunities to apply their knowledge of physics principles to real world questions or scenarios (including societal issues or technological innovations) to help them become scientifically literate citizens.

CR5: Students are provided with the opportunity to spend a minimum of 25 percent of instructional time engaging in hands-on laboratory work with an emphasis on inquiry-based investigations.

CR6*: The laboratory work used throughout the course includes investigations that support the foundational AP Physics 1 principles (**CR6a**) and includes guided-inquiry laboratory investigations allowing students to apply all seven science practices (**CR6b**).

CR7: The course provides opportunities for students to develop their communication skills by recording evidence of their research of literature or scientific investigations through verbal, written, and graphic presentations.

CR8: The course provides opportunities for students to develop written and oral scientific argumentation skills.

Science Practices for AP Physics 1

SP1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.

1.1: The student can *create representations and models* of natural or man-made phenomena and systems in the domain.
1.2: The student can *describe representations and models* of natural or man-made phenomena and systems in the domain.
1.3: The student can refine *representations and models* of natural or man-made phenomena and systems in the domain.
1.4: The student can *use representations and models* to analyze situations or solve problems qualitatively and quantitatively.
1.5: The student can *reexpress key elements of natural phenomena across multiple representations* in the domain.

SP2: The student can use mathematics appropriately.

2.1: The student can *justify the selection of a mathematical routine* to solve problems.
2.2: The student can *apply mathematical routines* to quantities that describe natural phenomena.
2.3: The student can e*stimate numerical quantities* that describe natural phenomena.

SP3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

3.1: The student can *pose scientific questions*.
3.2: The student can *refine scientific questions*.
3.3: The student can *evaluate scientific questions*.

SP4: The student can plan and implement data collection strategies in relation to a particular scientific question.

4.1: The student can justify the selection of the kind of data needed to answer a particular scientific question.
4.2: The student can design a plan for collecting data to answer a particular scientific question.
4.3: The student can collect data to answer a particular scientific question.
4.4: The student can evaluate sources of data to answer a particular scientifically question.

SP5: The student can perform data analysis and evaluation of evidence.

5.1: The student can *analyze data* to identify patterns or relationships.
5.2: The student can *refine observations and measurements* based on data analysis.
5.3: The student can *evaluate the evidence provided by data sets* in relation to a particular scientific question.

SP6: The student can work with scientific explanations and theories.

6.1: The student can *justify claims with evidence*.
6.2: The student can *construct explanations of phenomena based on evidence* produced through scientific practices.
6.3: The student can *articulate the reasons that scientific explanations and theories are refined and replaced*.
6.4: The student can *make claims and predictions about natural phenomena* based on scientific theories and models.
6.5: The student can *evaluate alternative scientific explanations*.

SP7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

7.1: The student can *connect phenomena and models* across spatial and temporal scales.
7.2: The student can *connect concepts* in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.