Randolph Township Schools
Randolph High School

AP Physics 2
Curriculum

"The scientist imposes only two things, namely truth and sincerity, imposes them upon himself and upon other scientists."
~ Erwin Schrodinger~

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Science, Technology, Engineering, and Math
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Randolph Township Schools
Department of Science, Technology, Engineering, and Math

AP Physics 2

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Randolph Township Schools

Mission Statement

We commit to inspiring and empowering all students in Randolph Schools to reach their full potential as unique, responsible and educated members of a global society.

Randolph Township Schools
Affirmative Action Statement

Equality and Equity in Curriculum

The Randolph Township School district ensures that the district's curriculum and instruction are aligned to the state's standards. The curriculum provides equity in instruction, educational programs and provides all students the opportunity to interact positively with others regardless of race, creed, color, national origin, ancestry, age, marital status, affectional or sexual orientation, gender, religion, disability or socioeconomic status.

N.J.A.C. 6A:7-1.7(b): Section 504, Rehabilitation Act of 1973; N.J.S.A. 10:5; Title IX, Education Amendments of 1972

RANDOLPH TOWNSHIP BOARD OF EDUCATION
EDUCATIONAL GOALS
VALUES IN EDUCATION

The statements represent the beliefs and values regarding our educational system. Education is the key to self-actualization, which is realized through achievement and self-respect. We believe our entire system must not only represent these values, but also demonstrate them in all that we do as a school system.

We believe:

- The needs of the child come first
- Mutual respect and trust are the cornerstones of a learning community
- The learning community consists of students, educators, parents, administrators, educational support personnel, the community and Board of Education members
- A successful learning community communicates honestly and openly in a non-threatening environment
- Members of our learning community have different needs at different times. There is openness to the challenge of meeting those needs in professional and supportive ways
- Assessment of professionals (i.e., educators, administrators and educational support personnel) is a dynamic process that requires review and revision based on evolving research, practices and experiences
- Development of desired capabilities comes in stages and is achieved through hard work, reflection and ongoing growth

Randolph Township Schools
Department of Science, Technology, Engineering, and Math

Introduction

Randolph Township Schools is committed to excellence. We believe that all children are entitled to an education that will equip them to become productive citizens of the 21st century. We believe that an education grounded in the fundamental principles of science, technology, engineering, and math (STEM) will provide students with the skills and content necessary to become future leaders and lifelong learners.

A sound STEM education is grounded in the principles of inquiry, rigor, and relevance. Students will be actively engaged in learning as they use real-world STEM skills to construct knowledge. They will have ample opportunities to manipulate materials and solve problems in ways that are developmentally appropriate to their age. They will work in an environment that encourages them to take risks, think critically, build models, observe patterns, and recognize anomalies in those patterns. Students will be encouraged to ask questions, not just the "how" and the "what" of observed phenomena, but also the "why". They will develop the ability, confidence, and motivation to succeed academically and personally.

STEM literacy requires understandings and habits of mind that enable students to make sense of how our world works. As described in Project 2061's *Benchmarks in Science Literacy, The Standards for Technological Literacy,* and *Professional Standards for Teaching Mathematics,* literacy in these subject areas enables people to think critically and independently. Scientifically and technologically literate citizens deal sensibly with problems that involve mathematics, evidence, patterns, logical arguments, uncertainty, and problem-solving.

AP PHYSICS 2

Introduction

AP Physics 2 is an elective course in the STEM department. It is a second year algebra based course for juniors and seniors who have completed AP Physics 1. This course covers electricity & magnetism, thermodynamics, fluids, optics, and modern physics. The electricity & magnetism portion of this course will introduce students to electrostatics, electric circuits, magnetic fields, and electromagnetism. Thermodynamics will introduce students to methods of heat transfer, heat engines, and the laws of thermodynamics. Fluids will investigate the equation of continuity, and Bernoulli's equation. The course provides students with the opportunity to earn AP college credit for an algebra based physics course. The course makes use of both technology and traditional methods to collect and analyze data.

RANDOLPH TOWNSHIP SCHOOL DISTRICT
Curriculum Pacing Chart
AP Physics 2

SUGGESTED TIME ALLOTMENT	UNIT NUMBER	CONTENT - UNIT OF STUDY
4 weeks	I	Fluid Statics and Dynamics
4 weeks	II	Laws of Thermodynamics, Ideal Gases, and Kinetic Theory
4 weeks	III	Electrostatics: Electric Force, Electric Field, and Electric Potential
4 weeks	IV	Electrical Circuits
4 weeks	V	Magnetism and Electromagnetic Induction
4 weeks	VI	Geometric and Physical Optics
4 weeks	VII	Quantum Physics, Atomic Physics, and Nuclear Physics
5 weeks	VIII	Putting it all together……AP exam review
3 weeks	IX	Extensions and Enrichment

Enduring Understanding	Essential Questions
Fluids have density and flow according to specific physical and mathematical laws.	• What causes pressure to be exerted by a fluid, and why does liquid pressure vary with depth when gas pressure does not?
The equation of continuity in conjunction with Bernoulli's equation describe the flow of fluids	• How is the buoyant force generated, and how can this force be mathematically modeled? • Why does the buoyant force not vary significantly with depth, even though liquid pressure does?
Using certain assumptions flow of gases can be approximated as a flow of a fluid.	• How can conservation of mass and conservation of energy be used to predict the behavior of moving liquids?

Knowledge	Skills	NGSS
Students will know: How 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. How to use Bernoulli's equation and the continuity equation to make calculations related to a moving fluid. The Continuity Equation related to flow of a fluid, using mass conservation principles.	**Students will be able to:** Select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. Make claims about various contact forces between objects based on the microscopic cause of those forces. Explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. Use Bernoulli's equation and the continuity equation to make calculations related to a moving fluid. Construct an explanation of Bernoulli's equation in terms of the conservation of energy. Make calculations of quantities related to flow of a fluid, using mass conservation principles (the Continuity Equation).	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
4 weeks	**Unit I- Fluid Statics and Dynamics** • **Hydrostatic Pressure** • **Gases and Incompressible Liquids** • **Buoyancy** • **Fluid Flow (Equation of Continuity)** • **Bernoulli's Equation**	**College Board Website:** **http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html** **Practice Problems:** **http://www.learnapphysics.com/apphysics1and2/index.html** **Video Presentations:** **http://www.bozemanscience.com/ap-physics-2-video-list** **Teaching Resources:** **http://apphysicsb.homestead.com/teach.html** **http://prettygoodphysics.wikispaces.com/APP2+Framework**

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2
Unit II: Laws of Thermodynamics, Ideal Gases, and Kinetic Theory

Enduring Understanding	Essential Questions
Pressure vs. Volume graphs and extrapolating work from them.	• How are heat and temperature explained on a molecular level?
Kinetic theory of gases and its connection to temperature.	• How do gas molecules exert pressure on walls of a container?
The Laws of Thermodynamics and how they impact the evolution of physical systems.	• How is the expansion of a gas related to mechanical work?
$PV = nRT$ in a physical context and how it relates to gases, the internal energy of a system, and the temperature.	• What is entropy and how is it related to the irreversibility of most real world processes?

Knowledge	Skills	NGSS
Students will know: Open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. Internal energy of systems is comprised of kinetic energy, potential energy, and energy transfers. The relationship between Pressure, Volume, and Work as it relates to gases.	**Students will be able to:** Design an experiment and analyze data from it to examine thermal conductivity. Describe and make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level. Calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. Make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy). Predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance. Design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5

	needed to determine the work done on or by the object or system.	
How heat and energy is transferred by conduction, convection, and radiation.	Describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation.	
Laws of Thermodynamics.	Predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles. Create a plot of pressure versus volume for a thermodynamic process from given data.	
The kinetic theory of gases and how it relates to the internal energy of a gas.	Use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the first law of thermodynamics). Make claims about how the pressure of an ideal gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system. Treating a gas molecule as an object (i.e., ignoring its internal structure), the student is able to analyze qualitatively the collisions with a container wall and determine the cause of pressure, and at thermal equilibrium, to quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables. Qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system. Connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes.	

$PV = nRT$ in a physical context relates to gases, the internal energy of a system, and the temperature.	Extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero. Design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables. Analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$. Connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how entropy behaves in reversible and irreversible processes.	

RANDOLPH TOWNSHIP SCHOOL DISTRICT
Curriculum Pacing Chart
AP Physics 2

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
4 weeks	**Unit II- Thermodynamics** • **Mechanical Equivalence of Heat** • **Temperature and Gas Laws** • **Specific Heat and Latent Heat** • **Heat Transfer and Thermal Expansion** • **Low Temperatures** • **Ideal Gases** • **Laws of Thermodynamics** • **Entropy**	**College Board Website:** **http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html** **Practice Problems:** **http://www.learnapphysics.com/apphysics1and2/index.html** **Video Presentations:** **http://www.bozemanscience.com/ap-physics-2-video-list** **Teaching Resources:** **http://apphysicsb.homestead.com/teach.html** **http://prettygoodphysics.wikispaces.com/APP2+Framework**

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2
Unit III: Electrostatics: Electric Force, Electric Field, and Electric Potential

Enduring Understanding	Essential Questions
Methods of charging are friction, conduction, and induction.	• What happens at the atomic level when an object is charged or polarized?
An object with a charge can exert a force on another charged object.	• What is an electric field, and how can it be used to calculate force?
An object with a charge generates an electric field.	• What is an electric potential, and how is it related to potential energy?
Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.	• How can we visualize the electric field and electric potential produced by a charge configuration?

Knowledge	Skills	NGSS
Students Will Know: The concept of electric charge and methods of charging.	**Students will be able to:** Make claims about natural phenomena based on conservation of electric charge. Make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. Make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes. Explain and challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object. Explain and challenge the claim that an electric charge smaller than the elementary charge has been isolated. Make predictions about the redistribution of charge during charging by friction, conduction, and induction.	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5 HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5

	Construct a representation of the distribution of fixed and mobile charge in insulators and conductors. Construct a representation of the distribution of fixed and mobile charge in insulators and conductors that predicts charge distribution in processes involving induction or conduction. Design an experiment and analyze the results in which electric charge rearrangement occurs by electrostatic induction, and refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure. Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. Predict the direction and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: F = Eq; a vector relation. Calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities	
Coulomb's Law and the principle of superposition.	Use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges Challenge a claim that an object can exert a force on itself. Describe a force as an interaction between two objects and identify both objects for any force. Make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge.	

The concept of an electric fields and field lines.	Qualitatively and semi-quantitatively apply the vector relationship between the electric field and the net electric charge creating that field. Explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object. Distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field) and make claims about the spatial behavior of the fields using qualitative or semi quantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field. Apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points. Create representations of the magnitude and direction of the electric field at various distances (small compared to plate size) from two electrically charged plates of equal magnitude and opposite signs, and is able to recognize that the assumption of uniform field is not appropriate near edges of plates. Calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates, given the charge of each plate, or the electric potential difference and plate separation Represent the motion of an electrically charged particle in the uniform field between two oppositely charged plates and express the connection of this motion to projectile motion of	

	an object with mass in the Earth's gravitational field. Construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential Determine the structure of isolines of electric potential by constructing them in a given electric field Predict the structure of isolines of electric potential by constructing them in a given electric field and make connections between these isolines and those found in a gravitational field. Qualitatively use the concept of isolines to construct isolines of electric potential in an electric field and determine the effect of that field on electrically charged objects. Apply mathematical routines to calculate the average value of the magnitude of the electric field in a region from a description of the electric potential in that region using the displacement along the line on which the difference in potential is evaluated.	

RANDOLPH TOWNSHIP SCHOOL DISTRICT
Curriculum Pacing Chart
AP Physics 2

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
4 weeks	**Unit III-Electrostatics** • Static Electricity; Electric Charge and its Conservation • Insulators and Conductors • Charging Processes: Friction, Conduction and Induction • Coulomb's Law • Electric Field • Electric Potential and Potential Difference • Relation Between Electric Potential and Electric Field • Equipotential Lines • Electric Potential due to Point Charges	**College Board Website:** http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html **Practice Problems:** http://www.learnapphysics.com/apphysics1and2/index.html **Video Presentations:** http://www.bozemanscience.com/ap-physics-2-video-list **Teaching Resources:** http://apphysicsb.homestead.com/teach.html http://prettygoodphysics.wikispaces.com/APP2+Framework

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2
Unit IV: Electrical Circuits

Enduring Understanding	Essential Questions
Electricity is a form of energy that can be transformed by moving electric charges and doing work in various devices.	• What factors affect the resistance of a material?
Phenomena occurring in electric circuits are described by physical quantities such as potential difference (voltage), electric current, electric resistance, and electric power.	• How do charge conservation and energy conservation apply to direct current circuits?
In order for electricity to flow a complete loop must be present.	• What is common to elements in series and parallel circuits?

Knowledge	Skills	NGSS
Students will know: Resistance and Capacitance of a component are determined by the materials used and the geometry of the component. Ohm's Law, where it applies and how to apply it.	**Students will be able to:** Choose and justify the selection of data needed to determine resistivity for a given material. Make predictions about the properties of resistors and/or capacitors when placed in a simple circuit, based on the geometry of the circuit element and supported by scientific theories and mathematical relationships. Design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors Analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors. Analyze and determine the total resistance in a circuit for resistors in series and in parallel. Use Ohm's Law to find values of the current, voltage, or resistance, given two of these values in a simple circuit.	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5 HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5

Changes in values of and arrangements of electromotive forces, resistors, and capacitors in a circuit will affect the operation of the circuit and values of circuit parameters. Kirchhoff’s Rules are used to analyze all circuits.	Make and justify a quantitative prediction of the effect of a change in values or arrangements of one or two circuit elements on the currents and potential differences in a circuit containing a small number of sources of electromotive force, resistors, capacitors, and switches in series and/or parallel. Make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel. Plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors. Analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff’s loop rule Use conservation of energy principles (Kirchhoff’s loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors Mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy Refine and analyze a scientific question for an experiment using Kirchhoff’s Loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor. Translate between graphical and symbolic representations of	

	experimental data describing relationships among power, current, and potential difference across a resistor Predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff’s junction rule and relate the rule to the law of charge conservation. Determine missing values and direction of electric current in branches of a circuit with resistors and NO capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule. Determine missing values and direction of electric current in branches of a circuit with both resistors and capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule. Determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other branches of the circuit.	

RANDOLPH TOWNSHIP SCHOOL DISTRICT
Curriculum Pacing Chart
AP Physics 2

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
4 weeks	**Unit IV-Electric Circuits** • Electric Current • Ohm's Law: Resistance and Resistors • Resistivity • Capacitance • Storage of Electric Energy • Electric Power • Resistors in Series and Parallel • Kirchhoff's Rules • RC Circuits (steady state only)	**College Board Website:** http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html **Practice Problems:** http://www.learnapphysics.com/apphysics1and2/index.html **Video Presentations:** http://www.bozemanscience.com/ap-physics-2-video-list **Teaching Resources:** http://apphysicsb.homestead.com/teach.html http://prettygoodphysics.wikispaces.com/APP2+Framework

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2
Unit V: Magnetism and Electromagnetic Induction

Enduring Understanding	Essential Questions
Magnetic fields are produced around moving charges.	• How can we describe a magnetic field due to single or multiple sources?
A changing magnetic field can induce a current in a closed conductor.	• How does a magnetic field interact with electric charge in a generator to produce electricity?

Knowledge	Skills	NGSS
Students will know: Magnetism is an inverse square law like gravity and electric field. Magnetic fields curl around long straight wires. These magnetic fields have a simple mathematical relationship. What ferromagnetic materials are and how magnetic fields apply to them. Magnetic fields exert a force on moving charges. These forces obey Newton's three laws.	**Students will be able to:** Distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field) and make claims about the spatial behavior of the fields using qualitative or semi-quantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field. Apply mathematical routines to express the force exerted on a moving charged object by a magnetic field. Create a verbal or visual representation of a magnetic field around a long straight wire or a pair of parallel wires. Describe the orientation of a magnetic dipole placed in a magnetic field in general and the particular cases of a compass in the magnetic field of the Earth and iron filings surrounding a bar magnet. Use the representation of magnetic domains to qualitatively analyze the magnetic behavior of a bar magnet composed of ferromagnetic material. Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5 HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5

	units during the analysis of a situation. Challenge a claim that an object can exert a force on itself. Describe a force as an interaction between two objects and identify both objects for any force. Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. Use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. Analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces.	
Right hand rule and its application to magnetic fields around current carrying wires.	Use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor.	
Mutual inductance and its relationship to current and magnetic fields.	Plan a data collection strategy appropriate to an investigation of the direction of the force on a moving electrically charged object caused by a current in a wire in the context of a specific set of equipment and instruments and analyze the resulting data to arrive at a conclusion. Use representations and models to qualitatively describe the magnetic properties of some materials that can be affected by magnetic properties of other objects in the system	
Practical application of magnetic fields in real world applications. Specifically electric current and simple microphones.	Construct an explanation of the function of a simple electromagnetic device in which an induced emf is produced by a changing magnetic flux through an area defined by a current loop (i.e., a simple microphone or generator) or of the effect on behavior of a device in which an induced emf is	

	produced by a constant magnetic field through a changing area.	

RANDOLPH TOWNSHIP SCHOOL DISTRICT
Curriculum Pacing Chart
AP Physics 2

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
4 weeks	**Unit V-Magnetism and Electromagnetic Induction** • Magnets and Magnetic Fields • Force on an Electric Current in a Magnetic Field • Force on an Electric Charge Moving in a Magnetic Field • Induced EMF • Faraday's Law of Induction; Lenz's Law • EMF Induced in a Moving Conductor	**College Board Website:** **http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html** **Practice Problems:** **http://www.learnapphysics.com/apphysics1and2/index.html** **Video Presentations:** **http://www.bozemanscience.com/ap-physics-2-video-list** **Teaching Resources:** **http://apphysicsb.homestead.com/teach.html** **http://prettygoodphysics.wikispaces.com/APP2+Framework**

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2
Unit VI: Geometrical and Physical Optics

Enduring Understanding	**Essential Questions**
Light is comprised of oscillating electric and magnetic fields which are orthogonal to one another.	• How do mechanical waves and electromagnetic waves propagate?
When light interacts with different medium it can bend	• What causes light to bend as it exits one medium and enters another?
Light can interfere with itself causing bright and dim areas which correspond to constructive and destructive interference.	• How can we use the thin lens (or mirror) equation to predict the size and location of an image?
	• How do the principal rays commonly used in ray diagrams obey the law of reflection for mirrors and the law of refraction for lenses?

Knowledge	**Skills**	**NGSS**
Students will know: Electromagnetic waves comprise of oscillating electric and magnetic fields.	**Students will be able to:** Describe representations of transverse and longitudinal waves Analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation Contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation. Construct an equation relating the wavelength and amplitude of a wave from a graphical representation of the electric or magnetic field value as a function of position at a given time instant and vice versa, or construct an equation relating the frequency or period and amplitude of	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5 HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5

	a wave from a graphical representation of the electric or magnetic field value at a given position as a function of time and vice versa. Make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves. Construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition.	
Analyze and explain the differences and similarities between Polarization, Reflection, and Refraction.	Make claims about the diffraction pattern produced when a wave passes through a small opening, and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave. Qualitatively apply the wave model to quantities that describe the generation of interference patterns to make predictions about interference patterns that form when waves pass through a set of openings whose spacing and widths are small compared to the wavelength of the waves.	
Practical application of Polarization, Reflection and Refraction.	Predict and explain, using representations and models, the ability or inability of waves to transfer energy around corners and behind obstacles in terms of the diffraction property of waves in situations involving various kinds of wave phenomena, including sound and light. Make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed.	

	Make predictions about the locations of object and image relative to the location of a reflecting surface. The prediction should be based on the model of specular reflection with all angles measured relative to the normal to the surface. Describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media. Plan data collection strategies as well as perform data analysis and evaluation of the evidence for finding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell's law). Make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation. Plan data collection strategies, and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from curved spherical mirrors.	
How Images are formed when light impinges on a spherical Mirror and on thin films.	Use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the reflection of light from surfaces.	
What Young's Double Slit experiment was and how diffraction is	Use quantitative and qualitative representations	

related to the interference pattern observed. Light can have interference when coming into contact with thin films.	and models to analyze situations and solve problems about image formation occurring due to the refraction of light through thin lenses. Plan data collection strategies, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses.	

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
4 weeks	**Unit VI-Geometric and Physical Optics** • Electromagnetic Waves • Polarization, Reflection and Refraction • Formation of Images by Spherical Mirrors • Formation of Images by Thin Lenses • Interference - Young's Double Slit Experiment • Diffraction • Interference by Thin Films	**College Board Website:** http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html **Practice Problems:** http://www.learnapphysics.com/apphysics1and2/index.html **Video Presentations:** http://www.bozemanscience.com/ap-physics-2-video-list **Teaching Resources:** http://apphysicsb.homestead.com/teach.html http://prettygoodphysics.wikispaces.com/APP2+Framework

Enduring Understanding	Essential Questions
Radioactive elements decay at predictable rates defined by half-life.	• What is the photoelectric effect?
The electron configuration of electrons determines properties of the element such as bonding, melting and freezing temperature, and conductivity.	• Under what conditions does a particle act like a wave or a wave act like a particle?
Particle wave duality of light and fundamental particles.	• What are the major implications of the theory of relativity?

Knowledge	Skills	NGSS
Students will know: Reasons that Classical Mechanics must be replaced by Special Relativity and Planck's Quantum Hypothesis.	**Students will be able to:** Construct representations of the differences between a fundamental particle and a system composed of fundamental particles and to relate this to the properties and scales of the systems being investigated. Construct representations of the energy-level structure of an electron in an atom and to relate this to the properties and scales of the systems being investigated. Articulate the reasons that the theory of conservation of mass was replaced by the theory of conservation of mass-energy. 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.	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5 HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5

	Articulate the reasons that classical mechanics must be replaced by special relativity to describe the experimental results and theoretical predictions that show that the properties of space and time are not absolute. [Students will be expected to recognize situations in which nonrelativistic classical physics breaks down and to explain how relativity addresses that breakdown, but students will not be expected to know in which of two reference frames a given series of events corresponds to a greater or lesser time interval, or a greater or lesser spatial distance; they will just need to know that observers in the two reference frames can "disagree" about some time and distance intervals.]	
The fundamental particles of nature, the fundamental nuclear forces, and how the relate to one another.	Identify the strong force as the force that is responsible for holding the nucleus together. Apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale.	
Atomic Energy Levels: Emission and Absorption Spectra and their relationship to electron energy levels.	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. Construct or interpret representations of transitions between atomic energy states involving the emission and absorption of photons. [For questions addressing stimulated emission, students will not be expected to recall the details of the process, such as the fact that the emitted photons have the same frequency and phase as the incident photon; but given a	

	representation of the process, students are expected to make inferences such as figuring out from energy conservation that since the atom loses energy in the process, the emitted photons taken together must carry more energy than the incident photon.]	
Conservation Laws: Charge, Nucleon and Mass-Energy.	Apply conservation of mass and conservation of energy concepts to a natural phenomenon and use the equation $E = mc^2$ to make a related calculation. Analyze electric charge conservation for nuclear and elementary particle reactions and make predictions related to such reactions based upon conservation of charge. Support the photon model of radiant energy with evidence provided by the photoelectric effect.	
The Photon Theory of Light, the Photoelectric Effect, and how they relate to photovoltaic cells.	Articulate the evidence supporting the claim that a wave model of matter is appropriate to explain the diffraction of matter interacting with a crystal, given conditions where a particle of matter has momentum corresponding to a de Broglie wavelength smaller than the separation between adjacent atoms in the crystal.	
The wave nature of matter and the de Broglie wavelength.	Make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate. Predict the dependence of major features of a diffraction pattern (e.g., spacing between interference maxima), based upon the particle speed and de Broglie wavelength of electrons in an electron beam interacting with a crystal. (de	

	Broglie wavelength need not be given, so students may need to obtain it.) Use a graphical wave function representation of a particle to predict qualitatively the probability of finding a particle in a specific spatial region. Use a standing wave model in which an electron orbit circumference is an integer multiple of the de Broglie wavelength to give a qualitative explanation that accounts for the existence of specific allowed energy states of an electron in an atom.	
Nuclear Reactions and Decays: fission, fusion, alpha decay, beta decay, or gamma decay.	Predict the number of radioactive nuclei remaining in a sample after a certain period of time, and also predict the missing species (alpha, beta, gamma) in a radioactive decay. 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. Select a model of radiant energy that is appropriate to the spatial or temporal scale of an interaction with matter Nuclei remaining in a sample after a certain period of time, and also predict the missing species (alpha, beta, gamma) in a radioactive decay.	

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
4 weeks	**Unit VII - Quantum Physics, Atomic Physics, and Nuclear Physics** • Reasons that Classical Mechanics must be replaced by Special Relativity • Planck's Quantum Hypothesis • Photon Theory of Light and the Photoelectric Effect • Wave Nature of Matter • Atomic Energy Levels: Emission and Absorption Spectra • Nuclear Reactions and Decays: fission, fusion, alpha decay, beta decay, or gamma decay. • Conservation Laws: Charge, Nucleon and Mass	**College Board Website:** http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html **Practice Problems:** http://www.learnapphysics.com/apphysics1and2/index.html **Video Presentations:** http://www.bozemanscience.com/ap-physics-2-video-list **Teaching Resources:** http://apphysicsb.homestead.com/teach.html http://prettygoodphysics.wikispaces.com/APP2+Framework

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2
Unit VIII: Putting it all together- Final Review

Enduring Understanding	Essential Questions
Physical phenomena typically encapsulate many different aspects of physics and are not restricted to only one topic of physics.	• What steps are required to solve a problem?
	• How can diagrams help you in solving combined problems?

Knowledge	Skills	NGSS
Students will know: The basic concepts of physics covered in this course in preparation for the AP Physics 2 exam.	**Students will be able to:** Solve problems systematically using diagrams and the given variables. Apply their knowledge of physics to solve problems that require principles from different units of physics to be applied at the same time. Use their knowledge of physics concepts to create lab experiments that will allow the determination of the unknown variable.	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5 HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5

RANDOLPH TOWNSHIP SCHOOL DISTRICT
Curriculum Pacing Chart
AP Physics 2

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
5 weeks	**Unit VIII:** Putting it all together- Final Review • **Fluid Statics and Dynamics** • **Laws of Thermodynamics, Ideal Gases, and Kinetic Theory** • **Electrostatics: Electric Force, Electric Field, and Electric Potential** • **Electrical Circuits** • **Magnetism and Electromagnetic Induction** • **Geometric and Physical Optics** • **Quantum Physics, Atomic Physics, and Nuclear Physics**	**College Board Website:** http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html **Practice Problems:** http://www.learnapphysics.com/apphysics1and2/index.html **Video Presentations:** http://www.bozemanscience.com/ap-physics-2-video-list **Teaching Resources:** http://apphysicsb.homestead.com/teach.html http://prettygoodphysics.wikispaces.com/APP2+Framework

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2
Unit IX: Extensions and Enrichment

Enduring Understanding	Essential Questions
Charge can be neither created nor destroyed – only transferred	• How does an understanding of electrical phenomena impact and inform our daily lives?
There are connections between electricity and magnetism that impact our lives on a daily basis.	• How is the connection between electricity and magnetism used in our daily lives?
Modern technology is becoming more compact and complicated due to the advances in physics.	• How does modern physics impact our lives?
Much of the research done in physics does not have a specific application in mind when it is first discussed. It is only after a physics discovery that applications are discovered.	• How does cutting edge research in physics impact society?

Knowledge	Skills	NGSS
Students will know: At least one specific real world application of physics. How knowledge of physics is helpful (and sometimes necessary) for utilizing and improving technology.	**Students will be able to:** Demonstrate in writing a thorough understanding of the application of skills and concepts in physics to the real world problems via assignments. Research a physics related technology topic. Prepare and deliver a presentation on the chosen topic and the impact of physics on this topic. Properly cite sources for written material and other media used in presentation. Prepare an authentic lab for your classmates to do that will illustrate one or more of the physics concepts which are incorporated in the design and utilization of the technology topic selected.	HS-PS1-1 HS-PS1-2 HS-PS1-3 HS-PS1-4 HS-PS1-5 HS-PS2-1 HS-PS2-2 HS-PS2-3 HS-PS2-4 HS-PS2-5 HS-PS3-1 HS-PS3-2 HS-PS3-3 HS-PS3-4 HS-PS3-5 HS-PS4-1 HS-PS4-2 HS-PS4-3 HS-PS4-4 HS-PS4-5

SUGGESTED TIME ALLOTMENT	CONTENT-UNIT OF STUDY	SUPPLEMENTAL UNIT RESOURCES
3 weeks	**Unit IX:** Extensions and Enrichment • **Application of all the previously studied units topics.**	**College Board Website:** http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html **Practice Problems:** http://www.learnapphysics.com/apphysics1and2/index.html **Video Presentations:** http://www.bozemanscience.com/ap-physics-2-video-list **Teaching Resources:** http://apphysicsb.homestead.com/teach.html http://prettygoodphysics.wikispaces.com/APP2+Framework

Appendix A

Resources:

Textbook:

Giancoli. *Physics 5th Edition*. New Jersey: Prentice Hall, 1998.

Technology:

- Vernier logger pro software and data collection system
- Spreadsheet software such as Excel
- Word processor software such as Word
- Presentation software such as PowerPoint
- Graphing calculator

Web addresses:

University of Colorado Virtual Labs: http://phet.colorado.edu/en/simulations/category/physics

Support materials for teachers of AP Physics 2 :

http://www.aplusphysics.com/ http://prettygoodphysics.wikispaces.com/ http://www.siprep.org/page.cfm?p=890&pback=1475
http://matterandinteractions.org/
http://relate.mit.edu/ http://modeling.asu.edu/Curriculum.html
http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/225113.html
http://www.learnapphysics.com/apphysics1and2/index.html
http://www.bozemanscience.com/ap-physics-2-video-list
http://apphysicsb.homestead.com/teach.html
http://prettygoodphysics.wikispaces.com/APP2+Framework

RANDOLPH TOWNSHIP SCHOOL DISTRICT
AP Physics 2

Appendix B

ASSESSMENT:

- Quiz
- Test
- Lab Reports
- Group Projects
- Homework
- Online Resources

Appendix C

Opportunities exist for interdisciplinary units with courses such as Calculus, and various science electives.

Appendix D

It is assumed that students taking AP Physics 2 have successfully completed AP Physics 1 prior to enrolling in the class. It is also assumed that students taking AP Physics 2 have completed or are currently enrolled in Pre-Calculus.