PHYSICS
GRADES 9-12

EWING PUBLIC SCHOOLS
2099 Pennington Road
Ewing, NJ 08618

Board Approval Date: September 19, 2022 Michael Nitti
Produced by: Craig Halpern Superintendent

In accordance with The Ewing Public Schools' Policy 2230, Course Guides, this curriculum has been reviewed and found to be in compliance with all policies and all affirmative action criteria.

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Course Description and Rationale

Physics, as one of the primary branches of science, focuses on the interactions of matter and energy on both the macroscopic and microscopic level. The work of physicists has always been to explain natural phenomena in terms of the most basic models. The laws of physics describe our universe from the tiniest subatomic particle to the largest galaxy. The theories of yesterday inspire the experiments of today, which then evolve into the practical applications of tomorrow.

The Next Generation Science Standards (NGSS) encompass this through three dimensions of student learning. Students are expected to demonstrate their conceptual understanding of the disciplinary core ideas through the use of the science and engineering practices and by making connections to cross-cutting concepts, such as cause and effect relationships, that appear across all the science disciplines.

The domain of physics spans time from the 'Big Bang' up to the present and future of the universe, from the scale of subatomic particles to intergalactic space, from clusters of atoms cooled with lasers to 10^{-12} Kelvin to the 10^{8} Kelvin interior of suns, to black holes, neutron stars, snowflakes, violins, ocean tides, earthquakes, planetary rings, nuclear fission…the list is endless!

In our ordinary life, we take for granted many technical marvels that ride on this fundamental knowledge of the ways of nature. Fuel cells, lasers, computer chips, CDs and DVDs, cell phones, nuclear power plants and solar cells are but a few examples of modern-day technology that owe their existence, in part, to the original work of physicists.

This course will follow a block semester schedule, with students meeting daily for 88 minutes. The course will take an investigative approach to exploring the core concepts of a first year physics course such as kinematics, dynamics, electricity, magnetism and optics. Other topics, such as the physics of the 20th and 21st century, will be covered, if time allows. The number one priority is for students to learn how to think critically, in a scientific manner, about the physical environment.

Students will use the following eight NGSS Science and Engineering Practices to demonstrate understanding of the disciplinary core ideas and develop critical thinking skills:

1. Asking questions (science) and defining problems (engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using math and computational thinking
6. Constructing explanations (science) and designing solutions (engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The following seven crosscutting concepts support the development of a deeper understanding of the disciplinary core ideas:

1. Patterns
2. Cause and effect: mechanism and explanation
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter: flows, cycles and conservation
6. Structure and function
7. Stability and change

Physics at Ewing High School incorporates problem-solving, hands-on activities, experiments and projects. Students are expected to plan and conduct investigations, analyze data and use math to support claims and apply scientific ideas to solve design problems in order to develop an understanding of ideas. These ideas relate to why some objects keep moving, some objects attract to each other, and others repel from each other, as well as how energy is conserved and transferred. Students are also able to apply science and engineering ideas to design, evaluate and refine a device that minimizes the force on a macroscopic object during a collision, transform energy as well as use electric currents to make magnetic fields.

The crosscutting concepts of patterns, cause and effect, and systems and systems models are called out as organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in planning and conducting investigations, developing and using models, analyzing data and using math to support claims, and applying scientific ideas to solve design problems and to use these practices to demonstrate understanding of the core ideas.

Use of state-of-the-art physics equipment is specified, such as data collection probes with computers and/or interfaces. This course also includes real-world applications of the physics concepts, with the goal of helping students to become informed citizens who are not intimidated by new and emerging technologies.

Career Readiness, Life Literacies, and Key Skills

During this course, students will work on developing, to an age appropriate level, the following Career Readiness, Life Literacies, and Key Skills:

Disciplinary Concepts:

- Career Awareness and Planning
  - An individual's strengths, lifestyle goals, choices, and interests affect employment and income.
  - Developing and implementing an action plan is an essential step for achieving one's personal and professional goals.
  - Communication skills and responsible behavior in addition to education, experience, certifications, and skills are all factors that affect employment and income.

- Creativity and Innovation
  - Gathering and evaluating knowledge and information from a variety of sources, including global perspectives, fosters creativity and innovative thinking.
- Critical Thinking and Problem-solving
  - Multiple solutions exist to solve a problem.
  - An essential aspect of problem solving is being able to self-reflect on why possible solutions for solving problems were or were not successful.
- Digital Citizenship
  - Detailed examples exist to illustrate crediting others when incorporating their digital artifacts in one's own work.
  - Digital communities are used by Individuals to share information, organize, and engage around issues and topics of interest.
  - Digital technology and data can be leveraged by communities to address effects of climate change.
- Global and Cultural Awareness
  - Awareness of and appreciation for cultural differences is critical to avoid barriers to productive and positive interaction.
- Information and Media Literacy
  - Increases in the quantity of information available through electronic means have heightened the need to check sources for possible distortion, exaggeration, or misrepresentation.

- Digital tools make it possible to analyze and interpret data, including text, images, and sound. These tools allow for broad concepts and data to be more effectively communicated.
- Sources of information are evaluated for accuracy and relevance when considering the use of information.
- There are ethical and unethical uses of information and media.

- Technology Literacy
  - Some digital tools are appropriate for gathering, organizing, analyzing, and presenting information, while other types of digital tools are appropriate for creating text, visualizations, models, and communicating with others. • Digital tools allow for remote collaboration and rapid sharing of ideas unrestricted by geographic location or time.

Technology Integration

Computer Science and Design Thinking

During this course, students will work on developing, to an age appropriate level, the following Computer Science and Design Thinking Skills:

Disciplinary Concepts and Core Ideas:

- Data & Analysis
  - People use digital devices and tools to automate the collection, use, and transformation of data.
  - The manner in which data is collected and transformed is influenced by the type of digital device(s) available and the intended use of the data.
  - Data is represented in many formats. Software tools translate the low-level representation of bits into a form understandable by individuals. Data is organized and accessible based on the application used to store it.
  - The purpose of cleaning data is to remove errors and make it easier for computers to process.
  - Computer models can be used to simulate events, examine theories and inferences, or make predictions.
- Engineering Design
  - Engineering design is a systematic, creative and iterative process used to address local and global problems.
  - The process includes generating ideas, choosing the best solution, and making, testing, and redesigning models or prototypes.

        - Engineering design requirements and specifications involve making trade-offs between competing requirements and desired design features.
    - Interaction of Technology and Humans
        - Economic, political, social, and cultural aspects of society drive development of new technological products, processes, and systems.
        - Technology interacts with society, sometimes bringing about changes in a society's economy, politics, and culture, and often leading to the creation of new needs and wants.
        - New needs and wants may create strains on local economies and workforces.
        - Improvements in technology are intended to make the completion of tasks easier, safer, and/or more efficient.
    - Nature of Technology
        - Technology advances through the processes of innovation and invention which relies upon the imaginative and inventive nature of people.
        - Sometimes a technology developed for one purpose is adapted to serve other purposes.
        - Engineers use a systematic process of creating or modifying technologies that is fueled and constrained by physical laws, cultural norms, and economic resources. Scientists use systematic investigation to understand the natural world.
    - Effects of Technology on the Natural World
        - Resources need to be utilized wisely to have positive effects on the environment and society.
- Some technological decisions involve trade-offs between environmental and economic needs, while others have positive effects for both the economy and environment.

ELA Integration:

- **NJSLS.RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- **NJSLS.RST.9-10.4** Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grade level texts and topics.
- **NJSLS.RST.9-10.5** Analyze the structure of the relationships among concepts in a text, including relationships among key terms.
- **NJSLS.RST.9-10.6** Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

- **NJSLS.RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- **NJSLS.WHST.9-10.1.E -** Provide a concluding statement or section that follows from or supports the argument presented.
- **NJSLS.WHST.9-10.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (Honors, Level 1)
- **NJSLS.WHST.9-10.2a** Introduce a topic and organize ideas, concepts and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables) and multimedia when useful to aiding comprehension.
- **NJSLS.WHST.9-10.2.d** Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.
- **NJSLS.WHST.9-10.9** Draw evidence from informational texts to support analysis, reflection and research.

Math Integration:

- **NJSLS.MP.6** Mathematically proficient students try to communicate precisely to others.
- **NJSLS.HS.A-CED.A.1** Create equations and inequalities in one variable and use them to solve problems.
- **NJSLS.HS.A-CED.A.2** Create equations in two or more variables to represent relationships between quantities.
- **NJSLS.HS.A.CED.A.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- **NJSLS.HS.A.REI.A.1** Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.
- **NJSLS.HSA.REI.B.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **NJSLS.HS.A-SSE.A.1** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **NJSLS.HS.A-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **NJSLS.HS.N.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- **NJSLS.HS.N.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Unit 1: One-Dimensional Kinematics (12 Days)

Why Is This Unit Important?

Motion is common to most of our everyday experiences. This is formalized mathematically in kinematics, which is the study of how objects move. Students should be reminded that the types of motion are highly idealized and may seem to have little to do with the real world as we observe it. However it is essential that students first investigate these simple and idealized motions and their descriptions to obtain a firm understanding of the basis of kinematics. Once this goal has been achieved, they are in a position to apply their knowledge to the more complex real world situations.

Disciplinary Core Ideas:

HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration. Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

Science and Engineering Practices:

- Asking questions about objects in motion
- Planning and carrying out investigations about moving objects
- Analyzing and interpreting data for a moving object
- Using Mathematics and computational thinking to describe an accelerating object
- Constructing Explanations and Designing Solutions to the inattentive driver problem
- Obtaining, Evaluating, and Communicating information about a falling object in writing a formal lab report

Cross Cutting Concepts:

- Patterns in data presentations are used to construct an understanding of motion
- Cause and effect relationship between acceleration and changing motion will be examined.
- Standard units are used to measure and describe physical quantities such as displacement and time.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.

Enduring Understandings:

- Relate the positions, velocities and accelerations of discrete objects.
- Describe the motion of an object using words, algebraically or graphically.
- Demonstrate an understanding of the relationships between time, displacement and velocity through applications of these relationships to problems in everyday one-dimensional situations.
- Apply the principles learned in kinematics to situations of objects in free fall, including non-zero initial vertical velocities.

Essential Questions:

- How can evidence be used to develop models describing the physical world?
- How can graphical analysis be used to develop models describing the physical world?
- How can fundamental kinematics principles be used to predict what will happen in a uniformly accelerating system? In any system?
- How do you describe the motion of a particle?

Acquired Knowledge:

- Analyze the motion of an object to determine its acceleration.
- Use provided data to calculate the acceleration of an object.
- Translate between different representations of the motion of objects: verbal and/or written descriptions, diagrams, data tables, graphical representations (position versus time graphs and instantaneous velocity versus time graphs) and mathematical representations.

Acquired Skills:

- Measure the displacement, velocity and acceleration of an object in one dimensional motion.
- Properly plot and format graphs comparing displacement, velocity or acceleration as functions of time.
- Determine the equation of a graph comparing displacement, velocity or acceleration as functions of time.
- Determine the displacement, velocity and acceleration of a moving object from the slope of and/or area under the appropriate graph.
- Straighten a parabolic graph into a linear graph.

- Account for error in measurement and its propagation as raw data is manipulated.
- Write a properly formatted lab report indicating a thorough understanding of the underlying physics principles.
- Solve one dimensional kinematics problems with 6 possible variables.

Assessments:

Formative Assessment:

Daily quizzes are given to assess the students' learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

A benchmark quiz is given to assess the student's mastery before the end of the unit.

All physics tests are given in three parts: a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Graph Matching Activity: One of the most effective methods of describing motion is to plot graphs of distance, velocity, and acceleration vs. time. From such a graphical representation, it is possible to determine in what direction an object is going, how fast it is moving, how far it traveled, and whether it is speeding up or slowing down. In this experiment, students will use a Motion Detector to determine this information by plotting a real time graph of their motion as they move across the classroom. Students will learn the basic concepts of kinematics by graphically and verbally describing their motion as they move across the room matching a position vs. time graph.

Free Fall Lab: Students organize data which represents the motion of an object, its position, initial velocity, final velocity and its acceleration. Students will then use tools, technologies and/or models to analyze the data and identify relationships within the datasets, to show that a change in an object's instantaneous velocity is the same in each successive unit time interval, the object has constant acceleration.

Kinematics Problem Set: Using the given mathematical representations, students identify and describe the relationships between position, velocity and acceleration for a moving object.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Graph matching
- Constant motion vehicle

In-Class Activities and Laboratory Experiences:

- Introduce students to motion by having them produce *specified graphs of simple* motion*s by walking towards or away from* motion detectors
- Vectorville Lab (Distance vs. Displacement)
- Measure the motion of objects and graphically analyze the data:
  - Analyze d vs. t graphs (slope and trends)
  - Analyze v vs. t graphs (slope and trends)
  - Analyze a vs. t graphs
- Derive and apply kinematic equations *to linear motion*
- Ticker tape diagram analysis
- Online Lab: The Moving Man (Constant Velocity vs. Acceleration)
- Measure 'g' *using* spark timers, photogates, motion detector, *or* stroboscopic photography (Assessment)

Closure and Reflection Activities:

- Lab: Stopping Your Car (Tying change in velocity to Newton's Laws)
- Challenge Problem: The Inattentive Driver

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Ticker timer
- Motion sensor
- Labquest or science workshop interface with a computer
- Meter sticks
- Stopwatches
- Various graphs of motion
- Index cards
- Tape

Formative Assessments

- Observation
- Homework
- Class work
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- Students may think that a change can occur at one point in time.
- Students may think that a measurement made at a specific time is equivalent to a measurement made over a period of time.
- Students may think that position and motion are absolute and need no reference frames.
- Students may not realize the origin on a position versus time graph refers to the origin of the coordinate system.
- Students may think that all positions must be positive numbers.
- Students may think that distance and displacement are always equal quantities.
- Students may think that all paths must be straight.
- Students may think that all velocities are constant.
- Students may think that velocity vs. time graphs indicate the position of an object.
- Students may think that velocity can only be positive and therefore is the same concept as speed.
- Students may think that velocity depends on the origin of a coordinate system.
- Students may think that two objects at the same position must have the same velocity.

- Students may think that the intercept on a velocity vs. time graph indicates where an object started.
- Students may think that the acceleration of a falling object depends upon its mass.
- Students may think that freely falling bodies can only move downward.
- Students may think that there is no gravity in a vacuum.
- Students may think that gravity only acts on things when they are falling.
- Students may think that acceleration and velocity are always in the same direction.
- Students may think that velocity is a force.
- Students may think that if velocity is zero, then acceleration must be zero too.

Technology Connections:
Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- Walking man: http://phet.colorado.edu/simulations/sims.php?sim=The_Moving_Man
- Maze Game: http://phet.colorado.edu/simulations/sims.php?sim=Maze_Game
- Motion with Constant Acceleration: http://www.walter-fendt.de/ph14e/acceleration.htm
- Apply the Brakes: http://www.surendranath.org/Applets/Kinematics/Brake/BrakeApplet.html
- Catch Up: http://www.surendranath.org/Applets/Kinematics/Catc
- hUp/CatchUpApplet.html
- Reaction Time: http://www.phy.ntnu.edu.tw/~hwang/Reaction/reactionTime.html
- Reaction Time and Car Accident: http://www.phy.ntnu.edu.tw/~hwang/Reaction/reactionTime.html
- Traffic Light System: http://www.phy.ntnu.edu.tw/~hwang/trafficControl/trafficControl.html
- Racing Balls: http://www.phy.ntnu.edu.tw/~hwang/racingBall/racingBall.html
- Displacement, Velocity, Acceleration: http://www.phy.ntnu.edu.tw/~hwang/xva/xva.html
- Graphs and Tracks: http://graphsandtracks.com

Resources:

- Scientific Calculator
- Motion Sensor
- Photogate
- Computer with word processor, spreadsheet, internet access
- Labquest or science workshop interface with a computer

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Solve constant acceleration problems with non-zero initial conditions.

Supplement:

- Teacher-designed and Concept Development worksheets from the Conceptual Physics program.
- Students are responsible for only a analysis of the data and to draw conclusions from the major assessment.

Unit 2: Newton's Laws of Motion (10 Days)

Why Is This Unit Important?

Our understandings of ideas of forces are powerful tools that can be used to describe and predict the phenomena of motion. The revolutionary insights of Sir Isaac Newton into the connection between movement and force have laid the foundations for our present understanding of motion. In our everyday context, most interactions and many common phenomena can be explained by considering specific forces. By considering the manifestations of the forces, students can reflect on such topics as such as motion, simple collisions and structures and materials—and extend their experience by considering topics such as satellite motion, nuclear energy powering the sun and radioactive decay.

Disciplinary Core Ideas:

HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration.

HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Science and Engineering Practices:

- Asking questions about objects that are accelerating
- Planning and carrying out investigations about objects experiencing a net force
- Developing and using Models to describe objects experiencing at least one force
- Analyzing and interpreting data for an accelerating object
- Using mathematics and computational thinking to describe an object experiencing a force
- Engaging in argument from evidence about the nature of friction
- Obtaining, Evaluating, and Communicating information in writing a formal lab report on the modified Atwood machine while investigating Newton's second law.

Cross Cutting Concepts:

- Patterns in the data collected lead to an understanding of Newton's 2^{nd} law of motion.
- Cause and effect relationship between force and acceleration will be explored
- Standard units are used to measure and describe physical quantities such as mass and force.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial and boundary conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Enduring Understandings:

It is expected that students will:

- Apply Newton's laws of motion to explain inertia; the relationships among force, mass and acceleration; and the interaction of forces between two objects.
- Analyze forces acting on an object utilizing free body diagrams to identify the net force.
- Apply the concepts of dynamics to analyze one-dimensional situations.
- Solve problems involving Newton's laws and frictional forces in more complex situations.
- Distinguish between relevant and irrelevant information in situations involving forces.
- Demonstrate an ability to describe and apply the concept of friction to everyday situations and determine the factors that affect it.

Essential Questions:

- How can evidence be used to develop models describing the physical world?
- How can graphical analysis be used to develop models describing the physical world?
- How can fundamental kinematics principles be used to predict what will happen in a uniformly accelerating system? In any system?
- What is the meaning of equilibrium for a body?
- What causes changes in motion of an object?
- How does running a controlled experiment enable us to isolate the effects of multivariable physical systems?
- What is the difference between the forces of kinetic and static friction and how could they be measured?

Acquired Knowledge:

- Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction and units during the analysis of a situation.
- Understand and apply the relationship between the net force exerted on an object, its inertial mass and its acceleration to a variety of situations.
- Represent and describe the two types of forces that a surface can exert on an object: a normal force and a friction force parallel to the surface and dependent on the normal force and textures of the two surfaces.
- Explain contact forces (tension, friction, normal) as arising from interatomic electric forces and their certain directions
- Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Acquired Skills:

- state a formal definition of Newton's First Law of Motion.
- recognize that a system at rest is also at "equilibrium".
- determine the weight of an object from its mass and the gravitational force constant, g.
- draw a "Free Body" diagram of an object at equilibrium.
- make freebody diagrams correctly identifying all of the forces acting on an object or system at equilibrium.
- use freebody diagrams to set up equations describing systems at equilibrium.
- use the equations derived from the freebody diagrams to solve problems involving systems at equilibrium.
- gain an appreciation of the causes of the force of friction.
- measure the frictional force between two surfaces.
- measure and calculate the frictional force between two surfaces.
- understand the difference between static and kinetic friction.
- explain how various factors affect the frictional force.
- solve Newton's 2nd Law problems involving the force of friction.
- become familiar with the meaning of Newton's 2nd Law of motion.
- relate the acceleration of a system to the magnitude of the force being applied and the mass of the system being accelerated.
- use Newton's 2nd Law to solve problems involving linearly accelerating systems.
- to concisely state Newton's 3rd Law.
- understand the implications of Newton's 3rd Law of motion.
- Write a properly formatted lab report indicating a thorough understanding of the underlying physics principles.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Newton's Second Law Lab: Students organize data that represent the net force on a macroscopic object, its mass (which is held constant) and its acceleration (e.g., via tables, graphs, charts, vector drawings). Students use tools, technologies, and/or models to analyze the data and identify relationships within the datasets, to show that a more massive object experiencing the same net force as a less massive object has a smaller acceleration and a larger net force on a given object produces a correspondingly larger acceleration.

Friction Prompt: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials, using the example of friction and a dragster.

Dynamics Problem Set: Using the given mathematical representations, students identify and describe how net force can change the motion of object or system of objects. The students look at all of Newton's laws of motion with a special focus on the second law. Students also represent forces in diagrams using appropriate labels that represent the magnitude and direction of each force.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Bowling ball inertia activity
- Demonstration of forces in action

In-Class Activities and Laboratory Experiences:

- Demonstrations Inertia to challenge student predictions
- Perform Newton's Second Law Labs (Assessment):
  - Perform Smart Pulley, Atwood Machine or Air track experiment with photogates and/or motion sensors
  - Design an experiment with available equipment (motion sensors, force sensor, carts and pulleys) to demonstrate F = ma
- Draw Free Body Diagrams and use them in to solve force problems
- Demonstrate static equilibrium with pulleys and weights to analyze the forces involved
- Study forces in various non-static cases using a spring scale or a force probe and interface
- Perform a Friction Lab:
  - Using different surfaces, measure the static and kinetic coefficients of friction using a spring scale or a force probe attached to an interface
- Write a paper describing the intermolecular interactions that cause friction (Assessment)

Closure and Reflection Activities:

- Momentum and Football (Tying Newton's Laws to momentum)
- Video: Sports Science
- Video: MythBusters
- Challenge Problem: Various Atwood and Modified Atwood Machine Problems

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific Calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Ticker timer
- Motion sensor
- Force sensor
- Labquest or science workshop interface with a computer
- Pasco tracks and carts
- Various masses
- Bowling ball and Brooms
- Friction blocks
- Various surfaces to put friction blocks on
- Teacher made worksheets
- Football measurements
- Videos (see above)

Formative Assessments

- Observation
- Homework
- Class work
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions:

- When two stationary objects push on each other, the "stronger" one exerts the larger force.
- When two objects push on each other, the harder one pushes with a greater force than the softer one.
- Gravity is the only natural force.
- All forces are unique.
- Gravity is the strongest force.
- All forces are equally effective over all ranges.
- All forces have to be contact forces.
- A force is required for motion.
- No force is required to move objects in space.
- All moving objects eventually stop.
- Inertia is a force that keeps things moving.
- Mass and weight are the same thing.
- A free-body diagram includes all forces on all bodies.
- A system can only be defined to include objects that are in contact.
- An internal force can propel an object forward.
- Action and reaction forces are on the same body.
- Newton's Third Law contradicts the Second Law.
- Action and reaction forces cancel each other.
- The reason that a horse can pull a cart is because the horse pulls harder on the cart than the cart pulls on the horse.
- The acceleration in Newton's Second Law and the acceleration studied in kinematics are different.
- Net force can always be determined by adding the magnitudes of all the forces.
- Friction cannot act in the direction of motion.
- The force of friction depends only on the smoothness of the surfaces.
- Surfaces can be made smooth enough to eliminate friction altogether.
- An object eventually falls at a constant speed because that is the natural motion of falling objects.
- "ma" is a force.

Interdisciplinary Connections:

ELA:

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- Newton's 2nd Law: http://www.walter-fendt.de/ph14e/n2law.htm
- Forces in 1D: http://phet.colorado.edu/simulations/sims.php?sim=Forces_in_1_Dimension
- Forces and motion: http://phet.colorado.edu/en/simulation/forces-and-motion
- Inclined Plane: http://www.walter-fendt.de/ph14e/inclplane.htm
- Inclined Plane/Friction: http://jersey.uoregon.edu/vlab/friction/Friction_plugin.html
- Freebody: http://www.physics.uoguelph.ca/tutorials/fbd/FBD.htm
- Friction: http://phet.colorado.edu/simulations/sims.php?sim=Friction
- Inclined Plane/Friction: http://jersey.uoregon.edu/vlab/friction/Friction_plugin.html
- Frictional Force: http://www.phy.ntnu.edu.tw/~hwang/friction/friction.html
- Parachute and Terminal Velocity: https://concord.org/stem-resources/parachute-and-terminal-velocity

Resources:

- Scientific calculator
- Motion sensor
- Photogate
- Computer with word processor, spreadsheet, internet access
- Labquest or science workshop interface with a computer

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:
- Solve problems involving forces on an incline.

Supplement:
- Teacher designed and Concept Development worksheets from the Conceptual Physics program.
- Students are responsible for only a analysis of the data and to draw conclusions from the major assessment.

Unit 3: Momentum (8 Days)

Why Is This Unit Important?

The universe has many remarkable qualities, among them a rather beautiful law: the total amount of motion in the universe balances out … always. This law only makes sense if we measure ‘motion’ in a specific way, as the product of mass and velocity. This product, called momentum, can be exchanged from one object to another in a collision. How quickly the momentum is exchanged over time is determined by the forces involved in the collision. The beauty of these laws is that they allow us to look at the world from a different perspective than before.

Disciplinary Core Ideas:

HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

HS-PS2-3 Apply scientific and engineering ideas to design, evaluate and refine a device that minimizes the force on a macroscopic object during a collision.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics, as well as possible social, cultural and environmental impacts.

Science and Engineering Practices:

- Asking questions about objects that are moving
- Planning and carrying out investigations about objects experiencing a collision or explosion
- Analyzing and interpreting data for objects undergoing a collision or explosion
- Developing and using models to explain momentum and its conservation
- Using mathematics and computational thinking to describe the conservation of momentum
- Designing solutions to minimize force during a collision
- Obtaining, Evaluating, and Communicating Information to write a summary report about how Newton’s laws relate to momentum and its conservation.

Cross Cutting Concepts:

- Patterns in data lead to an understanding of impulse momentum and momentum conservation
- Cause and effect relationship between impulse and momentum will be explored
- Standard units are used to measure and describe quantities such as momentum and impulse.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Enduring Understandings:

It is expected that students will:

- Understand that the total momentum of an isolated system does not change (Law of Conservation of Momentum). Another way of stating this is that the initial momentum of an isolated system is equal to its final momentum.
- Understand that momentum is a vector quantity. Its direction is always the same as the velocity. Impulse is a vector quantity acting in the same direction as the force which caused the impulse.
- Demonstrate an ability to describe and apply the concepts of momentum and impulse to everyday examples of collisions or explosions.

Essential Questions:

- How can the principle of momentum conservation be used to account for the interactions of two or more bodies?
- What implications does vector nature of linear momentum have on its application to physical systems consisting of two or more bodies?

Acquired Knowledge:

- Devise a model that would explain an explosion.
- Implement Newton's Second and Third Laws to analyze scenarios in which objects of equal or unequal mass interact with one another.
- Create a mathematical model of momentum of a moving body.
- Develop a model that distinguishes between elastic and inelastic collisions.
- Predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- Apply the Law of Conservation of Linear Momentum to problems involving colliding bodies.
- Apply scientific and engineering ideas to design, evaluate and refine a device that minimizes the force on a macroscopic object during a collision.

Acquired Skills:

- calculate the momentum of a moving object.
- calculate momentum using previously learned skills: kinematics, and Newton's Laws
- make appropriate diagrams describing the conservation of linear momentum.
- use the concept of linear momentum to solve problems involving the collision of two bodies in one dimension.
- measure and calculate the momentums of colliding object both before and after an interaction.
- use momentum conservation to predict the velocities of two colliding objects after they have interacted elastically, inelastically and in explosions.
- discriminate among elastic collisions, inelastic collisions and explosions.
- break momentum vectors into x, y and z components.
- solve momentum conservation problems involving two dimensions.
- demonstrate the ability to solve problems involving both one and two-dimensional momentum conservation.
- calculate the final velocity of a rocket from the exhaust velocity and mass ratio of a rocket in outer space.
- Write a properly formatted lab report indicating a thorough understanding of the underlying physics principles.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Conservation of Momentum Lab: Students clearly define the system of the two interacting objects that is represented mathematically by using a mathematical model. Students identify and describe the momentum of each object in the system as the product of its mass and its velocity. Students then use the mathematical representations to model and describe the total momentum of the system by calculating the vector sum of momenta of the two objects in the system. Students then use the analysis of motion of the objects to show that the total momentum of a system of two interacting objects is constant if there is no net force on the system. Students also identify that the analysis of the momentum of each object in the system indicates that any change in momentum of one object is balanced by a change in the momentum of the other object, so that the total momentum is constant.

Egg/Tile Drop: Students design a device that minimizes the force on a macroscopic object during a collision.

Impulse and Momentum Problem Set: Using the given mathematical representations, students identify and describe how net force can change the motion of object or system of objects. The students look at momentum and its conservation and how forces can change the momentum of one object.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Conservation of momentum lab/activity
- Impulse momentum lab/activity

In-Class Activities and Laboratory Experiences:

- Perform Momentum Labs using air tracks, dynamics tracks and spring-loaded carts with photogates/motion sensors to verify that momentum is conserved in two-body interactions (Assessment)
- Perform Impulse momentum lab using tracks, sensor carts and a foam bumper to determine that the area under a force-time graph to stop a cart is the same as its change in momentum.
- Solve Problems using Conservation of Momentum and Impulse
- Researching different aspects of automobile design, car accidents and safety
- Restraint lab/activity
- Egg Drop Contest (Assessment)

Closure and Reflection Activities:

- Video: Understanding Car Crashes, It's Basic Physics
- Challenge problem: The Drive Home

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Ticker timer
- Motion sensor
- Force sensor
- Labquest or science workshop interface with a computer
- Pasco tracks and carts
- Various masses
- Video (see above)

Formative Assessments

- Observation
- Homework
- Class workall
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Engineering Design projects
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- Momentum applies only to collisions.
- Direction of momentum is insignificant.
- Moving masses in space do not have momentum.
- Momentum and kinetic energy are the same thing.

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- Collision Lab: https://phet.colorado.edu/sims/collision-lab/collision-lab_en.html
- Exploding Blocks: http://canu.ucalgary.ca/map/content/force/newton3/exploding_blocks/applet.html
- Elastic and Inelastic Collision: http://www.walter-fendt.de/ph14e/collision.htm
- Newton's Cradle: http://www.walter-fendt.de/ph14e/ncradle.htm
- Collisions in 1D and 2D: http://www.surendranath.org/Applets/Dynamics/Collisions/CollisionApplet.html

- Billiards and Physics:
  http://www.phy.ntnu.edu.tw/~hwang/billiards/billiards.html
- Conservation of Momentum (1-D collisions):
  http://www.phy.ntnu.edu.tw/~hwang/collision1D/collision1D.html
- 2-D collisions:
  http://www.phy.ntnu.edu.tw/~hwang/collision2D/collision2D.html

Resources:

- Scientific calculator
- Motion sensor
- Photogate
- Force sensor
- Computer with word processor, spreadsheet, internet access
- Labquest or science workshop interface with a computer

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Solve two-dimensional collision problems.

Supplement:

- Teacher designed and Concept Development worksheets from the Conceptual Physics program.
- Students are responsible for only a analysis of the data and to draw conclusions from the major assessment.

Unit 4: Circular Motion (6 Days)

Why Is This Unit Important?

It really wasn't until the 1500s that people began to believe that the Earth rotates on its own axis. Until then, the rate of rotation of objects was of little consequence. Today, rotation and its measurement is of fundamental importance to society, whether it is the rotation of microwave carousels, DVDs, car tires, engines, sewing machines, nuclei or orbiting satellites. In this section, we will be looking at circular motion, that is, motion in a circle.

Disciplinary Core Ideas:

HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass and its acceleration.

Science and Engineering Practices:

- Asking questions about objects that are moving in a circle
- Planning and carrying out investigations about objects moving in a circle
- Developing and using Models to describe objects experiencing centripetal force
- Analyzing and interpreting data for an object moving in a circle
- Using mathematics and computational thinking to describe an object experiencing centripetal force
- Obtaining, Evaluating, and Communicating Information to write a lab report to how mass, radius and velocity relate to centripetal force.

Cross Cutting Concepts:

- Patterns in the data lead to an understanding of what factors effect centripetal force
- Cause and effect relationship between centripetal force and velocity will be explored
- Standard units are used to measure and describe physical quantities such as mass, velocity and force.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Enduring Understandings:

It is expected that students will:

- Circular motion is a type of 2D motion which is caused by a centripetal force.
- Centripetal Force is a net force, resulting from the other forces acting on the object.
- Angular speed is related to linear (tangential) speed for an object traveling on a circular path.

Essential Questions:

- How does inertia relate to an object traveling in a circular path?

- Describe the direction of the velocity, acceleration and net force for an object that moves in a circle at a constant speed.
- What is the relationship between the velocity of an object on a circular path and the net force? the relationship between the radius of the path and the net force?
- What is the relationship between rotational speed and tangential speed for an object on a circular path?

Acquired Knowledge:

- Apply Newton's Second Law to objects in uniform circular motion to derive Fnet = mv^2/r and use this model to predict unknown quantities when forces such as friction, tension and normal force result in uniform circular motion.
- Relate the period, orbital radius and speed of an object in a circular orbit and use the model speed = $2\pi R/T$ to predict unknown quantities.

Acquired Skills:

- Apply the kinematic relationships to an angular motion.
- Solve problems involving Newton's 2nd Law and centripetal acceleration.
- Apply the dynamics equations to an object traveling in a horizontal or vertical circle.
- Determine the direction and magnitude of the centripetal acceleration of an object following a circular path.
- Run a controlled experiment involving at least three independent variables.
- Determine the mathematical relationship between a dependent variable and the corresponding independent variable from the shape of the applicable graph.
- Write a properly formatted lab report indicating a thorough understanding of the underlying physics principles.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Centripetal Force Lab: Students use the data as empirical evidence to distinguish between causal and correlation relationships linking force, mass, velocity, and radius for an object traveling in a circle.

Circular Motion Problem Set: Using the given mathematical representations, students identify and describe how net force can change the motion of object or system of objects. The students look at Newton's second law applies to the motion of objects moving in a circle, both vertical and horizontal. Students also represent forces in diagrams using appropriate labels that represent the magnitude and direction of each force.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Circular Force lab (as an explore the relationship activity)

In-Class Activities and Laboratory Experiences:

- Complete a lab that finds the relationship between Force, mass, radius and velocity for an object that is moving in a horizontal circle (Assessment).
- Solve Problems using Newton's second law for objects in both vertical and horizontal circles.

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Meter stick
- Spring scale
- Centripetal force apparatus
- Various massed stoppers
- Bucket

Formative Assessments:

- Observation
- Homework
- Class work
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Lab work
- Quizzes

Summative Assessments:

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- No force is needed for circular motion.
- Centrifugal forces are real.
- An object moving in a circle with constant speed is not accelerating.
- Objects will continue in circular motion when released.

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- Ladybug Revolution: https://phet.colorado.edu/en/simulation/rotation
- Circular motion: http://www.wiley.com/college/halliday/0470469080/simulations/sim06/sim06.html
- Uniform circular motion: http://www.walter-fendt.de/ph14e/circmotion.htm
- Carousel: http://www.walter-fendt.de/ph14e/carousel.htm
- Circular motion: http://physics.bu.edu/~duffy/Ejs/EP_chapter05/circular_motion.html
- Classic circular force lab: http://www.thephysicsaviary.com/Physics/Programs/Labs/ClassicCircularForceLab/index.html
- Circular force lab:
- http://www.thephysicsaviary.com/Physics/Programs/Labs/CircularForceLab/index.html

Resources:

- Scientific calculator
- Force sensor
- Rotational motion sensor
- Computer with word processor, spreadsheet, internet access
- Labquest or science workshop interface with a computer

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:
- Teacher-designed problem set.

Supplement:
- Teacher designed and Concept Development worksheets from the Conceptual Physics program.
- Students are responsible for only a analysis of the data and to draw conclusions from the major assessment.

Unit 5: Gravity (6 Days)

Why Is This Unit Important?

The purpose of this unit is to help the students better understand the most dominant force in their everyday life -- gravity. Gravity is a concept termed by Sir Isaac Newton. His Law of Universal Gravitation is still being used by NASA scientists to plan the space shuttle launches, moon trips and the planned Mars mission. In his Law of Universal Gravitation, Newton finds a correlation between the mass of the objects that are attracted towards each other and the distance between these objects. This law does not, however, explain the gravitational effects that large masses produce; i.e. black holes, satellites near large planets or the orbit of the planet Mercury.

In the early 20th century, Albert Einstein proposed a new model Gravitation. In the Theory of General Relativity, he stated that the distance between the masses does not matter in finding the gravitational interaction, only the mass of the largest object. Einstein said that mass bends space-time and this warp in space-time would cause an object to 'fall' in towards the initial mass. General Relativity is used today in GPS systems and in the delivery of deep space satellites.

Disciplinary Core Ideas:

HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation to describe and predict the gravitational forces between objects.

HS-ESS1-4 Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Science and Engineering Practices:

- Asking questions about objects that are moving under the influence of gravity
- Planning and carrying out investigations about objects in orbits and experiencing gravity
- Developing and using Models to describe objects with mass interacting with each other
- Analyzing and interpreting data for objects experiencing gravity and in orbit around a distant star
- Using mathematics and computational thinking to describe an object in orbit or experiencing gravity

Cross Cutting Concepts:

- Patterns in the data lead to an understanding of Kepler's third law of planetary motion and to Newton's law of gravitation.
- Cause and effect gravity and planetary motion will be explored
- Standard units are used to measure and describe physical quantities such as mass and force.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial and boundary conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Enduring Understandings:

It is expected that students will:

- Demonstrate an ability to explain qualitatively Kepler's three laws as a vehicle to describe planetary motion.
- Demonstrate an understanding of the nature of gravitational attraction between masses.
- Recognize that when a scientific model fails to account for certain phenomena, the theory upon which it is based has to be revised or discarded in favor of more suitable theories.

Essential Questions:

- What is the importance of the three Kepler's Laws of planetary motion?
- What are the graphical models and the mathematical models that are used to represent and analyze the gravitational interactions between objects?
- What is the relationship between the gravitational force exerted on one object by another object and the mass of the two objects? the separation distance between the objects?
- How can the Law of Universal Gravity be applied?
- How did our current understanding of the universe develop from the Greek's to General Relativity?

Acquired Knowledge:

- Calculate the gravitational force two objects exert on each other in a uniform field.
- Use Newton's Universal Law of Gravitation to derive the acceleration due to gravity for the surface of the Earth and for the surfaces of other planets when the radii and the masses of the planets are given.
- Use mathematical representations of Kepler's Third Law to relate the radius of an orbit to its period.
- Use Newton's second law of motion, the universal law of gravitation and the concept of centripetal acceleration to solve problems involving the orbital motion of satellites.

Acquired Skills:

- Understand the historical development of the heliocentric model of the solar system.
- Concisely state Kepler's three laws of planetary motion.
- Solve problems using Kepler's third law of planetary motion.
- understand the theoretical development of Newton's equation for universal gravitation $F_g = Gm_1m_2/r^2$
- solve problems involving Universal Gravitation and Newton's 2nd Law.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Gravity Problem Set: Using the given mathematical representations, students identify and describe the gravitational attraction between two objects as the product of their masses divided by the separation distance squared ($F_G = -Gm_1m_2/d^2$), where a negative force is understood to be attractive.

Kepler's Law Simulation: Students use the given mathematical or computational representation of Kepler's third law of planetary motion ($T^2 \propto R^3$, where T is the orbital period and R is the semi-major axis of the orbit) to predict how either the orbital distance or orbital period changes given a change in the other variable.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Review of the history of astronomy

In-Class Activities and Laboratory Experiences:

- Solve problems involving Newton's Law of Universal Gravitation (Assessment)
- Complete Simulation on Universal Gravitation
- Solve problems involving Kepler's 3rd law of planetary motion
- Perform a lab to understand Kepler's Laws describing the movements of planets in the solar system
- Complete a simulation on planetary orbits (Assessment)

Closure and Reflection Activities:

- Movie: The Science Behind Doctor Who
- Video: Dark Matter

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Scale
- Orbit of Mars lab
- Rulers
- Movie (see above)

Formative Assessments

- Observation
- Homework
- Class work
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- The moon stays in orbit because the forces acting on it are balanced.
- The force of gravity is the same for all bodies.
- A distinction can be made between gravity and acceleration.
- Light always travels in straight lines.
- A black hole has a greater gravitational force than the star from which it was formed.
- The moon is not falling.
- The force the earth exerts on a falling apple and the force the earth exerts on the moon are not the same kind.
- The force of gravity is the same on all falling bodies.
- Gravitational force is not mutual.
- There is no gravity in space or on the moon.
- Black holes are big
- Black holes cannot exist

Technology Connections:

Websites:

- Physics Classroom Tutorials
  http://www.physicsclassroom.com/Class/index.cfm
- Pendulum Lab:
  http://phet.colorado.edu/simulations/sims.php?sim=Pendulum_Lab
- Lunar Lander:
  http://phet.colorado.edu/simulations/sims.php?sim=Lunar_Lander
- Gravity Lab:
  http://phet.colorado.edu/simulations/sims.php?sim=Gravity_Force_Lab
- My Solar System:
  http://phet.colorado.edu/simulations/sims.php?sim=My_Solar_System
- Kepler's First Law: http://www.walter-fendt.de/ph14e/keplerlaw1.htm
- Kepler's Second Law: http://www.walter-fendt.de/ph14e/keplerlaw2.htm
- Kepler's Laws:
  http://www.surendranath.org/Applets/Dynamics/Kepler/Kepler1Applet.html
- Satellite motion:
  http://www.surendranath.org/Applets/Dynamics/Kepler/SatelliteApplet.html
- Newton's Cannon:
  http://galileo.phys.virginia.edu/classes/109N/more_stuff/Applets/newt/newtmtn.html

Resources:

- Computer with word processor, spreadsheet, internet access
  - Scientific calculator

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Solve Universal Gravitation problems that involve more than two masses not arranged in a line.
- Complete Newton's synthesis of Kepler's laws

Supplement:

- Teacher designed and Concept Development worksheets from the Conceptual Physics program.

Unit 6: Energy and Its Conservation (9 Days)

Why Is This Unit Important?

The world is made up of objects which interact with each other and, in doing so, energy is usually transferred. This unit develops the concept of energy and culminates in the law of conservation of energy. This conservation law facilitates powerful and elegant solutions to a wide range of problems. This unit also has social significance in that it reinforces the student's appreciation that production of a particular form of energy is at the expense of other forms of energy.

Disciplinary Core Ideas:

HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects)

HS-PS3-3 Design a device that works to convert one form of energy into another form of energy.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics, as well as possible social, cultural and environmental impacts.

Science and Engineering Practices:

- Asking Questions about energy
- Planning and carrying out investigations about energy transformations
- Analyzing and interpreting data for objects undergoing an energy transformation
- Developing and using models to explain energy
- Using mathematics and computational thinking to describe the conservation and distributions of energy
- Designing a device to transfer energy from one type to another (mousetrap car)
- Obtaining, Evaluating, and Communicating Information in a lab report on the conservation of energy.

Cross Cutting Concepts:

- Patterns in the data lead to an understanding of the conservation of energy.
- Cause and effect relationship between force and energy will be explored
- Standard units are used to measure and describe physical quantities such as energy and power.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial and boundary conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Energy cannot be created or destroyed – it only moves between one place and another place, between objects and/or fields, or between systems.

Enduring Understandings:

It is expected that students will:

- Demonstrate an understanding of the relationship between work, force and displacement.
- Demonstrate an understanding of the relationship between work and the different forms of energy.
- Demonstrate an understanding of the law of conservation of energy and the relationships among work, kinetic energy, potential energy and thermal energy, including the loss of energy due to heat, sound and/or light.
- Demonstrate an ability to describe and apply the concepts of power and efficiency to everyday situations.

Essential Questions:

- How do you know something has energy? In what ways do we witness the effects of something having energy?
- How does the principle of energy conservation set fundamental limits on the exploitation of our physical environment?
- How has our understanding of work, energy and heat impacted the development of modern technology?

Acquired Knowledge:

- Identify and quantify the various types of energies within a system of objects in a well-defined state, such as elastic potential energy, gravitational potential energy, kinetic energy and thermal energy and represent how these energies may change over time.
- Use work ($W = F_x \Delta x$) for mechanical energy transfers into or out of a system, caused by external forces exerted over a distance on the objects of that system and use heat and radiation for other energy transfers.
- Develop a mathematical model that demonstrates changes in kinetic energy and various potential energies of a system using representations of that system.
- Use representational tools to describe the energy and its changes within a system and the transfer of energy into and out of a system, for different defined systems or time intervals of the same event.
- Design a device that works to convert one form of energy into another form of energy.

Acquired Skills:

- calculate the work done by a constant force.
- take into account the direction of the force used to generate work.
- calculate kinetic, gravitational potential and thermal energies.
- solve problems involving the conservation of mechanical energy.
- calculate power based both on work done per unit time and the product of force and velocity.
- recognize the appropriate MKS units for work [Joule] and power [Watt] as well as their fundamental MKS equivalents [Joule = kg m2/s2 and Watt = kg m2/s3].
- measure the amount of heat stored in a suspended mass by converting the object's gravitational energy into heat energy through the frictional force.
- calculate the kinetic energy of a moving object based on its mass and velocity.
- understand how to calculate the work done by a force by calculating the area under a graph comparing the force applied to the displacement of the object.
- appreciate the importance of a closed system in the conservation of energy.
- Write a properly formatted lab report indicating a thorough understanding of the underlying physics principles.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student’s mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Bouncing Ball Lab: Students drop a ball from above a protected motion sensor and record its position and velocity. From this data students calculate the kinetic energy and potential energy it has as it moves downward and bounces back up. they then look at the total mechanical energy of the ball as it bounces seeing the energy that was transferred away from it during each bounce.

Energy Transforming Device: Students design a device that converts one form of energy into another form of energy. (e.g., Mousetrap car, Rube Goldberg Apparatus)

Conservation of Energy Problem Set: Using the given mathematical representations, students identify and describe how the concepts of energy can be used to describe and represent any physical situation. The students look at different types of energy focusing on translational kinetic energy, gravitational potential energy, thermal energy and work. Students look at these energies and how they relate to energy conservation.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

In-Class Activities and Laboratory Experiences:

- Present examples and demonstrations that illustrate situations where work is or is not done including positive and negative work.
- Discuss how the parallel and perpendicular components of the force and displacement affect the work done.
- Perform a Work and Power Lab: Students walk/run upstairs and calculate the work and power.
- Derive the relationship of Work to Energy.
- Perform a lab activity that investigates the relationship between work and energy to force and motion.
- Solve problems involving the Work/Energy theorem (Assessment).

- Develop a list of the various types of energy.
- Demonstrate various energy conversions (mechanical-electrical, heat-mechanical, etc.) (Assessment).
- Derive potential energy equations for gravity.
- Perform Conservation of Energy Labs such as Elastic vs. Gravitational using a mass on a spring or Kinetic vs. Potential using carts or balls on an inclined plane.
- Demonstrate or do a lab activity making work easier through use of simple machines and accounting for the energy transferred to heat/friction in a machine.
- Build a device that transforms Energy from one form to another (Assessment).

Closure and Reflection Activities:

- Lab: Can a Shoe Power Your House?
- Lab: Rollercoaster Loops (Tying gravity/gravitational potential energy to energy conservation)

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific Calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Motion sensor
- Car tracks
- Toy cars
- Photogates
- Labquest or Science workshop interface with a computer
- Everyday objects (shoe, headphones, book, etc.)
- Sample electric bill (students can get their own)

  Formative Assessments
  - Observation
  - Homework
  - Class work
  - Class participation
  - Writing assessments
  - Computer simulations
  - Do-Now
  - Engineering projects
  - Lab work
  - Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- Students think of energy only as a gravitational potential energy and kinetic energy of motion.
- Students believe that everything regarding energy is frame dependent.
- Energy can be recycled.
- Energy is destroyed in transformations from one type to another.
- Energy is lost to heat
- Adding or subtracting heat to or from a system always changes the temperature of the system.
- Heat and temperature are equivalent
- Energy can be created or lost.
- Energy can be transferred with no loss to heat.
- Since energy is conserved there is no need to practice "energy conservation."
- Kinetic Energy and Momentum are always conserved in all interactions.
- Momentum is not conserved in collisions with immovable objects.
- Kinetic Energy and Momentum are the same.
- A force acting on an object does work even if the object does not move.
- Force is energy.
- Work, power and energy are the same.

- **8.1.12.AP.5:** Decompose problems into smaller components through systematic analysis, using constructs such as procedures, modules, and/or objects.

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- The Ramp: http://phet.colorado.edu/simulations/sims.php?sim=The_Ramp
- Energy Skate Park: http://phet.colorado.edu/simulations/sims.php?sim=Energy_Skate_Park
- Pulley system: http://www.walter-fendt.de/ph14e/pulleysystem.htm
- Pulleys: http://www.phy.ntnu.edu.tw/~hwang/wheelAxle/pulley.html
- Work: http://jersey.uoregon.edu/vlab/Work/index.html
- Racing Balls: http://www.phy.ntnu.edu.tw/~hwang/racingBall/racingBall.html

Resources:

- Scientific calculator
- Motion sensor
- Photogate
- Force sensor
- Computer with word processor, spreadsheet, internet access
- Labquest or science workshop interface with a computer

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Determine the work done due to forces acting at various angles.

Supplement:

- Teacher designed and Concept Development worksheets from the Conceptual Physics program.

Unit 7: Electrostatics (8 Days)

Why Is This Unit Important?

In the same way that the gravitational force depends on mass, the electric force depends on a property known as electric *charge.* The electric force is responsible for many of the forces we discussed previously: the normal force, contact forces, friction and so on… *all* of these forces arise in the mutual attraction and repulsion of charged particles. Electricity is the dominant force in our lives and worthy of our extended attention.

Disciplinary Core Ideas:

HS-PS2-4 Use mathematical representations of Coulomb's Law to describe and predict the electrostatic forces between objects.

HS-PS3-5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Science and Engineering Practices:

- Asking questions about objects with charge and their behavior
- Planning and carrying out investigations about objects with charge and their behavior
- Analyzing and interpreting data of the behavior of objects with charge
- Developing and using models to explain how objects with net charge behave
- Using mathematics and computational thinking to describe the interactions of objects with a net charge

Cross Cutting Concepts:

- Patterns in the data lead to an understanding of Coulomb's law and electric field that surrounds a charge.
- Cause and effect relationship between electric charge and electric field and force will be explored
- Standard units are used to measure and describe physical quantities such as charge and force.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.

- When investigating a system, the initial and boundary conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Energy cannot be created or destroyed – it only moves between one place and another place, between objects and/or fields, or between systems.

Enduring Understandings:

It is expected that students will:

- Demonstrate an understanding of the laws governing electrical interactions are used to explain the behavior of electric charges at rest.
- Apply Coulomb's law to situations involving point charges and demonstrate an understanding of electric fields and their effects on charged objects.
- Apply the concept of electric potential, potential difference and electric potential energy to analyze situations involving point charges.

Essential Questions:

- How is charge similar and different than mass?
- How can a body become charged?
- How is knowledge of electric fields useful?
- What is Coulomb's law?
- What is the difference between on insulator and conductor?
- What is voltage?

Acquired Knowledge:

- Calculate the electrical force two charged bodies exert on each other in a uniform field.
- Make predictions about the sign and relative quantity of net charge of objects or systems after various charging processes.
- Diagram force interactions among charged objects.
- Describe the interactions of matter in electric fields both macroscopically and microscopically.
- Make predictions of the outcomes of the phenomena involving electrically charged objects using the concepts of force and field.
- Predict motion of elementary particles electric fields.

Acquired Skills:

- Justify electrostatic "action at a distance" through field theory.
- Explain how to mechanically generate positive and negative electrostatic charges.

- Predict whether charged and uncharged objects will attract or repel one another.
- Explain the atomic basis of the electrostatic force.
- Explain the differences between conductors and insulators.
- Calculate the electrostatic force between charged objects.
- Predict the direction of the electrostatic force between two charged particles.
- Calculate both the direction and magnitude of the electrostatic force between charged objects.
- Sketch the electric field in the vicinity of positive and negative charges.
- Use Gauss's Law to calculate the electric field of uniform and non-uniform charge distributions.
- Determine the electric field from the electrostatic force and charge.
- Demonstrate how a positive test charge can be used to determine the direction of the electric field.
- Calculate the electric field as the vector sum of separate electric fields.
- Determine the electric field strength as a function of distance from the charge causing that field.
- Calculate the electrostatic force on a charged particle if the electric field strength and charge are known.
- Determine the direction and magnitude of the electric field produced by distributions of charge in 1, 2 and 3 dimensional systems.
- Calculate the electrostatic potential difference between two different points in a uniform electric field.
- Calculate the potential difference between two points in a radial electrostatic field.
- Explain that for point sources the zero potential point is taken to be at infinity.
- Determine the electrostatic potential produced by two or more individual point charges.
- Demonstrate an understanding of the relationship between electrostatic potential and the electric field.
- Measure the electric field as a function of distance from a point charge.
- Measure the electrostatic potential as a function of distance from a point source.
- Calculate the energy content of a system of charges and use energy conservation to make prediction regarding changes in that total energy.
- Calculate the electrostatic potential and potential energy of a system of charged particles at rest.
- Predict the kinetic energies and velocities of charged particles as electrostatic work is done.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.
- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Sticky Tape and Charge Activity: In these investigations, students will be using the laboratory to learn what makes things behave the way they do. This material will help you to understand the behavior of the electrical interactions of matter, and to seek some pleasure in pitting your wits against nature to build a model for the understanding of some aspects of this behavior, much in the way William Gilbert, Benjamin Franklin and other experimenters did in their attempts to understand nature. Students will observe the behaviors of charged and uncharged objects to build a working definition of what electric charge is and when an object has a surplus of it.

Coulomb's Law Problem Set: Using the given mathematical representations, students identify and describe the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared ($F_E = kq_1q_2/d^2$), where a negative force is understood to be attractive.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Sticky tape activity
- Electric charge demonstrations

In-Class Activities and Laboratory Experiences:

- Demonstrate static electricity:
  - Charge insulators by friction (sticky tape, plastic/glass rods) to demonstrate static charge.
  - Charge a metallic object by induction [demonstrate the Van de Graaff Generator].
  - Classify materials as conductors or insulators as indicated by whether they can be charged by induction.
  - Classify charges as positive and negative.
- Demonstrate an electroscope and discuss how it works.
- Perform a Coulomb's Law lab to demonstrate the inverse square dependence of electrostatic force on distance.
- Demonstrate charge separation with a Van de Graaff generator.
- Define the electric field and demonstrate rules for sketching fields.
- Perform an electric field plotting lab (Field mapping apparatus, probe-ware, simulation)
- Solve problems related to electrostatic forces and fields produced by point charges, infinite line of charge and parallel plates (Assessment).
- Measure the voltage between parallel plates (demos) to show the dependence of voltage on plate separation and relate voltage to work done.
- Solve problems calculating the electrostatic potential for multiple point charges.
- Equipotential lab.

Closure and Reflection Activities:

- Electricity and Magnetism Paper

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Charge sensor
- Labquest or science workshop interface with a computer
- Van De Graaff generator
- Electroscope
- Electrostatic kit (fur, wool, glass, rubber)
- Pith balls or balloons

Assessments:

Formative Assessments

- Observation
- Homework
- Class work
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- A charged body has only one type of charge.
- An electron is pure negative charge and has no mass.
- Charge can occur in any amount.
- Protons and electrons can both be transferred.
- Attraction between objects occurs only if both are charged.
- Only conductors are attracted by electrostatic forces.
- The electrical force is the same as the gravitational force, a one way force.
- Coulomb's Law applies to charge systems consisting of something other than charges.
- Electrical force can only be transferred directly; you must touch something in order to see or feel the effects of an electrical force.
- The strength of the electrical force decreases by the inverse instead of the inverse square.
- Gravitational force is stronger than electrical force.
- The electric field and force are the same thing and in the same direction.
- Field lines can begin/end anywhere
- There are a finite number field lines.
- Fields don't exist unless there is something to detect them.

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- John Travoltage: http://phet.colorado.edu/simulations/sims.php?sim=John_Travoltage
- Charges and Fields: http://phet.colorado.edu/simulations/sims.php?sim=Charges_and_Fields
- Balloons and Static Electricity: http://phet.colorado.edu/simulations/sims.php?sim=Balloons_and_Static_Electricity
- Electric Field of Dreams: http://phet.colorado.edu/simulations/sims.php?sim=Electric_Field_of_Dreams
- Electric Field Hockey: http://phet.colorado.edu/simulations/sims.php?sim=Electric_Field_Hockey
- Electric Field Lines: http://www.surendranath.org/Applets/Electricity/FieldLines/FieldLinesApplet.html
- Electric Field Hockey http://www.electricfieldhockey.com/

Resources:

- Physics academic software: E-M Field
- Physics academic software: Electric Field Hockey
- Scientific calculator
- Computer with internet access
- Charge sensor
- Labquest or science workshop interface with a computer

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Solve point charge problems (Electric Field and Potential as well as Electrostatic Force) that involve more than two charges not arranged in a line.

Supplement:

- Teacher designed and Concept Development worksheets from the Conceptual Physics program.

Unit 8: DC Circuits (7 Days)

Why Is This Unit Important?

An electric circuit is a device that harnesses the motion of the electrons in order to get something done. The motion of electrons is accomplished through the application of an electric field. We'll start with some simple devices that do nothing more than heat up when electrons crash into each other: for example, the filaments of light bulbs, toasters and hair dryers are based solely on this concept. In this unit we will study the effects of direct current circuits and how these currents are produced and some of the uses to which they can be put.

Disciplinary Core Ideas:

HS-PS3-5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Science and Engineering Practices:

- Asking questions about the flow of current
- Planning and carrying out investigations about DC circuits
- Analyzing and interpreting data for a DC circuit
- Developing and using models to explain how current flows through a series and/or parallel circuit
- Using mathematics and computational thinking to solve problems involving series and/or parallel circuit

Cross Cutting Concepts:

- Patterns in the data lead to an understanding of how current travels in circuits.
- Cause and effect relationship between voltage and electric current will be explored
- Standard units are used to measure and describe physical quantities such as voltage, resistance and current.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial and boundary conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Energy cannot be created or destroyed – it only moves between one place and another place, between objects and/or fields, or between systems.

Enduring Understandings:

It is expected that students will:

- Apply Ohm's law to direct current circuits.
- Demonstrate an understanding of the relationships between electric power, electric potential difference, current and resistance.

Essential Questions:

- What is resistance, current and Voltage and how do they relate?
- How are parallel and series circuits different?
- How the behaviors in DC circuits can be explained?
- How does the current in a circuit depend on the elements in and the structure of the circuit?
- What is the difference between power and energy?

Acquired Knowledge:

- Use energy conservation to analyze processes in simple electric circuits (series and parallel) using the concepts of electric current, potential difference and power.
- Calculate equivalent resistance, current through, potential difference across and power dissipated in different circuit elements using Ohm's law and Joule's law.

Acquired Skills:

- Explain the function and operation of an electrochemical cell.
- Define the terminology applicable to electrical circuits.
- Use appropriate schematic symbols for voltmeters, cells, batteries etc.
- Measure the EMF of electrochemical cells individually, in series and in parallel.
- Describe the differences between series and parallel arrangements in batteries.
- Differentiate between a battery and a cell.
- Recognize that when cells are arranged in series that the total EMF is equal to the sum of the separate EMF's.
- Show that if a cell is reversed it subtracts from the total EMF.
- Explain why adding electrochemical cells in parallel, has no effect on the resulting EMF.
- Correctly measure the current flow through and the voltage across a circuit.
- Draw the schematic symbols for ammeters and light bulbs/resistors.

- Assemble circuits where light bulbs/resistors are connected either in series or in parallel.
- Measure the current at various points in both series and parallel circuits.
- Explain how currents are related in both series and parallel circuits.
- Explain why currents in series and in parallel circuits are related as they are.
- Measure the potential difference across both series and parallel circuits.
- Explain how potential differences are related in both series and parallel circuits.
- Predict the potential difference across series and parallel circuits.
- Explain why the potential relationships in parallel and series are what they are.
- Measure the resistance of a resistor using a multimeter.
- Calculate the resistance of a resistor.
- Recognize the schematic symbol of a resistor.
- Use the resistor code to determine the resistance of a resistor.
- Determine the resistance of two or more resistors connected in series.
- Calculate the total resistance of two or more resistors connected in parallel.
- Explain why the resistance of resistors in parallel is given by $1/R_t = 1/R_1 + 1/R_2 + 1/R_n$.
- Measure the internal resistance of a battery.
- Explain the meanings of: short circuit, closed circuit, open circuit voltage, short circuit voltage, internal resistance, terminal voltage.
- Calculate the resistance of a wire based on the wire's resistivity, length and cross section.
- Explain why the resistance of a wire is determined by the wire's resistivity, length and cross section.
- Explain the effect of temperature on the conductivities of conductors, resistors and semiconductors.
- Measure the resistivity of a conducting wire.
- Measure the power generated in an electrical circuit.
- Use Joule's Law to calculate the heat energy produced by an electrical circuit.
- Solve complex DC Circuit problems.
- Solve circuit problems involving two closed conducting loops.
- Determine the currents & voltages at all points in an electric circuit.
- Determine what will happen in an electrical circuit if specific changes are made to that circuit.
- Answer qualitative questions about the nature of DC circuits.
- Demonstrate a thorough understanding of DC circuits both quantitatively and qualitatively.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

DC Circuit Lab: In the investigation students use an electric circuit through which electric current can flow, a source of electrical energy that can be placed in the circuit, the shape and orientation of the wire and the types and positions of detectors and develop a means to indicate or measure when electric current is flowing through the circuit and how changing resistance can affect it. This will facilitate the development of a model of how energy is stored and travels through a circuit.

DC Circuit Problem Set: Using the given mathematical representations, students identify and describe how currents flow in a circuit and how voltage plays a role in causing this. Students will use Ohm's law to solve simple circuits both series and parallel as well as combination circuits. Students will be introduced to Kirchhoff's laws about energy and charge conservation in circuits.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Seat experiment: lighting a light bulb with one wire and a battery

In-Class Activities and Laboratory Experiences:

- Demonstrate parallel, series and combination circuits using lamp boards
- Perform a lab to measure current and voltage in parallel, series and combination circuits (Assessment)
- Diagram circuits showing all components and measuring instruments
- Calculate the equivalent resistance for parallel, series and combination circuits.
  - Calculate current, voltage drop and power utilized in each element of a circuit using Ohm's Law and P=IV

Closure and Reflection Activities:

- Electricity and Magnetism Paper

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific Calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Current sensor
- Differential voltage sensor
- Labquest or science workshop interface with a computer
- Multimeter
- Various resistors
- Alligator clips
- Voltage sources (batteries or power supplies)

Assessments

Formative Assessments

- Observation
- Homework
- Class work
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Engineering projects
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- Current is the same thing as voltage.
- Charges move by themselves.
- Current is an excess charge.
- Charges that flow in a circuit are from the battery or power supply.
- Electrons move near light's speed through a circuit.
- Resistors consume charge.
- The bigger the container, the larger the resistance.
- A conductor has no resistance.
- Electric power is the same as electric energy.

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- Voltage: http://jersey.uoregon.edu/vlab/Voltage/index.html
- Ohm's Law: http://www.walter-fendt.de/ph14e/ohmslaw.htm
- Multimeter (VOM): http://www.phy.ntnu.edu.tw/~hwang/electronics/multimeter.html
- Circuit Construction Kit DC Only: http://phet.colorado.edu/simulations/sims.php?sim=Circuit_Construction_Kit_DC_Only
- Resistance in a Wire: http://phet.colorado.edu/simulations/sims.php?sim=Resistance_in_a_Wire
- Battery Resistor Circuit: http://phet.colorado.edu/simulations/sims.php?sim=BatteryResistor_Circuit
- Conductivity: http://phet.colorado.edu/simulations/sims.php?sim=Conductivity
- Circuit Construction Kit AC/DC: http://phet.colorado.edu/simulations/sims.php?sim=Circuit_Construction_Kit_ACDC
- Ohm's Law: http://phet.colorado.edu/simulations/sims.php?sim=Ohms_Law

- Resistance in a Wire:
  http://phet.colorado.edu/simulations/sims.php?sim=Resistance_in_a_Wire
- Battery Voltage:
  http://phet.colorado.edu/simulations/sims.php?sim=Battery_Voltage

Resources:

- Multimeter
- Scientific calculator
- Differential voltage probe
- Voltage probe
- Current probe
- Labquest or science workshop interface with a computer
- Computer with internet access

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Solve Electric Circuits using Kirchhoff's Laws

Supplement:

- Teacher designed and Concept Development worksheets from the Conceptual Physics program.
- Students are responsible for only a analysis of the data and to draw conclusions from the major assessment.

Unit 9: Magnetism (8 Days)

Why Is This Unit Important?

Our realization in the 19th century that electricity and magnetism are actually the same force completely changed the world we live in. The industrial revolution was made possible by the discovery of electromagnetism. Moving charges – electric current – create magnetic fields.
Varying magnetic fields create electric fields. The light waves we use to see consist of a combination of varying magnetic fields and varying electric fields. This is the principle of electromagnetic induction. Practically, the principle of electromagnetic induction has led to the development of engines, electric power generators and many more useful devices.

Disciplinary Core Ideas:

HS-PS2-5 Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

HS-PS3-5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics, as well as possible social, cultural and environmental impacts.

Science and Engineering Practices:

- Asking Questions about magnets and their interactions
- Planning and carrying out investigations about magnetism and electromagnetism
- Analyzing and interpreting data for objects experiencing a magnetic force
- Developing and using models to explain magnetism and electromagnetism
- Using mathematics and computational thinking to describe how moving charges or magnets behave in magnetic fields
- Designing solutions that allow you to convert electricity to magnetism

Cross Cutting Concepts:

- Patterns in the data lead to an understanding of how electric currents interact with magnetic fields and how moving magnets make electric current.
- Cause and effect relationship between magnetic force and moving charges will be explored.
- Standard units are used to measure and describe physical quantities such as magnetic field, and force.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial and boundary conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function.

Enduring Understandings:

It is expected that students will:

- Demonstrate an understanding of the nature of magnetic fields and magnetic forces.
- Analyze electromagnetism, with reference to magnetic fields and their effects on moving charges and vice versa.
- Analyze the process of electromagnetic induction.

Essential Questions:

- How do magnetic forces and fields impact the technology of our daily lives?
- What is the fundamental relationship between electric fields and magnetic fields?

Acquired Knowledge:

- Make predictions of the outcomes of the phenomena involving permanent magnets and current carrying wires using the concepts of force and field.
- Predict motion of elementary particles magnetic fields.
- Investigate and make claims about the variables that affect the magnitude of the induced electric current created by changing a magnetic field.
- Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Acquired Skills:

- Explain the basis for all magnetism.
- Understand that magnetism in matter is dependent on the atom's electron structure.
- Categorize matter as paramagnetic, diamagnetic of ferromagnetic.
- Understand that moving charged particles feel a magnetic force only when their velocities have a component perpendicular to the magnetic field.
- Calculate the path of a charged particle through a magnetic field.
- Use the "right hand rule" to predict the direction of the magnetic force acting on a moving charged particle as it passes through a uniform magnetic field.
- Measure the strength of a magnetic field using a Hall Effect probe.
- Explain how a Hall Effect sensor measures the magnetic field strength B.
- Predict the direction of the magnetic force on a current carrying wire.
- Determine the effect that an external magnetic field has on a current carrying loop of wire.
- Measure the strength of a magnetic field using a Hall Effect probe.
- Predict the direction of the magnetic force on a current carrying wire.
- Determine the effect that an external magnetic field has on a current carrying loop of wire.
- Use Ampere's Law to calculate the magnetic field near a current carrying wire and through a long, thin solenoid.
- Measure the magnetic field as a function of distance from a current carrying wire.
- Explain why the magnetic field strength decreases inversely with the distance from a current carrying wire.
- Calculate the magnetic force between two parallel, current carrying wires.
- Determine the direction of the magnetic force between two parallel, current carrying wires.
- Determine the direction of the magnetic field near a long, straight current carrying wire by using the right hand rule.
- Calculate the magnetic force on a current carrying loop and/or on a loop of current carrying wire.
- Use Lenz's Law to determine the direction of current flow within a closed conducting path under various conditions.
- Use Faraday's law to calculate the EMF generated by a changing magnetic flux under various conditions.
- Calculate the magnetic flux through a closed conducting path.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Magnetic Induction Lab: Students describe the phenomenon that an electric current produces a magnetic field and that a changing magnetic field produces an electric current and build a device (e.g. motor or speaker) that demonstrates this phenomenon.

Magnetism Problem Set: Using the given mathematical and physical representations, students describe how magnets and current carrying wires interact with moving charges. Students will also model how magnetic fields establish and how they affect moving charges.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Exploring magnetism with a compass

In-Class Activities and Laboratory Experiences:

- Demonstration of magnetic fields
- Students will test various materials to observe their magnetic properties:
    - Use bar magnets to demonstrate the forces between poles of magnets (compare to the forces between electrostatic charges).
    - Use iron filings or a compass to show the shape of the magnetic field of a bar magnet.
    - Use iron filings or a compass to show the shape of the magnetic field around a current carrying wire.
    - Use iron filings or a compass to show the shape of the magnetic field around a coil or multiple coils of current carrying wire.
    - Deflection of a beam in a cathode ray tube using a bar magnet.
- Perform labs to show the shape of magnetic fields around combinations of magnets (i.e., south to south).
- Solve for the force on a charge moving through a magnetic field
- Perform various magnetic field labs to show the relationship between magnetic fields and current carrying wires.
- Use electromagnetic probes to measure the field around a current carrying wire.
- Tangent galvanometer (compare current in a loop to Earth's magnetic field).
- Perform Oersted's experiment and/or Faraday's experiment.
- Demonstrate Lenz's Law.
- Build a speaker or a motor activity (Assessment).

Closure and Reflection Activities:

- Electricity and Magnetism Paper

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific Calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Magnetic field sensor
- Differential voltage sensor
- Current sensor
- Multimeter
- Labquest or science workshop interface with a computer
- Magnet
- Magnet Wire
- Simplest motor kit
- Compass
- Induction coils
- Voltage supply

Formative Assessments

- Observation
- Homework
- Class work
- Class participation
- Computer simulations
- Writing assessments
- Engineering projects
- Do-Now
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- Electricity and magnetism are two different forces.
- North and South magnetic poles are the same as positive and negative charges.
- Magnetic field lines start at one pole and end at the other.
- Poles can be isolated.
- Flux is the same as field lines.
- Flux is actually the flow of the magnetic field.
- Magnetic fields are the same as electric fields.
- Charges at rest can experience magnetic forces.
- Magnetic fields around magnets are not caused by moving charges.
- Magnetic fields are not 3-dimensional.
- Magnetic field lines hold you on the earth.
- Charges, when released, will move toward the poles of a magnet..

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- Thomson's Positive Ray Analysis: http://www.surendranath.org/Applets/Electricity/Thomson/ThomsonApplet.html
- Charge in Electric & Magnetic Fields: http://www.surendranath.org/Applets/Electricity/MovChgEleMag/MovChgEleMagApplet.html
- Charge in a Magnetic Field: http://www.surendranath.org/Applets/Electricity/MovChgMag/MovChgMagApplet.html
- Magnetic Field of a Bar Magnet: http://www.walter-fendt.de/ph14e/mfbar.htm
- Magnetic Field of a Straight Current-Carrying Wire: http://www.walter-fendt.de/ph14e/mfwire.htm
- Lorentz Force: http://www.walter-fendt.de/ph14e/lorentzforce.htm
- Direct Current Electrical Motor: http://www.walter-fendt.de/ph14e/electricmotor.htm
- Generator: http://www.walter-fendt.de/ph14e/generator_e.htm
- Simple AC Circuits: http://www.walter-fendt.de/ph14e/accircuit.htm
- Charged Particle motion in EM field: http://www.phy.ntnu.edu.tw/~hwang/emField/emField.html
- Cyclotron: http://www.phy.ntnu.edu.tw/~hwang/cyclotro%5dn/cyclotron.html
- Biot Savart Law: http://www.phy.ntnu.edu.tw/~hwang/BiotSavart/BiotSavart.html

Resources:

- Scientific calculator
- Differential voltage probe
- Voltage probe
- Current probe
- Force sensor
- Magnetic field probe
- Labquest or science workshop Interface with a computer
- Computer with word processor, spreadsheet, internet access

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Solve problems dealing with magnetic flux and induced current.

Supplement:

- Teacher designed and Concept Development worksheets from the Conceptual Physics program.
- Students are responsible for only a analysis of the data and to draw conclusions from the major assessment.

Unit 10: Electromagnetic Interactions (Light and Optics) (10 Days)

Why Is This Unit Important?

A wave is a traveling disturbance in a medium that transport energy from one place to another. These disturbances can be along the wave or across it. Light travels and transports energy. Light has played a part in the development of civilization over time. Scientists have developed many devices that enhance our perception of the world around us. This unit will specifically analyze the use of lenses and mirrors in optical instruments such as microscopes and telescopes.

The modern theory of light is elegant and rich. Light is a wave whose medium is both the electric and magnetic field. Light waves are caused by the acceleration of charged particles (such as electrons) and have a dual nature: at times, they act like waves; at other times they act like particles, called photons. Light travels through space at the maximum speed allowed by the laws of physics. It is the fastest thing in the universe. Light has no mass, but it carries energy and even momentum. Hot objects radiate light as they cool – this is why the stars shine. Light comes in an infinitude of colors, most of which are invisible to us.

Disciplinary Core Ideas:

HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength and speed of waves traveling in various mediums.

HS-PS4-3 Evaluate the claims, evidence and reasoning behind the idea that electromagnetic radiation can be described by either a wave model or a particle model and that for some situations one model is more useful than the other.

Science and Engineering Practices:

- Asking Questions about light and waves
- Planning and carrying out investigations about the behavior of light
- Analyzing and interpreting data to explain the behavior of waves
- Developing and using models to explain light as a wave and a particle
- Using mathematics and computational thinking to describe the behavior of waves
- Obtaining, Evaluating, and Communicating information about how a device can capture information and energy using light

Cross Cutting Concepts:

- Patterns in the data reveal how light behaves at boundary conditions.
- Cause and effect relationship between light and its behaviors will be explored
- Standard units are used to measure and describe physical quantities such as wavelength and speed.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.
- When investigating a system, the initial and boundary conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Energy cannot be created or destroyed – it only moves between one place and another place, between objects and/or fields, or between systems.

Enduring Understandings:

It is expected that students will:

- Demonstrate an understanding that electromagnetic radiation, light, is a physical manifestation of the interaction of electricity and magnetism.
- Explain, quantitatively, the characteristics and behaviors of the various constituents of the electromagnetic spectrum and algebraically solve problems, using the relationship among speed, wavelength and frequency of electromagnetic waves.
- Demonstrate an ability to describe and apply the characteristics and properties of waves to light and other everyday phenomena.
- Demonstrate an understanding of the relationship between energy and the frequency of light.

Essential Questions:

- In what ways has the understanding of mechanical waves impacted our understanding of the physical world?
- How does our understanding of the wave nature of light affect the ways that we manipulate light?
- How does an understanding of ray optics enable us to use and manipulate light?

Acquired Knowledge:

- Analyze and interpret data to refine the physical and mathematical relationships among the wavelength, frequency and wave speed and how they are affected by the medium through which the wave travels.
- Calculate the velocity of light and changes to wavelength as light travels through various mediums.
- Use Snell's Law to determine angle of incidence, angle of refraction or critical angle.
- Investigate and make a claim about, the variables that affect the interaction of waves with different barriers and boundaries with another material. Analyze and represent observations with a drawing and, when appropriate, with a ray diagram.
- Recognize, for electromagnetic radiation (light), examples of reflection, refraction, diffraction and interference.
- Describe the difficulties with applying a wave model to the photoelectric effect.
- Differentiate between wave and particle properties in visible light.
- Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- Evaluate questions about the advantages of using a digital transmission and storage of information.

Acquired Skills:

- Describe the interactions of waves using appropriate wave terminology.
- Measure the characteristics of water waves including: reflection, refraction, diffraction, interference and wave speed.
- Explain how Huygen's Theorem can be used to justify the diffraction of water waves.
- Measure the speed, frequency and wavelength of water waves and show that they are related through v = f☐.
- Demonstrate that all waves reflect from an interface according to the Law of Reflection.
- Understand the meaning of "index of refraction" and will be able to use the index of refraction to determine the speed and wavelength of light in a material for which the index is known.
- Measure the index of refraction of a medium through the use of Snell's Law.
- Use Snell's Law to predict the path of a light ray through a glass plate and through a triangular prism.
- Recognize that Snell's Law is a variation on the Law of Refraction.

- Recognize that the index of refraction is directly related to the impedance of the medium.
- Determine the critical angle between two different mediums.
- Recognize that they must use the Law of Reflection if the critical angle is exceeded.
- Use Snell's Law, in combination with complementary and supplementary angles, to predict the path of a light wave through a triangular prism.
- Demonstrate that they understand how reflection and refraction support the wave nature of light.
- Understand how single and double slits support the wave nature of light through the diffraction and interference of light waves.
- Understand the differences between the patterns produced by both double and single slits.
- Use the necessary equation to predict the nodes and antinodes generated by both double and single slits.
- Predict the path of a light ray as it passes from one medium into another.
- Calculate the critical angle between two mediums.
- State the difference between the interference patterns produced by single and double slits.
- Identify various ways of polarizing light.
- Explain how light can be polarized through selective absorption, reflection, scattering and double refraction.
- Determine the intensity of light transmitted when 1, 2 or 3 polarizing filters are used to polarize light.
- Explain how diffraction limits the resolution of any measurement involving light waves.
- Calculate the resolution of an optical situation involving light waves.
- Explain how the Michelson Interferometer was supposed to detect the medium for light.
- Explain why the particle model of light is necessary to explain the results of the Photoelectric Effect.
- Use the conflicting evidence concerning light's nature to reconcile them into the wave-particle duality.
- Explain how the wave-particle nature applies to matter as well as to light through the deBroglie relationship.
- Calculate the wavelength of matter waves and the momentum of light waves through the deBroglie relationship.
- list the fundamental difference among plane, concave and convex mirrors.
- complete ray diagrams for plane, concave and convex mirrors and in doing so locate the positions of virtual and real images.

- differentiate between real and virtual images.
- draw ray diagrams involving plane, concave and convex mirrors.
- locate the position of both real and virtual images by drawing appropriate ray diagrams.
- use the mirror and magnification equations to solve problems involving plane, concave and convex mirrors.
- list the differences and similarities between mirrors and lenses.
- use the "lens maker's formula" to determine the focal length of both concave and convex lenses.
- calculate the focal length of both concave and convex lenses using the "lens maker's formula".
- draw ray diagrams involving lenses and use those diagrams to predict the positions of both real and virtual images.
- predict the positions of both real and virtual images produced by lenses using appropriately drawn ray diagrams.
- explain how the similarities between mirrors and lenses enable them to use the same equations for lenses as for mirrors.
- predict the position of both virtual and real images for concave and convex lenses using the applicable mathematical relationships.
- use the image from one lens as the object for a second lens when thin lenses are used together.
- explain the various types of vision deficiencies, their causes, and their solutions.

Assessments:

Formative Assessment:

- Daily quizzes are given to assess the students learning progress in the unit. These quizzes are assessed for understanding not mastery.

Summative Assessment:

- A benchmark quiz is given to assess the student's mastery before the end of the unit.

- All physics tests are given in three parts a multiple-choice section that they take on their own, another multiple-choice section they take in a small group and an open-ended section they complete at home.

Benchmark Assessment:

Reflecting and Refraction Lab: Students collect data on what happens to a beam of light when it is incident on a new medium. Students study reflection, refraction, and internal reflection.

Light Properties Paper: Students will develop arguments around whether electromagnetic radiation is a wave or particle or some combination of both. Students will support claims with evidence from multiple lab experiences. Lab experiences may explore the following phenomena but are not limited to these: interference behavior by electromagnetic radiation, the photoelectric effect, reflection of electromagnetic radiation, refraction of electromagnetic radiation and polarization of electromagnetic radiation.

Technological Device Paper: Students communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

Waves and Light Problem Set: Using the given mathematical representations, students identify and describe light, and waves interact with other waves and at boundary conditions. The students look at the behaviors of light and solve representative problems to understand them. Students also represent light rays in diagrams and study its behavior as it travels through lens and off mirrors.

Suggested Learning Experiences and Instructional Activities:

Anticipatory Sets:

- Standing waves in a spring

In-Class Activities and Laboratory Experiences:

- Demonstrate and do labs with Slinkys to show characteristics and types of waves:
  - Standing wave lab: Students produce standing waves measuring frequency and wavelength and compute the velocity of the waves.
- Solve problems involving frequency, period, wavelength and wave speed.
- Discuss practical applications of the various parts of the electromagnetic spectrum
- Demonstrate that light can behave as a wave:
  - Double slit diffraction grating demo shows diffraction and interference
  - Shine a laser at a painted glass shows reflection and refraction
- Do a Snell's Law Lab and/or Activities to observe refraction at boundary:
  - Semicircular water filled container
  - Thick cut glass plate

- Demonstrations with aquarium, optical fibers, water streams (Total Internal Reflection demonstration)

- Observe Reflection and Refraction for Curved Surfaces:
  - Optical bench labs involving concave mirrors and convex lenses
  - Blackboard Optics kit – demonstration
  - Ray diagrams to locate and describe images
  - Problems involving the mirror and lens equations.
- Perform Interference Lab with Young's Experiment
- Research how light transfers energy to a device. (Assessment)
- Write a paper explaining the advantages of digital transmission of data. (Assessment)
- Discuss the dual nature of light:
  - Students list wave and particle properties of light
  - Famous Physicists Research Project
  - Career Exploration: Applications Engineer

Closure and Reflection Activities:

- Light Paper (Assessment)

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); CCP: Conceptual Physics (12th edition) by Paul Hewitt (2015)).
- Scientific Calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Light sensor
- Labquest or Science workshop interface with a computer
- Laser level or ray box
- Semi-circular prism
- Concave and convex mirror
- Cornell Diffraction Plates
- Slinky
- Planoconvex lens
- Meter stick optical bench

Formative Assessments

- Observation
- Homework
- Class work
- Class participation
- Writing assessments
- Computer simulations
- Do-Now
- Lab work
- Quizzes

Summative Assessments

- Chapter/Unit Tests
- Lab reports
- Presentations/Projects
- Final exams

Common Misconceptions

- All waves travel the same way.
- There must be a medium for a wave to travel through.
- Light and sound have the same wave nature.
- There are three different types of waves: sound, light, and EM.
- Rays and wavefronts are the same thing.
- Wave speed and frequency are the same thing.
- Wave speed and frequency are the same thing.
- Period of oscillation depends on amplitude.
- Pitch is related to loudness.
- You need a medium to have a wave.
- Waves do not have energy.
- All waves travel the same way.
- The medium moves along with the wave.
- The speed of sound is the same in all media.
- Big waves travel faster than small waves in the same medium.
- The speed of light never changes.
- Waves transport matter from one place to another.
- Wave speed and frequency are the same thing.
- Pitch is related to loudness.
- Changes in wave speeds produce the Doppler effect.
- Two waves are more disturbing than one.

- Light exists in the crest of a wave, dark in the trough.
- Sound cannot cancel sound.
- In refraction, characteristics of light change.
- Different colors of light are different kinds of waves.
- All colors of light add up to black.
- The speed of light never changes.
- Wave speed and frequency are the same thing.
- The period of oscillation depends on amplitude.
- Different colors of light are different types of waves.
- A hologram is magic.
- All lasers are extremely dangerous.
- Polarized light is a special kind of light.
- Light that is polarized can only be seen from one viewpoint.
- "UV blocking" sunglasses are polarizing sunglasses.
- Polarizing sunglasses are darker than normal sunglasses.
- Period of oscillation depends on amplitude.
- The law of reflection is limited to plane surfaces.
- Half a mirror gives half an image.
- If you back up far enough from a mirror you can see the image of your entire body in the mirror
- In refraction, characteristics of light change.
- Different colors of light are different kinds of waves.
- All colors of light add up to black.
- A lens can produce energy.
- Light bends once at the geometric center of a lens.

Technology Connections:

Websites:

- Physics Classroom Tutorials: http://www.physicsclassroom.com/Class/index.cfm
- Electromagnetic Wave: http://www.walter-fendt.de/ph14e/emwave.htm
- Refraction: http://www.walter-fendt.de/ph14e/refraction.htm
- Reflection and Refraction: http://www.walter-fendt.de/ph14e/huygenspr.htm
- Wave Interference: http://phet.colorado.edu/simulations/sims.php?sim=Wave_Interference
- Transverse Wave Interference: http://www.surendranath.org/Applets/Waves/Twave02/Twave02Applet.html
- Doppler Effect: http://www.walter-fendt.de/ph14e/dopplereff.htm

- Reflection/Refraction (Water-air Interface):
  http://www.phy.ntnu.edu.tw/~hwang/light/flashLight.html
- Thin Lens Demonstration:
  http://www.phy.ntnu.edu.tw/~hwang/Lens/lens_e.html
- Thin Lens Combination:
  http://www.phy.ntnu.edu.tw/~hwang/thinLens/thinLens.html
- Thick Lens: http://www.phy.ntnu.edu.tw/~hwang/thickLens/thickLens.html
- Physics of Rainbows:
  http://www.phy.ntnu.edu.tw/~hwang/Rainbow/rainbow.html
- Shadow/Image and Color:
  http://www.phy.ntnu.edu.tw/~hwang/shadow/shadow.html
- Fermat Principal: http://www.phy.ntnu.edu.tw/~hwang/Fermat/Fermat.html
- The World of Color:
  http://www.phy.ntnu.edu.tw/~hwang/color/color_e.html
- Mixing Colored Light Beams:
  http://www.phy.ntnu.edu.tw/~hwang/image/rgbColor.html
- Light: A Myriad of Colors:
  http://ir.chem.cmu.edu/irproject/applets/color/default.asp
- How a pinhole camera works:
  http://www.phy.ntnu.edu.tw/~hwang/pinHole/pinhole.html

Resources:

- Scientific calculator
- Light probe
- Spectrometer
- Photogate
- Labquest or science workshop Interface with a computer
- Computer with word processor, spreadsheet, internet access

Accommodations or Modifications for Special Education, ESL or Gifted Learners:

Enrichment:

- Solve challenging problems dealing with wave properties and characteristics.

Supplement:

- Teacher designed and Concept Development worksheets from the Conceptual Physics program.
- Students are responsible for only an analysis of the data and to draw conclusions from the major assessment.

Sample Standards Integration

<u>Career Readiness, Life Literacies, and Key Skills</u> **9.4.12.CI.1:** For example, in Unit 7 where students develop a model to illustrate ahow electrical forces and fields work. **9.4.12.CT.2:** For example, in Unit 9 where students collaborate to analyze and determine magnetic fields **9.4.8.IML.3:** For example, in Unit 10 where students evaluate the claims, evidence and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model and that for some situations one model is more useful than the other.
<u>8.1 Computer Science and Design Thinking</u> **All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and create and communicate knowledge.** An example of the application of this standard is found in unit 4 Graphing Motion
LGBT and Disabilities Law: In Unit 10 the Famous Physicists Research Project has students explore the contributions of famous chemists from varying minorities including those who are LGBTQ and have disabilities
Career Exploration: • In Unit 10 there is a Career Exploration: Applications Engineer
<u>ELA Integration:</u> **NJSLS.RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

NJSLS.RST.9-10.4 Determine the meaning of symbols, key terms and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grade level texts and topics.

NJSLS.RST.9-10.5 Analyze the structure of the relationships among concepts in a text, including relationships among key terms.

NJSLS.RST.9-10.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

NJSLS.RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
NJSLS.WHST.9-10.1.E - Provide a concluding statement or section that follows from or supports the argument presented.
NJSLS.WHST.9-10.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (Honors, Level 1)
NJSLS.WHST.9-10.2a Introduce a topic and organize ideas, concepts and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables) and multimedia when useful to aiding comprehension.
NJSLS.WHST.9-10.2.d Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.
NJSLS.WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection and research
These standards are met through the completion of the benchmark performances. For example in:

- Unit 2: **Friction Prompt:** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials, using the example of friction and a dragster.
- Unit 4: **Circular Motion:** Students identify and describe how net force can change the motion of object or system of objects. The students look at Newton’s second law applies to the motion of objects moving in a circle, both vertical and horizontal. Students also represent forces in diagrams using appropriate labels that represent the magnitude and direction of each force.

- Unit 7: **Sticky Tape and Charge Activity**: In these investigations, students will be using the laboratory to learn what makes things behave the way they do. This material will help you to understand the behavior of the electrical interactions of matter, and to seek some pleasure in pitting your wits against nature to build a model for the understanding of some aspects of this behavior, much in the way William Gilbert, Benjamin Franklin and other experimenters did in their attempts to understand nature. Students will observe the behaviors of charged and uncharged objects to build a working definition of what electric charge is and when an object has a surplus of it.

Mathematics Integration:

NJSLS.MP.6 Mathematically proficient students try to communicate precisely to others.

NJSLS.HS.A-CED.A.1 Create equations and inequalities in one variable and use them to solve problems.
NJSLS.HS.A-CED.A.2 Create equations in two or more variables to represent relationships between quantities.

NJSLS.HS.A.CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

NJSLS.HS.A.REI.A.1 Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

NJSLS.HSA.REI.B.3 Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
NJSLS.HS.A-SSE.A.1 Interpret complicated expressions by viewing one or more of their parts as a single entity.

NJSLS.HS.A-SSE.A.2 Use the structure of an expression to identify ways to rewrite it.
NJSLS.HS.N.Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

NJSLS.HS.N.Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

These standards are met through the completion of the benchmark performances. For example in:

- Unit 2: **Dynamics Problem Set:** Using the given mathematical representations, students identify and describe how net force can change the motion of object or system of objects. The students look at all of Newton's laws of motion with a special focus on the second law. Students also represent forces in diagrams using appropriate labels that represent the magnitude and direction of each force
- Unit 4: **Centripetal Force Lab:** Students use the data as empirical evidence to distinguish between causal and correlation relationships linking force, mass, velocity, and radius for an object traveling in a circle.

- Unit 7: **Coulomb's Law Problem Set:** Using the given mathematical representations, students identify and describe the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared ($F_E = kq_1q_2/d^2$), where a negative force is understood to be attractive.