ALAMEDA UNIFIED SCHOOL DISTRICT

SECTION A. COURSE DESCRIPTION COVER PAGE

Date Received:
(Educational Services Office use only)

1. Course Title: AP Physics 2	6. Prerequisite(s): Geometry and Concurrent Enrollment in Algebra II
2. Action: _X__ New Course ___ Course Revision ___ Title Change Only	7. Grade Level: 11-12
3. Transcript Title/Abbreviation: (For Educational Services)	8. Elective/Required: Elective
4. Transcript Course Code/Course Number: (For Educational Services)	9. Subject Area: Physics (Science)
5. CBEDS Code: (For Educational Services)	10. Department: Physics (Science)

11. Length /Credits:
___ 0.5 (half year or semester equivalent) _X__ 1.0 (one year equivalent)
___ 2.0 (two year equivalent)

12. Was this course previously approved by UC? ___ Yes __X_ No (Former version -'AP Physics B' was approved
If so, year removed from list: ______________

13. Meets the "___D____" requirements in the a-g university/college entrance requirement. Approval date:
_________To Be Approved______________-

14. School Contact Information
Name: _______Scott Mathieson______________________ Title/Position: ______Teacher_____________
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16. Signatures:
Department Chair: ______________________________
Principal: Robert F. [signature]

Acknowledged by Other Principals: ______________________________

____

Educational Services: Barbara S Adams [signature]

16. Date Approved by Board of Education:

SECTION B. COURSE CONTENT

17. Course Description:

This class is designed to be a breadth course in Algebra Based Physics, adhering to key concepts of Electrostatics, Electric Circuits, Magnetism & Electromagnetic Induction, Thermodynamics, Fluids, Geometric & Physical Optics, Quantum Physics, and Atomic & Nuclear Physics. The course will initiate with the students examining the scientific method as well as means of measurement appropriate to the physics laboratory setting. It will continue with the concepts above which will be investigated through lecture and both Guided Inquiry and Open-Inquiry laboratory exercises. Thermodynamics will include investigation of the Conservation energy and matter. The study of waves will serve to integrate energy concepts with Sound and Light. Optics will introduce the properties of light and it's interactions with lenses and mirrors. Electromagnetism will serve to show the relationship that exists between electricity and magnetism and introduce circuitry and electronics.

18. Course Goals and/or Major Student Outcomes:

AP Physics 2: Algebra-based is the equivalent of the first semester of introductory, algebra-based college courses. This is intended to be yearlong course, teachers have time to foster deeper conceptual understanding through student-centered, inquiry-based instruction. Students have time to master foundational physics principles while engaging in science practices to earn credit or placement.

AP Physics 2 is an algebra-based, introductory college-level physics course that explores topics such as fluid statics and dynamics; thermodynamics with kinetic theory; PV diagrams and probability; electrostatics; electrical circuits with capacitors; magnetic fields; electromagnetism; physical and geometric optics; and quantum, atomic, and nuclear physics. Through inquiry-based learning, students will develop scientific critical thinking and reasoning skills.

19. Course Objectives (standards):

As a result of taking this course students should be able to do the following:

1. Read, understand, and interpret physical information—verbal, mathematical, and graphical
2. Describe and explain the sequence of steps in the analysis of a particular physical phenomenon or problem; that is,
   a. describe the idealized model to be used in the analysis, including simplifying assumptions where necessary;
   b. state the concepts or definitions that are applicable;
   c. specify relevant limitations on applications of these principles;
   d. carry out and describe the steps of the analysis, verbally or mathematically;
   e. interpret the results or conclusions, including discussion of particular cases of special interest
3. Use basic mathematical reasoning—arithmetic, algebraic, geometric, trigonometric, or calculus, where appropriate—in a physical situation or problem
4. Perform experiments and interpret the results of observations, including making an assessment of experimental uncertainties

20. Course Outline:

UNIT 1. ELECTROSTATICS
- Electric force
- Electric field
- Electric potential

UNIT 2. ELECTRIC CIRCUITS
- Electric resistance
- Ohm's Law
- DC circuits with resistors only
- Kirchhoff's Laws
- Series, parallel, and series-parallel circuits
- Capacitance
- DC circuits with resistors and capacitors

UNIT 3. MAGNETISM AND ELECTROMAGNETIC INDUCTION
- Magnetic field
- Magnetic force on a charged particle
- Magnetic force on a current-carrying wire
- Magnetic flux
- Electromagnetic induction: Faraday's Law
- Lenz's Law
- Motional emf

UNIT 4. THERMODYNAMICS
- Kinetic theory
- Ideal gases
- First law of thermodynamics
- Thermodynamic processes and PV diagrams
- Heat engines
- Carnot cycle
- Efficiency
- Second law of thermodynamics: entropy

UNIT 5. FLUIDS
- Density
- Pressure: atmospheric and fluid pressure
- Pascal's principle
- Buoyant force
- Archimedes' principle
- Flow rate
- Continuity equation
- *Bernoulli's principle*

UNIT 6. GEOMETRIC AND PHYSICAL OPTICS
- Reflection
- Image formation by flat and curved mirrors
- Refraction and Snell's Law
- Image formation by thin lenses
- Interference and diffraction
- Double slit, single slit, and diffraction grating interference
- Thin film interference

UNIT 7. QUANTUM PHYSICS, ATOMIC AND NUCLEAR PHYSICS [CR2g]
- Atoms, atomic mass, mass number, and isotopes
- Atomic energy levels

- Absorption and emission spectra
- Models of light: wave and particle
- Photoelectric effect
- DeBroglie wavelength
- Wave function graphs
- Mass-energy equivalence
- Radioactive decay: alpha, beta and gamma decay
- Half life
- Conservation of nucleon number: fission and fusion

21. Instructional Materials:

Board approved required text:

Giancoli, Douglas C., *Physics*, Principles With Applications, San Francisco, CA: Pearson Prentice Hall, 2009.

Supplementary materials:

TEACHING RESOURCES

Etkina, Eugenia, Michael Gentile, and Alan Van Heuvelen. *College Physics*. San Francisco, CA: Pearson, 2014.

Knight, Randall D., Brian Jones, and Stuart Field. *College Physics: A Strategic Approach.* 2nd ed., AP® ed. Boston: Pearson, 2013.

Walker, James S., *Physics*, San Francisco, CA: Pearson Addison-Wesley, 2010.

Giambattista, Alan, Betty M. Richardson, and Robert C. Richardson, *Physics*, New York, NY: McGraw-Hill, 2010.

22. Instructional Methods and/or Strategies

LABORATORY INVESTIGATIONS AND THE SCIENCE PRACTICES

The AP Physics 2 course devotes over **25% of the time** to laboratory investigations.
The laboratory component of the course allows the students to demonstrate the seven **science practices** through a variety of investigations in all of the foundational principles.
The students use **guided–inquiry (GI)** or **open–inquiry (OI)** in the design of their laboratory investigations. Some labs focus on investigating a physical phenomenon without having expectations of its outcomes. In other experiments, the student has an expectation of its outcome based on concepts constructed from prior experiences. In application experiments, the students use acquired physics principles to address practical problems. Students also investigate topic related questions that are formulated through student designed/selected procedures.
All investigations are reported in a **laboratory journal**. Students are expected to record their observations, data, and data analyses. Data analyses include identification of the sources and effects of experimental uncertainty, calculations, results and conclusions, and suggestions for further refinement of the experiment as appropriate.

UNIT LAB INVESTIGATION OBJECTIVE(S)
(Investigation identifier: Guided–Inquiry: **GI** Open–Inquiry: **OI**)

UNIT 1.
ELECTROSTATICS

1. Electrostatics Investigations (GI)
To investigate the behavior of electric charges, charging processes, and the distribution of charge on a conducting object.

2. The Electroscope (GI)
To make qualitative observations of the behavior of an electroscope when it is charged by conduction and by induction.

3. Coulomb's Law
To estimate the net charge on identical spherical pith balls by measuring the deflection (angle and separation) between two equally charged pith balls.

4. Electric Field and Equipotentials (GI)
To map equipotential isolines around charged conducting electrodes painted with conductive ink and construction of isolines of electric fields.

5. Resistance and Resistivity (GI)
To explore the microscopic and macroscopic factors that influence the electrical resistance of conducting materials. Students will investigate how geometry affects the resistance of an ionic conductor using Play-Doh™.

UNIT 2.
ELECTRIC CIRCUITS

6. DC Circuits: Brightness (GI)
To make predictions about the brightness of light bulbs in a variety of DC circuit configurations (series, parallel, and series-parallel) when some of the bulbs are removed.

UNIT 4.
THERMODYNAMICS

12. Gas Laws
To verify the relationships between pressure, temperature, and volume of a gas (air).

7. DC Circuits: Resistors
To investigate the behavior of resistors in series, parallel, and series/parallel DC circuits. The lab includes measurements of cur- rents and potential differences.

8. RC Circuits: Resistors and Capacitors (GI)
This investigation consists of two parts:
• An observational experiment where the students make qualitative descriptions of the charging and discharging of a capacitor.
• To investigate the behavior of resistors in a series-parallel combination with a capacitor in series. Their investigation includes measurement of currents and potential differences.

9. Magnetic Field of the Earth (GI)
To measure the horizontal component of the Earth's magnetic field using a solenoid and a compass.

10. Magnetic Force on a Current-Carrying Wire (GI)
To determine the magnitude and direction of the magnetic force exerted on a current-carrying wire.

UNIT 3.
MAGNETISM AND ELECTROMAGNETIC INDUCTION

11. Electromagnetic Induction (GI)
The students move a bar magnet in and out of a solenoid and observe the deflection of the galvanometer. They examine the effects of a changing magnetic field by observing currents induced in a solenoid and determine whether the observations agree with the theory of electromagnetic induction and Lenz' Law.

UNIT 6.
GEOMETRIC & PHYSICAL OPTICS

12. Reflection (GI)
Students design an investigation to answer the following question: "Are there any patterns in the way plane mirrors and curved mirrors reflect light?"

13. Thermal Conductivity (GI)
To determine the thermal conductivity of a material by comparing the difference in temperature across one material to the difference in temperature across a second material of known thermal conductivity.

14. Heat Engine (GI)
To determine how the work done by an engine that raises mass during each of its cycles is related to the area enclosed by its *P-V* graph.

15. Efficiency of a Hair Dryer (GI)
To determine the efficiency of a hair dryer as it dries a wet towel.

16. Archimedes' Principle
To determine the densities of a liquid and two unknown objects by using the method that is attributed to Archimedes.
Science Practices 1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2

17. Torricelli's Theorem (GI)
To determine the exit velocity of a liquid and predict the range attained with holes at varying heights using a clear 2 L plastic bottle.

UNIT 5.
FLUIDS

18. Water Fountain Lab (GI)
The students design an investigation to determine:
• Exit angle and exit speed of the water
• Maximum height of water
• Radius of the fountain's exit hole
• Flow volume rate

20. Concave Mirrors (GI)
This investigation has two parts:
• To determine the focal length of a concave mirror.
• To determine two locations where a magnified image can be formed using a concave mirror.

21. Index of Refraction (GI)
To determine the index of refraction of an acrylic block.

22. Lenses (GI)
This investigation is divided into two parts:
• To directly determine the focal length of a converging lens directly.
• To determine the focal length of a diverging lens by combining it with a converging lens.

23. Double-slit Interference and Diffraction
This lab activity consists of three parts where the students design each investigation:
• To determine the wavelength of a green laser using a double slit.
• The students apply the results of the previous experiment to predict the location of bright and dark fringes when a red laser of known wavelength is used.
• The students determine the spacing in a diffraction grating using either the green or the red laser.

24. Spectroscopy (GI)
Students use a quantitative analysis spectroscope to analyze flame tests and spectrum tubes.

25. Photoelectric Effect
The determine Planck's constant from data collected from a circuit with an LED color strip.

UNIT 7.
QUANTUM PHYSICS, ATOMIC AND NUCLEAR PHYSICS

26. Radioactive Decay and Half-Life (GI)
In this investigation, students simulate radioactive decay and determine half-life.

INSTRUCTIONAL ACTIVITIES
Throughout the course, the students engage in a variety of activities designed to build the students' reasoning skills and deepen their conceptual understanding of physics principles. Students conduct activities and projects that enable them to connect the concepts learned in class to real world applications. Examples of activities are described below.

1. PROJECT DESIGN
Students engage in hands-on activities outside of the laboratory experience that support the connection to more than one Learning Objective.

ACTIVITY 1: In-Depth Research and/or Model Construction:

DESCRIPTION:
With over a hundred approved project topics to choose from (new topics can be proposed) students, in small groups of 2 to 4 do in-depth research towards a presentation to the class or construction and demonstration of their project in and to the class. Typically, the research, internet and through personal interviews, requires 25-30 hours of their time and results in, typically, excellent presentations focused in a leading-edge topics in Physics or the production of working models ranging from a trebuchet, gravity demonstration, or EMP generator.

Learning Objective 5.B.3.1
The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.
Learning Objective 5.B.3.2
The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.

Learning Objective 5.B.3.3
The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.
Learning Objective 5.B.4.2
The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.
Learning Objective 4.C.1.1
The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.
Learning Objective 4.C.1.2
The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.

2. SIMULATION ACTIVITY

Students engage in activities outside of the laboratory experience that support the connection to more than one Learning Objective.

ACTIVITY 1: Quantum Wave Interference

DESCRIPTION:
The PhET Quantum Wave Interference simulation (http://phet.colorado.edu/en/ simulation/wave interference) helps students to visualize the behavior of photons, electrons, and atoms as particles and as waves through a double-slit. The students work in small groups through a series of 'experiments' that confront students with the basic conflict between the wave model and particle model. The groups have to gather **evidence** that will allow them to justify how the double slit interference pattern is consistent with both the classical wave view and the photon view. After the class discussion, the students should be able to articulate how the wave view is related to the photon view. This activity is designed to allow students to apply the following Learning Objectives:

Learning objective 1.D.1.1
The student is able to explain why classical mechanics cannot describe all properties of objects by articulating the reasons that classical mechanics must be refined and an alternative explanation developed when classical particles display wave properties.
Learning objective 6.G.1.1
The student is able to make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate.

3. REAL WORLD APPLICATIONS

ACTIVITY 1. Fluid Applications

DESCRIPTION:
Students write a series of questions that they wonder about related to buoyancy and density in real world contexts. In teams of two, the students select one research question. They have two class periods to post their results of the research on a Google Doc. Each team presents their information and any sources of data found to the class. Sample questions are:

- How do metal ships float?
- Will a ship full of oil float differently than an empty ship?
- If an oil tanker develops a leak, why does it sink?
- How will a ship float in fresh water as opposed to salt water?
- How and why do hot air balloons work?
- Would hydrogen balloons float better than balloons filled with hot air?

Learning objective 1.e.1.1
The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction.
Learning objective 1.e.1.2
The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects.
Learning objective 3.C.4.2
The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.

ACTIVITY 2. Laser Applications

DESCRIPTION:
Students first investigate how a laser works using the PhET Laser simulation (http://phet.colorado.edu/en/simulation/lasers). The simulation helps the students understand how absorption and spontaneous and stimulated emission work.

Students will be able to explain how these factors: intensity and wavelength of the lamp, the mirror reflectivity, and the lifetimes of the excited states of the atom influence the laser. After writing their observations, they conduct online research to submit a paper that will demonstrate their ability to read and synthesize scientific literature about the applications of lasers in modern medicine. Common research topics of applications include vision correction (LASIK surgery), tattoo removal, and varicose vein treatments.

Learning objective 5.B.8.1
The student is able to describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including characterization of the frequency of radiation emitted or absorbed.

4. SCIENTIFIC ARGUMENTATION

In the course, students become familiar with the three components of **scientific argumentation**. The first element is the claim, which is the response to a prediction. A claim provides an explanation for why or how something happens in a laboratory investigation. The second component is the evidence, which supports the claim and consists of the analysis of the data collected during the investigation. The third component consists of questioning, in which students examine and defend one another's claims. Students receive explicit instruction in posing meaningful questions that include questions of clarification, questions that probe assumptions, and questions that probe implications and consequences. As a result of the scientific argumentation process, students are able to revise their claims and make revisions as appropriate.

ACTIVITY 1: Nuclear energy: Friend or Foe

DESCRIPTION:
In addition to the physics concepts, this project requires the evaluation of ethical concerns in order to arrive at a decision regarding nuclear energy. This project is meaningful and engaging to students as it requires the use of **evidence-based reasoning** through **dialogue** and provides a context for understanding scientific information.

Students work in teams of two to investigate the socio-scientific issue about the pros and cons of the use of nuclear energy. The research includes an explanation of the process of nuclear fission, the basic operation of a nuclear reactor, how a chain reaction works and how magnetic and inertial confinements can provide thermonuclear power. Students have to discuss safety, cost effectiveness,

and environmental impact including wildlife and human health.
The culmination activity is a debate moderated by the students themselves.

Learning objective 5.G.1.1
The student is able to apply conservation of nucleon number and conservation of electric charge to make predictions about nuclear reactions and decays such as fission, fusion, alpha decay, beta decay, or gamma decay.

Instructional Methods and/or Strategies:

AP Physics, Part 1 uses a variety of instructional strategies including lectures, embedded assessment PowerPoint presentations, guided practice in problem solving, Socratic questioning, computer simulations, and hands-on laboratory experiences.

Teaming of students for short projects, problem solving, and labs is done as randomly as possible.

EL modifications
- Emphasis on vocabulary
- Learning new words and concepts with VAK learning
- Having notebooks/journals with vocabulary and use of color
- Making students aware of the glossary (and Spanish glossary) in the back

Differentiating Instruction for Advanced students
- Provide challenging questions/ advancing questions
- Inquiry-based lessons/labs
- Collaboration
  - Peer tutoring
  - Open-ended projects and performance tasks with groups
  - Labs to put concepts into context
- Provide more depth and context for the standards

Technology
- Excel
- Scientific and graphing calculators
- Computer simulations of physics concepts
- Varied presentation tools

Cross-curricular links

Labs

Checking for understanding
- Exit tickets
- Informal assessment
- Formal assessments
- Warm-ups

23. Assessment and Evaluation

Unit Exams, Quizzes, FRQ Practice.
Practice Exams are formatted as close as possible to the AP Exam format to allow testing strategies to develop over the period before the Exam in May.

Content-based learning targets:

I can distinguish
I know how

Process-based learning targets:

I can construct
I can design

Formative assessments:

Students will be constantly assessed throughout a lesson and lab.

Summative assessments

Students will be assessed in a culminating, end-of-unit exam by allowing them to demonstrate their learning targets designed around the concepts throughout the unit and lab. The assessment will mainly be free-response based to allow students to fully explain their learned knowledge and be effectively measured in their learning. Portions of the assessment will include various forms of questions that require argumentation, experimental design, model constructing, and data analysis. Questions prompts include "explain, define, analyze, draw, design, construct, argue, propose, and calculate." They are to assess conceptual knowledge, reasoning, and validity of responses.

Rubrics:

The rubrics will measure student mastery of specific concepts in a unit and lab.

24. Grading Policy

Approximately 70% of the grade is determined by tests and quizzes, 15 % by laboratory reports and 15% by homework

SECTION C. OPTIONAL INFORMATION

25. Context for offering the course:

Advanced Placement/The CollegeBoard have converted the former AP Physics B course to the new AP Physics 1 and AP Physics 2 courses being proposed as part of this change.

26. History of Course Description:

The information present in this course description is consistent with that developed as part of the Advanced Placement syllabus submission and the approval to be submitted to the University of California.

Proposed AP® Physics 2 -
Syllabus v1

Curricular Requirements	Page(s)
CR1 Students and teachers have access to college-level resources including college-level textbooks and reference materials in print or electronic format.	1
CR2a The course design provides opportunities for students to develop an understanding of the foundational principles of thermodynamics in the context of the big ideas that organize the curriculum framework.	2
CR2b The course design provides opportunities for students to develop an understanding of the foundational principles of fluids in the context of the big ideas that organize the curriculum framework.	2
CR2c The course design provides opportunities for students to develop an understanding of the foundational principles of electrostatics in the context of the big ideas that organize the curriculum framework.	1
CR2d The course design provides opportunities for students to develop an understanding of the foundational principles of electric circuits in the context of the big ideas that organize the curriculum framework.	2
CR2e The course design provides opportunities for students to develop an understanding of the foundational principles of magnetism and electromagnetic induction in the context of the big ideas that organize the curriculum framework.	2
CR2f The course design provides opportunities for students to develop an understanding of the foundational principles of optics in the context of the big ideas that organize the curriculum framework.	3
CR2g The course design provides opportunities for students to develop an understanding of the foundational principles of modern physics in the context of the big ideas that organize the curriculum framework.	3
CR3 Students have opportunities to apply AP Physics 2 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.	8
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.	8
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.	3
CR6a The laboratory work used throughout the course includes a variety of investigations that support the foundational AP Physics 2 principles.	4,5,6,7
CR6b The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.	4,5,6,7
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.	4
CR8 The course provides opportunities for students to develop written and oral scientific argumentation skills.	9

RESOURCES

TEXTBOOK
Giancoli, Douglas C., *Physics*, Principles With Applications, San Francisco, CA: Pearson Prentice Hall, 2009. **[CR1]**

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

TEACHING RESOURCES
Etkina, Eugenia, Michael Gentile, and Alan Van Heuvelen. *College Physics*. San Francisco, CA: Pearson, 2014.

Knight, Randall D., Brian Jones, and Stuart Field. *College Physics: A Strategic Approach.* 2nd ed., AP® ed. Boston: Pearson, 2013.

Walker, James S., *Physics*, San Francisco, CA: Pearson Addison-Wesley, 2010.

Giambattista, Alan, Betty M. Richardson, and Robert C. Richardson, *Physics*, New York, NY: McGraw-Hill, 2010.

INSTRUCTIONAL STRATEGIES

The AP Physics 2 course is conducted using **inquiry-based instructional strategies** that focus on experimentation to develop students' conceptual understanding of physics principles. The students begin studying a topic by making observations and discovering patterns of natural phenomena. The next steps involve developing, testing, and applying models. Throughout the course, the students construct and use multiple representations of physical processes, solve multi-step problems, design investigations, and reflect on knowledge construction through self-assessment rubrics.

In most labs, the students use probeware technology in data acquisition. In the classroom, they use graphing calculators and digital devices for interactive simulations, Physlet-based exercises, collaborative activities, and formative assessments.

COURSE SYLLABUS

UNIT 1. ELECTROSTATICS [CR2c]
- Electric force
- Electric field
- Electric potential

Big Ideas 1, 2, 3, 4, 5

Learning objectives: 1.B.1.1, 1.B.1.2, 1.B.2.2, 1.B.2.3, 1.B.3.1, 2.C.1.1, 2.C.1.2, 2.C.2.1, 2.C.3.1, 2.C.4.1, 2.C.4.2, 2.C.5.1, 2.C.5.2, 2.C.5.3, 2.E.2.1, 2.E.2.2, 2.E.2.3, 2.E.3.1, 2.E.3.2, 3.A.2.1, 3.A.3.2, 3.A.3.3, 3.A.3.4, 3.A.4.1, 3.A.4.2, 3.A.4.3, 3.B.1.3, 3.B.1.4, 3.B.2.1, 3.C.2.1, 3.C.2.2, 3.C.2.3, 3.G.1.2, 3.G.2.1, 3.G.3.1, 4.E.3.1, 4.E.3.2, 4.E.3.3, 4.E.3.4, 4.E.3.5, 5.A.2.1

> **CR2c**— *The course design provides opportunities for students to develop an understanding of the foundational principles of electrostatics in the context of the big ideas that organize the curriculum framework.*

UNIT 2. ELECTRIC CIRCUITS [CR2d]

- Electric resistance
- Ohm's Law
- DC circuits with resistors only
- Kirchhoff's Laws
- Series, parallel, and series-parallel circuits
- Capacitance
- DC circuits with resistors and capacitors

Big Ideas 1, 4, 5

Learning objectives: 1.E.2.1, 4.E.4.1, 4.E.4.2, 4.E.4.3, 4.E.5.1, 4.E.5.2, 4.E.5.3, 5.B.9.4, 5.B.9.5, 5.B.9.6, 5.B.9.7, 5.B.9.8, 5.C.3.4, 5.C.3.5, 5.C.3.6, 5.C.3.7

> CR2d— *The course design provides opportunities for students to develop an understanding of the foundational principles of electric circuits in the context of the big ideas that organize the curriculum framework.*

UNIT 3. MAGNETISM AND ELECTROMAGNETIC INDuCTIoN [CR2e]

- Magnetic field
- Magnetic force on a charged particle
- Magnetic force on a current-carrying wire
- Magnetic flux
- Electromagnetic induction: Faraday's Law
- Lenz's Law
- Motional emf

Big Ideas 1, 2, 3, 4

Learning objectives: 2.C.4.1, 2.D.1.1, 2.D.2.1, 2.D.3.1, 2.D.4.1, 3.A.2.1, 3.A.3.2, 3.A.3.3, 3.A.4.1, 3.A.4.2, 3.A.4.3, 3.C.3.1, 3.C.3.2, 4.E.1.1, 4.E.2.1

> CR2e— *The course design provides opportunities for students to develop an understanding of the foundational principles of magnetism and electromagnetic induction in the context of the big ideas that organize the curriculum framework.*

UNIT 4. THERMODYNAMICS [CR2a]

- Kinetic theory
- Ideal gases
- First law of thermodynamics
- Thermodynamic processes and PV diagrams
- Heat engines
- Carnot cycle
- Efficiency
- Second law of thermodynamics: entropy

Big Ideas 1, 4, 5, 7

Learning objectives: 1.E.3.1, 4.C.3.1, 5.A.2.1, 5.B.4.1, 5.B.4.2, 5.B.5.4, 5.B.5.5, 5.B.5.6, 5.B.6.1, 5.B.7.1, 5.B.7.2, 5.B.7.3, 7.A.1.1, 7.A.1.2, 7.A.2.1, 7.A.2.2, 7.A.3.1, 7.A.3.2, 7.A.3.3, 7.B.1.1, 7.B.2.1

> CR2a— *The course design provides opportunities for students to develop an understanding of the foundational principles of thermodynamics in the context of the big ideas that organize the curriculum framework.*

UNIT 5. FLUIDS [CR2b]

- Density
- Pressure: atmospheric and fluid pressure
- Pascal's principle
- Buoyant force
- Archimedes' principle
- Flow rate
- Continuity equation

> CR2b— *The course design provides opportunities for students to develop an understanding of the foundational principles of fluids in the context of the big ideas that organize the curriculum framework.*

- *Bernoulli's principle*

Big Ideas 1, 3, 5

Learning objectives: 1.E.1.1, 1.E.1.2, 3.C.4.1, 3.C.4.2, 5.B.10.1, 5.B.10.2, 5.B.10.3, 5.B.10.4, 5.F.1.1

UNIT 6. GEOMETRIC AND PHYSICAL OPTICS [CR2f]

- Reflection
- Image formation by flat and curved mirrors
- Refraction and Snell's Law
- Image formation by thin lenses
- Interference and diffraction
- Double slit, single slit, and diffraction grating interference
- Thin film interference

Big Idea 6

Learning objectives: 6.A.1.2, 6.A.1.3, 6.A.2.2, 6.B.3.1, 6.C.1.1, 6.C.1.2, 6.C.2.1, 6.C.3.1, 6.C.4.1, 6.E.1.1, 6.E.2.1, 6.E.3.1, 6.E.3.2, 6.E.3.3, 6.E.4.1, 6.E.4.2, 6.E.5.1, 6.E.5.2, 6.F.1.1, 6.F.2.1

> CR2f— *The course design provides opportunities for students to develop an understanding of the foundational principles of optics in the context of the big ideas that organize the curriculum framework.*

UNIT 7. QUANTUM PHYSICS, ATOMIC AND NUCLEAR PHYSICS [CR2g]

- Atoms, atomic mass, mass number, and isotopes
- Atomic energy levels
- Absorption and emission spectra
- Models of light: wave and particle
- Photoelectric effect
- DeBroglie wavelength
- Wave function graphs
- Mass-energy equivalence
- Radioactive decay: alpha, beta and gamma decay
- Half life
- Conservation of nucleon number: fission and fusion

Big Ideas 1, 3, 4, 5, 6, 7

Learning objectives: 1.A.2.1, 1.A.4.1, 1.C.4.1, 1.D.1.1, 1.D.3.1, 4.C.4.1, 5.B.8.1, 5.B.11.1, 5.C.1.1, 5.D.1.6, 5.D.1.7, 5.D.2.5, 5.D.2.6, 5.D.3.2, 5.D.3.3, 5.G.1.1, 6.F.3.1, 6.F.4.1, 6.G.1.1, 6.G.2.1, 6.G.2.2, 7.C.1.1, 7.C.2.1, 7.C.3.1, 7.C.4.1

> CR2g— *The course design provides opportunities for students to develop an understanding of the foundational principles of modern physics in the context of the big ideas that organize the curriculum framework.*

LABORATORY INVESTIGATIONS AND THE SCIENCE PRACTICES

The AP Physics 2 course devotes over **25% of the time** to laboratory investigations. **[CR5]** The laboratory component of the course allows the students to demonstrate the seven **science practices** through a variety of investigations in all of the foundational principles.

> 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*

The students use **guided-inquiry (GI)** *or* **open-inquiry (OI)** *in the design of their laboratory investigations. Some labs focus on investigating a physical phenomenon without having expectations of its outcomes. In other experiments, the student has an expectation of its outcome based on concepts constructed from prior experiences. In application experiments, the students use acquired physics principles to address practical*

> 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.*

problems. . Students also investigate topic-related questions that are formulated through student designed/selected procedures.

All investigations are reported in a **laboratory journal**. Students are expected to record their observations, data, and data analyses. Data analyses include identification of the sources and effects of experimental uncertainty, calculations, results and conclusions, and suggestions for further refinement of the experiment as appropriate. **[CR7]**

UNIT	LAB INVESTIGATION OBJECTIVE(s) (Investigation identifier: Guided–Inquiry: **GI** Open–Inquiry: **OI**)
UNIT 1. ELECTRO-STATICS **[CR6a]**	**1. Electrostatics Investigations (GI) [CR6b]** To investigate the behavior of electric charges, charging processes, and the distribution of charge on a conducting object. Science Practices 1.1, 3.1, 4.1, 4.2, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2
	2. The Electroscope (GI) [CR6b] To make qualitative observations of the behavior of an electroscope when it is charged by conduction and by induction. Science Practices 1.1, 3.1, 4.1, 4.2, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2
	3. Coulomb's Law To estimate the net charge on identical spherical pith balls by measuring the deflection (angle and separation) between two equally charged pith balls. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	4. Electric Field and Equipotentials (GI) [CR6b] To map equipotential isolines around charged conducting electrodes painted with conductive ink and construction of isolines of electric fields. Science Practices 1.1, 1.2, 1.4, 3.1, 4.1, 4.2, 4.3, 5.1, 6.1, 6.2, 6.4, 7.2
UNIT 2. ELECTRIC CIRCUITS **[CR6a]**	**5. Resistance and Resistivity (GI) [CR6b]** To explore the microscopic and macroscopic factors that influence the electrical resistance of conducting materials. Students will investigate how geometry affects the resistance of an ionic conductor using Play-Doh™. Science Practices 1.2, 1.4, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2, 6.4, 7.2
	6. DC Circuits: Brightness (GI) [CR6b] To make predictions about the brightness of light bulbs in a variety of DC circuit configurations (series, parallel, and series-parallel) when some of the bulbs are removed. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2

CR6a— The laboratory work used throughout the course includes a variety of investigations that support the foundational AP Physics 2 principles.

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

	7. DC Circuits: Resistors To investigate the behavior of resistors in series, parallel, and series-parallel DC circuits. The lab includes measurements of cur- rents and potential differences. Science Practices 1.2, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2
	8. RC Circuits: Resistors and Capacitors (GI) [CR6b] This investigation consists of two parts: · An observational experiment where the students make qualitative descriptions of the charging and discharging of a capacitor. · To investigate the behavior of resistors in a series-parallel combination with a capacitor in series. Their investigation includes measurement of currents and potential differences. Science Practices 1.2, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2
UNIT 3. MAGNETISM AND ELECTRO-MAGNETIC INDUCTION **[CR6a]**	**9. Magnetic Field of the Earth (GI) [CR6b]** To measure the horizontal component of the Earth's magnetic field using a solenoid and a compass. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	10. Magnetic Force on a Current-Carrying Wire (GI) [CR6b] To determine the magnitude and direction of the magnetic force exerted on a current-carrying wire. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4,
	11. Electromagnetic Induction (GI) [CR6b] The students move a bar magnet in and out of a solenoid and observe the deflection of the galvanometer. They examine the effects of a changing magnetic field by observing currents induced in a solenoid and determine whether the observations agree with the theory of electromagnetic induction and Lenz' Law. Science Practices 1.1, 1.2, 1.4, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.2, 6.4, 7.2
UNIT 4. THERMO-DYNAMICS **[CR6a]**	**12. Gas Laws** To verify the relationships between pressure, temperature, and volume of a gas (air). Science Practices 1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

CR6a— The laboratory work used throughout the course includes a variety of investigations that support the foundational AP Physics 2 principles.

	13. Thermal Conductivity (GI) [CR6b] To determine the thermal conductivity of a material by comparing the difference in temperature across one material to the difference in temperature across a second material of known thermal conductivity. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 6.1, 6.2, 6.4, 7.2
	14. Heat Engine (GI) [CR6b] To determine how the work done by an engine that raises mass during each of its cycles is related to the area enclosed by its *P-V* graph. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 6.1, 6.2, 6.4, 7.2
	15. Efficiency of a Hair Dryer (GI) [CR6b] To determine the efficiency of a hair dryer as it dries a wet towel. Science Practices 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 6.1, 6.2, 6.4, 7.2
UNIT 5. FLUIDS **[CR6a]**	**16. Archimedes' Principle** To determine the densities of a liquid and two unknown objects by using the method that is attributed to Archimedes. Science Practices 1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	17. Torricelli's Theorem (GI) [CR6b] To determine the exit velocity of a liquid and predict the range attained with holes at varying heights using a clear 2 L plastic bottle. Science Practices 1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	18. Water Fountain Lab (GI) [CR6b] The students design an investigation to determine: · Exit angle and exit speed of the water · Maximum height of water · Radius of the fountain's exit hole · Flow volume rate Science Practices 1.1, 1.4, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
UNIT 6. GEOMETRIC & PHYSICAL OPTICS **[CR6a]**	**19. Reflection (GI) [CR6b]** Students design an investigation to answer the following question: "Are there any patterns in the way plane mirrors and curved mirrors reflect light?" Science Practices 1.1, 1.2, 1.3, 1.4, 3.3, 4.1, 4.2, 4.3, 5.3, 6.1, 6.4, 7.2

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

CR6a— The laboratory work used throughout the course includes a variety of investigations that support the foundational AP Physics 2 principles.

	20. Concave Mirrors (GI) [CR6b] This investigation has two parts: · To determine the focal length of a concave mirror. · To determine two locations where a magnified image can be formed using a concave mirror. Science Practices 1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.4, 7.2
	21. Index of Refraction (GI) [CR6b] To determine the index of refraction of an acrylic block. Science Practices 1.1, 1.2, 1.4, 1.5, 2.1, 2.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	22. Lenses (GI) [CR6b] This investigation is divided into two parts: · To directly determine the focal length of a converging lens directly. · To determine the focal length of a diverging lens by combining it with a converging lens. Science Practices 1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.4, 7.2
	23. Double-slit Interference and Diffraction This lab activity consists of three parts where the students design each investigation: · To determine the wavelength of a green laser using a double slit. · The students apply the results of the previous experiment to predict the location of bright and dark fringes when a red laser of known wavelength is used. · The students determine the spacing in a diffraction grating using either the green or the red laser. Science Practices 1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.4, 7.2
UNIT 7. QUANTUM PHYSICS, ATOMIC AND NUCLEAR PHYSICS **[CR6a]**	**24. Spectroscopy (GI) [CR6b]** Students use a quantitative analysis spectroscope to analyze flame tests and spectrum tubes. Science Practices 1.2, 3.1, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2
	25. Photoelectric Effect The determine Planck's constant from data collected from a circuit with an LED color strip. Science Practices 1.1, 1.4, 1.5, 2.1, 2.2, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.4, 7.2
	26. Radioactive Decay and Half-Life (GI) [CR6b] In this investigation, students simulate radioactive decay and determine half-life. Science Practices 1.1, 1.2, 1.3, 1.4, 2.3, 3.1, 3.2, 4.1, 4.2, 4.3, 5.1, 5.3, 6.1, 6.4, 7.2

CR6b— The laboratory work used throughout the course includes guided-inquiry laboratory investigations allowing students to apply all seven science practices.

CR6a— The laboratory work used throughout the course includes a variety of investigations that support the foundational AP Physics 2 principles.

INSTRUCTIONAL ACTIVITIES

Throughout the course, the students engage in a variety of activities designed to build the students' reasoning skills and deepen their conceptual understanding of physics principles. Students conduct activities and projects that enable them to connect the concepts learned in class to real world applications. Examples of activities are described below.

1. PROJECT DESIGN [CR3]

Students engage in hands-on activities outside of the laboratory experience that support the connection to more than one Learning Objective.

ACTIVITY 1: In-Depth Research and/or Model Construction:

DESCRIPTION:
With over a hundred approved project topics to choose from (new topics can be proposed) students, in small groups of 2 to 4 do in-depth research towards a presentation to the class or construction and demonstration of their project in and to the class. Typically, the research, internet and through personal interviews, requires 25-30 hours of their time and results in, typically, excellent presentations focused in a leading-edge topics in Physics or the production of working models ranging from a trebuchet, gravity demonstration, or EMP generator.

CR3— Students have opportunities to apply AP Physics 2 learning objectives connecting across enduring understandings as described in the curriculum framework. These opportunities must occur in addition to those within laboratory investigations.

Learning Objective 5.B.3.1
The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.
Learning Objective 5.B.3.2
The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.
Learning Objective 5.B.3.3
The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.
Learning Objective 5.B.4.2
The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.
Learning Objective 4.C.1.1
The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.
Learning Objective 4.C.1.2
The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.

2. SIMULATION ACTIVITY

Students engage in activities outside of the laboratory experience that support the connection to more than one Learning Objective.

ACTIVITY 1: Quantum Wave Interference [CR3]

DESCRIPTION:
The PhET Quantum Wave Interference simulation (http://phet.colorado.edu/en/ simulation/wave-interference) helps students to visualize the behavior of photons, electrons, and atoms as particles and as waves through a double-slit. The students work in small groups through a series of 'experiments' that confront students with the basic conflict between the wave model and particle model. The groups have to gather **evidence** that will allow them to justify how the double slit interference pattern is consistent with both the classical wave view and the photon view. After the class discussion, the students should be able to articulate how the wave view is related to the photon view. This activity is designed to allow students to apply the following Learning Objectives:
Learning objective 1.D.1.1
The student is able to explain why classical mechanics cannot describe all properties of objects by articulating the reasons that classical mechanics must be refined and an alternative explanation developed when classical particles display wave properties.
Learning objective 6.G.1.1
The student is able to make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate.

3. REAL WORLD APPLICATIONS

ACTIVITY 1. Fluid Applications [CR4]

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.

DESCRIPTION:
Students write a series of questions that they wonder about related to buoyancy and density in real world contexts. In teams of two, the students select one research question. They have two class periods to post their results of the research on a Google Doc. Each team presents their information and any sources of data found to the class. Sample questions are:

- How do metal ships float?
- Will a ship full of oil float differently than an empty ship?
- If an oil tanker develops a leak, why does it sink?
- How will a ship float in fresh water as opposed to salt water?
- How and why do hot air balloons work?
- Would hydrogen balloons float better than balloons filled with hot air?

Learning objective 1.e.1.1
The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction.
Learning objective 1.e.1.2
The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects.
Learning objective 3.C.4.2
The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.

ACTIVITY 2. Laser Applications

DESCRIPTION:
Students first investigate how a laser works using the PhET Laser simulation (http://phet.colorado.edu/en/simulation/lasers). The simulation helps the students understand how absorption and spontaneous and stimulated emission work.
Students will be able to explain how these factors: intensity and wavelength of the lamp, the mirror reflectivity, and the lifetimes of the excited states of the atom influence the laser. After writing their observations, they conduct online research to submit a paper that will demonstrate their ability to read and synthesize scientific literature about the applications of lasers in modern medicine. Common research topics of applications include vision correction (LASIK surgery), tattoo removal, and varicose vein treatments.

Learning objective 5.B.8.1
The student is able to describe emission or absorption spectra associated with electronic or nuclear transitions as transitions between allowed energy states of the atom in terms of the principle of energy conservation, including characterization of the frequency of radiation emitted or absorbed.

4. SCIENTIFIC ARGUMENTATION

In the course, students become familiar with the three components of **scientific argumentation.** The first element is the claim, which is the response to a prediction. A claim provides an explanation for why or how something happens in a laboratory investigation. The second component is the evidence, which supports the claim and consists of the analysis of the data collected during the investigation. The third component consists of questioning, in which students examine and defend one another's claims. Students receive explicit instruction in posing meaningful questions that include questions of clarification, questions that probe assumptions, and questions that probe implications and consequences. As a result of the scientific argumentation process, students are able to revise their claims and make revisions as appropriate. **[CR8]**

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

ACTIVITY 1: Nuclear energy: Friend or Foe

DESCRIPTION:
In addition to the physics concepts, this project requires the evaluation of ethical concerns in order to arrive at a decision regarding nuclear energy. This project is meaningful and engaging to students as it requires the use of **evidence-based reasoning** through **dialogue** and provides a context for understanding scientific information.

Students work in teams of two to investigate the socio-scientific issue about the pros and cons of the use of nuclear energy. The research includes an explanation of the process of nuclear fission, the basic operation of a nuclear reactor, how a chain reaction works and how magnetic and inertial confinements can provide thermonuclear power. Students have to discuss safety, cost-effectiveness, and environmental impact including wildlife and human health. The culmination activity is a debate moderated by the students themselves.

Learning objective 5.G.1.1
The student is able to apply conservation of nucleon number and conservation of electric charge to make predictions about nuclear reactions and decays such as fission, fusion, alpha decay, beta decay, or gamma decay.