PHYSICS II [HONORS]
GRADES 11-12

THE EWING PUBLIC SCHOOLS
2099 Pennington Road
Ewing, NJ 08618

BOE Approval Date: September 19, 2022
Revised: Craig Halpern
Donald Wahlers, Supervisor

Michael Nitti
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.

TABLE OF CONTENTS

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. This laboratory course develops a deep understanding of the physical laws basic to all sciences and the interrelationships and effects the laws have on the development of society in general, A multi-activity/laboratory-based approach, including video demonstrations, computer and non-computer-assisted laboratories and interactive computer simulations is to be used. Advanced skills in mathematics are developed when needed and combined with appropriate technology and problem-solving skills to explore concepts in detail. The concept of conservations laws is reintroduced with a special focus conservation of energy and heat. Students will explore thermodynamics through ideas like its role in the human body, in electricity and ultimately into a look at the emerging fields in 21st century physics
Students will use the following eight NGSS Science and Engineering Practices to demonstrate understanding of the disciplinary core ideas and develop critical thinking skills:

- Asking questions (science) and defining problems (engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using math and computational thinking
- Constructing explanations (science) and designing solutions (engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

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

- Patterns
- Cause and effect: mechanism and explanation
- Scale, proportion and quantity
- Systems and system models
- Energy and matter: flows, cycles and conservation
- Structure and function
- 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: Conservation Laws (20 Days)

Why Is This Unit Important?
The universe has many remarkable qualities, among them a rather beautiful law: If a system does not interact with its environment in any way, then certain mechanical properties of the system cannot change. … always. These quantities are said to be "conserved" and the conservation laws which result can be considered to be the most fundamental principles of mechanics. In mechanics, some examples of conserved quantities are energy and momentum. These conservation laws facilitates powerful and elegant solutions to a wide range of problems. 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-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-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 and about energy
- Planning and carrying out investigations about objects experiencing a collision or explosion and/or about energy transformation
- Analyzing and interpreting data for objects undergoing a collision or explosion and/or an energy transformation
- Developing and using models to explain momentum and energy and their conservation
- Using mathematics and computational thinking to describe the conservation of momentum and energy as well as energy distributions.
- Obtaining, Evaluating, and Communicating Information to write a summary report about how Newton's laws relate to momentum and its conservation and a report on conservation of energy.

Cross Cutting Concepts:

- Patterns in data lead to an understanding of impulse momentum and momentum conservation as well as the conservation of energy
- Cause and effect relationship between impulse and momentum as well as force and energy will be explored
- Standard units are used to measure and describe quantities such as momentum, impulse, 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 conditions of the system need to be defined and their inputs and outputs analyzed and described using models.
- Systems can be designed for greater or lesser stability.
- 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:

- 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.
- Work can describe the relationship between different forms of energy and their transformation.
- Energy and matter are neither created nor destroyed, but can transform from one form to another.

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?
- 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:

- 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.
- Define physical work.
- State the conditions necessary for the performance of physical work.
- Define the joule as work or energy units.

- Write a mathematical statement for calculating the work done by a given force and demonstrate that the equation is dimensionally correct.
- Recognize that the area beneath a Force vs. Distance curve is work done over the distance interval.
- Define kinetic energy.
- Demonstrate by example and by experiment the relationship between the performance of work and the corresponding change in kinetic energy.
- Calculate the kinetic energy of a body when its mass or weight is given.
- Discuss the Work-Energy Theorem and express it as a mathematical statement.
- Define potential energy.
- Define gravitational potential energy.
- Write an equation that will determine the gravitational potential energy of a known mass or weight relative to a given location in space.
- State and write the Law of Conservation of Mechanical Energy. Include kinetic, spring potential, gravitational potential energies and work due to friction.
- Give examples of different forms of energy.
- Define power.
- Understand the relationship between work, energy and power.
- Define and compare the units of the watt, kilowatt and horsepower as they are used to measure power.
- Demonstrate by example an understanding of the concept of power.

Acquired Skills:

- 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
- Calculate the work done by a constant force.
- Take into account the direction of the force used to generate work.
- Calculate kinetic, gravitational potential 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 m^2/s^2 and watt = kg m^2/s^3].

- 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.
- Be able to calculate the gravitational potential energy of an object sitting on the surface of planets, orbiting planets and very far away from a planet..
- Calculate the total energy of an orbiting satellite.
- Understand that gravitational energy is zero ‘very far away’ from the body causing the gravitational effect.
- Calculate the escape velocity from the surface of a planet.
- Calculate the escape velocity from orbit.
- Determine the shape of a force-displacement graph from the shape of the corresponding potential energy graph.
- Determine the amount of work and power it takes to walk up a set of stairs.
- Determine the work and power generated during a rigorous workout.
- Write a high quality lab report on the topics of work and power.

Assessments:

Formative Assessment:

- Daily quizzes maybe 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 or Major Assessments:

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.

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.

Conservation of Energy Lab: Students use a toy that stores energy and releases that energy as it leaves the ground. Students record all relevant data. 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. They also find the amount of stored energy at the beginning of the experiment.

Energy Transforming Device: Students design a system of devices that converts one form of energy into another form of energy. They will use various forms of energy discussed during the course (e.g. Rube Goldberg Apparatus)

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 translation kinetic energy, gravitational potential energy, thermal energy and work. Students look at these energies and how they relate to energy conservation.

Anticipatory Sets:

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

In-Class Activities and Laboratory Experiences:

- Perform Conservation of Momentum Lab in 2-Dimensions to verify that momentum is conserved in two-body interactions (Assessment)
- Solve Problems using Conservation of Momentum and Impulse (Assessment)
- Solve problems involving the Work/Energy theorem (Assessment)
- Researching different aspects of automobile design, car accidents and safety
- Perform a Work and Power Lab: Students walk/run upstairs and calculate the work and power.
- Perform a lab activity that investigates the relationship between work and energy to force and motion.
- Rube-Goldberg machine
- Demonstrate various energy conversions (mechanical-electrical, heat-mechanical, etc.) (Assessment).

Closure and Reflection Activities:

- Lab: Rollercoaster Loops

Instructional Materials/Teacher Resources:

- College Physics. Randall Knight et.al. Pearson/ Prentice Hall, 2016
- 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

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

Resources:

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

Accommodations and Extensions (Special Education, ELL, Gifted Learners):

Enrichment

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

Supplement

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

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
- 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)
- Racing Balls (http://www.phy.ntnu.edu.tw/~hwang/racingBall/racingBall.html)

Unit 2: Fluids Mechanics (15 Days)

In studying fluids we apply the concepts of force, momentum, and energy, which we have learned previously, to new phenomena. Since fluids are made from a large number of individual molecules, we have to look at their behavior as a group. For this reason, we develop a new set of conservation laws specific to fluids.

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-PS2-2 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-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

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-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-ETS1-4. 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 fluids
- Planning and carrying out investigations about fluids and their behavior
- Analyzing and interpreting data for fluids as they move
- Developing and using models to explain the behavior of fluids
- Using mathematics and computational thinking to describe the behavior of fluids
- Obtaining, Evaluating, and Communicating Information to write a summary report about how fluids behave.

Cross Cutting Concepts:

- Patterns in data lead to an understanding of fluids and their behavior
- Cause and effect relationship between motion and fluid behavior
- Standard units are used to measure and describe quantities such as pressure and volume
- 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.
- Systems can be designed for greater or lesser stability.
- 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 the pressure of a fluid is a measure of the forces exerted by a large number of molecules when they collide and bounce off a boundary. The unit of pressure is the Pascal (Pa).
- Understand that fluids as having gravitational potential energy density, kinetic energy density, and momentum density. These represent the amount of energy or momentum possessed by a given volume of fluid.
- Appreciate that liquids obey a continuity equation which is based on the fact that liquids are very difficult to compress. This means that the total volume of a sample of fluid will always be the same. Imagine trying to compress a filled water balloon …

Essential Questions

- How is density defined?
- What is the difference between gauge pressure and absolute pressure?
- How do hydraulic lifts work?
- What is the buoyant force?
- How do water speeds vary in pipes?

Acquired Knowledge
After studying the material of this unit, the student should be able to:

- Matter has a property called density.
- The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction.
- The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects.
- Pascal's Principle reminds us that, for a fluid of uniform pressure, the force exerted on a small area in contact with the fluid will be smaller than the force exerted on a large area.
- Bernoulli's equation describes the conservation of energy in fluid flow.
- The student is able to use Bernoulli's equation to make calculations related to a moving fluid.
- The student is able to use Bernoulli's equation and/or the relationship between force and pressure to make calculations related to a moving fluid.
- The student is able to use Bernoulli's equation and the continuity equation to make calculations related to a moving fluid.
- The student is able to construct an explanation of Bernoulli's equation in terms of the conservation of energy.
- Contact forces result from the interaction of one object touching another object and they arise from interatomic electric forces. These forces include tension, friction, normal, spring (Physics 1), and buoyant (Physics 2).
- The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.
- Energy can be lost in fluid flow if there is viscosity, or deviation from smooth flow.
- Viscosity is related to turbulence, the tendency of fluids to become chaotic in their motion.

Acquired Skills

- calculate the density of a substance.
- Find gauge pressure.
- Use Bernoulli's equation.
- solve problems involving the conservation of energy in a fluid.
- write a high quality lab report on the topic of draining a water pipe.

Formative Assessment:

- Daily quizzes maybe 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 or Major Assessments:

Fluids Problem Set: Students use the computational model to calculate how pressure is exerted in and on a fluid that is static and in motion. The concept of buoyance is modeled as a result of pressure. Students develop models in which they identify and describe the components of the system and the surroundings. Students work with Bernoulli's law to study dynamic fluids.

Fluid Flow Lab: Water draining out of holes in containers has been a problem since slightly after the invention of the water container. This experiment focuses on how fast the water leaves the container. Instead of worrying about the size of the hole, we will focus on how the rate changes with the amount of water left in the container. From the water's weight and constant values, such as the cross-section of the pipe, students can calculate many other quantities that they may need. Since all of these quantities are either factors or resultant of other values, a general trend will likely be shared by many of them. Students will determine which factors are causes and not correlations to the rate that the water exits the tube.

Fluid Pressure Simulation: Students will be able to qualitatively investigate how pressure varies in air and water, predict pressure in a variety of situations, discover how you can change pressure, and determine the fluid density of liquids using pressure measurements.

Instructional Materials/Teacher Resources:

- College Physics. Randall Knight et.al. Pearson/ Prentice Hall, 2016
- 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

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

Resources:

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

Accommodations and Extensions (Special Education, ELL, Gifted Learners):

Enrichment

- Determine the rate various tubes will empty given a set opening size

Supplement

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

Unit 3: Thermodynamics (20 Days)

Why Is This Unit Important?

Thermodynamics is essentially the study of the internal motions of many body systems. Virtually all substances which we encounter in everyday life are many-body systems of some sort or other (e.g., solids, liquids, gases and light). Not surprisingly, therefore, thermodynamics is a discipline with an exceptionally wide range of applicability. Thermodynamics can explain more things about the world around us than any other physical theory. In this unit, the focus will be on those physical properties of everyday materials which are associated with the motions of their constituent atoms or molecules. In particular, the focus will be concerned with the type of motion which is normally called 'heat', establishing what controls the flow of heat from one body to another when they are brought into thermal contact. The relationship between heat and mechanical work will be further explored. The big ideas explored in this unit:

- Heat is a form of energy transfer.
- Entropy is a measure of disorder.

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-PS2-2 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-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 either motions of particles or energy stored in fields.

HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

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 heat, gases, and energy
- Planning and carrying out investigations about heat and the behavior of gases
- Analyzing and interpreting data for gases as heat is added to them
- Developing and using models to explain the behavior of gases
- Using mathematics and computational thinking to describe the behavior of gases and heat flow
- Obtaining, Evaluating, and Communicating Information to write a summary report about how gases behave and how heat flows.

Cross Cutting Concepts:

- Patterns in data lead to an understanding of gases and their behavior
- Cause and effect relationship between heat and the behavior of gases
- Standard units are used to measure and describe quantities such as pressure and volume
- 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.
- Systems can be designed for greater or lesser stability.
- 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:

- Temperature is related to the motion of molecules and heat is the transfer of energy due to temperature differences.
- Different substances require different amounts of energy to change temperature or phase.
- Energy can be transferred as heat (conduction, convection, radiation) or work.
- The second law of thermodynamics can be written in many forms:

  - Heat will not flow spontaneously from a colder body to a warmer body.
  - Heat energy cannot be transformed completely into mechanical work (some heat must be given off to the surroundings).
  - The disorder of all natural systems increases.

Essential Questions:

- How can an understanding of heat and thermodynamics help to improve the ways that we utilize our energy resources?
- What does the 2nd law of thermodynamics tell you about the direction of heat flow?
- What is the difference between temperature and heat?

Acquired Knowledge:

- Define the following terms: thermal energy, heat, temperature, convection, conduction, radiation, thermal expansion, linear expansion, coefficient of linear expansion.
- Understand that heat is an energy form.
- Discuss the significance of Joule's experiment.
- Represent the heat gained or lost in a given process in terms of calories, joules and BTUs.
- Explain the difference between heat and temperature.
- Explain that heat cannot be measured directly whereas temperature can.
- Understand that a thermometer, like any other measuring instrument, must be calibrated in some way and that there are limitations of certain materials that are used in making thermometers.
- Explain the reference points that were used to calibrate the Celsius temperature scale.
- Compare the Celsius and Kelvin temperature scales.

- Convert a temperature reading from degrees Celsius to Kelvin and vice versa.

- Apply the Law of Conservation of Energy to a given process in order to determine unknown parameters such as mass, specific heat, temperature, or latent heats of fusion or vaporization.
- Recognize any potentially hazardous situations that could arise from the thermal expansion of materials, especially those involving an increase in pressure from the expansion of gases in closed containers.
- State that substances vary in their amount of thermal expansion.
- State three important factors which determine the linear expansion of a material.
- State the correct units for the coefficient of linear expansion.
- Recognize that the coefficient of linear expansion is based on the unique physical properties of different substances.
- Suggest some applications in which an understanding of thermal expansion would be extremely useful.
- Solve problems involving heat and temperature and thermal expansion.
- Identify some important postulates of the kinetic molecular theory.
- Give an example of an observable phenomenon which lends support to the kinetic molecular theory.
- Demonstrate by example and by experiment an understanding of specific heat and its distinction from heat capacity.
- Explain practical advantages or disadvantages of metals with large specific heat capacities.
- Describe the changes that take place during phase changes in terms of atomic and molecular structure of matter.
- Demonstrate by two examples in each case the application of heat transfer by radiation, conduction and convection currents.

Acquired Skills:

- Explain the connection between the average kinetic energy on the molecular level and the temperature of a system or body.
- Convert temperatures among the three temperature scales: Celsius, Kelvin and Fahrenheit.
- Explain how the Kelvin scale differs conceptually from the Celsius and Fahrenheit scales.
- Calculate the heat that must be added or subtracted from a system in order to change either the temperature or phase of that system.
- Predict the change in temperature of a system based upon the amount of heat added to the system.
- Calculate the heat needed to change the phase of a system.

- Measure the heat added or subtracted to a system as it reaches thermal equilibrium.
- Predict the temperature of a cooling object as it cools to equilibrium with its environment.
- Predict the change in length, area or volume resulting from a change in the temperature of solids and liquids.
- List the three different modes of heat transfer.
- Predict the rate of heat transfer through both radiation and conduction.
- State the conditions specified in the ideal gas law.
- Calculate the resulting changes in pressure, volume and temperature in an ideal gas where conditions have been changed.
- Show that heat can be converted into useful work through the manipulation of the pressure and volume of a closed thermodynamic system.
- Calculate the work done by a simplified heat engine.
- Calculate the heat that enters or exits a system.
- Determine the work done by each phase of a simplified heat engine.
- Calculate the heat that enters and exits a simplified heat engine.
- Calculate the work input and output of a simplified heat engine.
- Determine the thermal efficiency of a simplified heat engine.
- Determine the thermal efficiency of a Carnot cycle engine.
- Understand the difference between an isobaric process and an isometric process.
- Calculate the entropy change in a system by the addition or removal of heat energy at a constant temperature.
- Use PV graphs to predict the behavior of an ideal heat engine.
- List and explain the Zeroth, First and Second Laws of Thermodynamics.
- Discuss the importance of the laws of thermodynamics in heat engine design.

Formative Assessment:

- Daily quizzes maybe 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 or Major Assessments:

Heat Problem Set: Students use the computational model to calculate how heat is transferred and flows through materials. The use the concept of heat flow to better understand what happens to the size and shape of an object when it is heated. Students develop models in which they identify and describe the components of the system and the surroundings. Students analyze qualitatively the effects of conduction, radiation, and convection in thermal processes.

Gas Laws Problem Set: Students use the computational model to calculate how gases behave. The concept of an ideal gas and its behavior is modeled. Students develop models in which they identify and describe the components of the system and the surroundings. Students work with the ideal gas law to better understand the thermodynamic principles.

Thermodynamics Problem Set: Students use the computational model to calculate how gasses behave under different types of expansions or compressions with pressure, volume, temperature or energy held constant. The concepts of heat and are applied to these expanding and contracting gasses. Students develop models in which they identify and describe the components of the system and the surroundings. Students work with the law of entropy to better understand the efficiency of a heat engine.

Newton's law of Cooling Lab: A container of hot liquid at temperature, *T*, placed in a room of lower temperature *Troom*, will result in an exchange of heat from the hot water to the room. The water will eventually cool to the same temperature as the room. You observe this cooling process every time you wait for a hot drink to cool. In this experiment students will examine the cooling of a hot liquid, with the goal of creating a model that describes the process. They can also predict the time it takes for the hot liquid to cool to room temperature.

Gas Law Lab: This is an inquiry lab that asks students to design experiments and derive relationships between pressure, volume, and temperature using a simulation. Students then make qualitative statements about the relationships between pressure, volume and temperature using molecular models.

Hot Air Balloon: Students design a hot air balloon powered by a candle and take a video of it flying and write a report on how it works.

Instructional Materials/Teacher Resources:

- College Physics. Randall Knight et.al. Pearson/ Prentice Hall, 2016
- RealTime Physics Active Learning Laboratories Module 2 Heat and Thermodynamics. David R. Sokoloff, Priscilla W. Laws, Ronald K. Thornton. Wiley, 2012
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Motion Sensor
- Pressure Sensor
- Temperature Sensor
- Heat Pulser
- Hot Plate
- Labquest or science workshop interface with a computer

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

Resources:

- Scientific calculator
- Motion Sensor
- Pressure Sensor
- Temperature Sensor
- Heat Pulser
- Hot Plate
- Labquest or Science Workshop Interface with a computer
- Computer with Word processor, Spreadsheet, internet access

Accommodations and Extensions (Special Education, ELL, Gifted Learners):

Enrichment

- Solve complex multistep problems at the most advanced level.

Supplement

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

Technology Connections:

Websites:

- http://lectureonline.cl.msu.edu/~mmp/kap10/cd283.htm
- http://www.phy.ntnu.edu.tw/ntnujava/index.php?topic=25
- http://zebu.uoregon.edu/nsf/piston.html
- http://zebu.uoregon.edu/nsf/balloon.html
- http://jersey.uoregon.edu/vlab/Thermodynamics/index.html

Unit 4: Thermodynamics – Biological Systems (7 Days)

Why Is This Unit Important?

All living systems need energy to function. Living organisms are also thermodynamic entities, in which thermal process are characterized by energy flows and fluxes both within the body and between the body and its environment. It is obvious that humans need food to live, but the reason for this is less obvious. The body does not consume energy; it changes it from one form to another. Energy is also transformed from the cells to their surroundings by conduction because of thermal gradient created between the cells and their environment. This process of homeostasis, maintaining the body in a narrow range of optimal function, is one of the central areas of investigation also how changing the energy requirements can affect the maintenance of both body mass and mass distribution between cell types. The big idea explored in this unit:

- The laws of physics have been developed to explain the behavior of energy and matter. This behavior is universal and applies to all phenomena and systems, including the biological.

Disciplinary Core Ideas:

HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

HS-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

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 either motions of particles or energy stored in fields.

HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

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.

List of Applicable Performance Expectations (PE) Covered in This Unit:

Science and Engineering Practices:

- Asking questions about heat and energy and how they relate to biological systems
- Planning and carrying out investigations about heat and energy and how they relate to biological systems
- Analyzing and interpreting data for energy balance in organisms
- Developing and using models to explain how organisms gain weight as a result of energy consumption
- Using mathematics and computational thinking to describe how organisms gain weight
- Obtaining, Evaluating, and Communicating Information to write a summary report about energy balance in biological systems.

Cross Cutting Concepts:

- Patterns in data lead to an understanding of gases and their behavior
- Cause and effect relationship between heat and the behavior of gases
- Standard units are used to measure and describe quantities such as pressure and volume
- 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.
- Systems can be designed for greater or lesser stability.
- 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:

- The principles of thermodynamics are applicable to biological systems.
- There are mechanisms for energy storage and transformation in the human body.

Essential Questions:

- Can we use thermodynamics to better understand the human body as a thermodynamic system?
- What role does energy and thermodynamics play in weight gain or loss?
- How does thermodynamics effect the functioning of cells?

Acquired Knowledge:

- Understand the interrelationships among the various forms of chemical, thermal, and mechanical energy, and be able to perform mathematical conversions from one form of energy to another.
- Identify the three major human energy systems, their major energy sources as stored in the body, and various nutrients needed to sustain them.
- List the components of total daily energy expenditure (TDEE) and how each contributes to the total amount of caloric energy expended over a 24-hour period.
- Describe the various factors that may influence resting energy expenditure (REE).
- List and explain the various means whereby energy expenditure during exercise, or the thermic effect of exercise (TEE), may be measured, and be able to calculate conversions among the various methods.
- Explain the relationship between exercise intensity, particularly walking and running, and energy expenditure, and relate walking and running intensity to other types of physical activities.
- Understand the concept of the physical activity level (PAL) and how it relates to estimated energy expenditure (EER).
- Calculate your EER based on an estimate of your PAL and the physical activity coefficient (PA).
- Describe the role of the three energy systems during exercise.
- Explain the various causes of fatigue during exercise and discuss nutritional interventions that may help delay the onset of fatigue.

Formative Assessment:

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

Summative Assessment:

- Write a research paper determining if the human body functions as a closed or open thermodynamic system.

Benchmark or Major Assessments:

- Write a research paper determining if the human body functions as a closed or open thermodynamic system.

Instructional Materials/Teacher Resources:

- College Physics. Randall Knight et.al. Pearson/ Prentice Hall, 2016
- RealTime Physics Active Learning Laboratories Module 2 Heat and Thermodynamics. David R. Sokoloff, Priscilla W. Laws, Ronald K. Thornton. Wiley, 2012
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Labquest or science workshop interface with a computer
- Motion Sensor
- Pressure Sensor
- Temperature Sensor
- Heat Pulser
- Hot Plate
- Force Plate

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

Resources:

- Scientific calculator
- Motion Sensor
- Pressure Sensor
- Temperature Sensor
- Heat Pulser
- Hot Plate
- Labquest or Science Workshop Interface with a computer
- Ticker timer
- Computer with Word processor, Spreadsheet, internet access

Accommodations and Extensions (Special Education, ELL, Gifted Learners):

Enrichment

- Solve complex multistep problems at the most advanced level.

Supplement

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

Unit 5: Circuits – Advanced (20 Days)

Why Is This Unit Important?

A conductor is a material in which some of the charged particles are free to move; these particles are the conductor's charge carriers. For example, we regard a metal as a fixed arrangement of positive ions with electrons which are free to move about within the structure making them the charge carriers. When these charge carriers flow in a given direction through the lattice structure, we call this electric current. Upon deeper inspection, this simple model needs to be expanded to explain how each electron behaves in the presence of other electrons since they all repel each other and are attracted to the fixed positive ions. The amount and type of interactions will change the properties of a material making not only a conductor, but an insulator, a semi-conductor and even devices like capacitors or diodes. In this unit, students will develop their understanding of an electric circuit and also how basic electronic devices work. The big idea explored in this unit:

- While electricity and magnetism have often been seen as separate phenomena, they are indeed linked and are phenomena which occur jointly.

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 and storage of charge
- Planning and carrying out investigations about DC circuits with different elements
- Analyzing and interpreting data for a RC circuit
- Developing and using models to explain how current flows through a series and/or parallel circuit and how capacitors work
- 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:

- The behaviors of DC circuits can be explained by using the classical physics concepts of matter, energy conservation and thermodynamics.

Essential Questions:

- How do circuit components like resistors, capacitors, diodes, inductors and transistors affect the circuit they are in?
- From the point of view of the electron, what is a circuit?
- How does thermodynamics explain the relationship between current, resistance, capacitance and an electron?

Acquired Knowledge:

- Define the ampere as the unit of electrical current.
- Distinguish between conventional flow and electron flow.
- State Ohm's Law for electrical components.
- Define the unit of resistance, the ohm.
- Calculate the resistance across a bank of resistors in series, parallel and combined.
- Discuss EMF and its role in DC electrical theory.
- Distinguish between EMF and potential difference.
- Define and describe voltage, current and equivalent resistance for resistors connected in series, parallel and combined.
- State Ohm's Law for an entire electrical circuit and apply it to the solution of electrical problems involving internal battery resistance and total resistance of the circuit.

- Calculate the total resistance of an entire DC circuit.
- Compute power loss in a given DC circuit.
- Determine the terminal voltage, given the EMF of a battery, its internal resistance and the load resistance.
- Determine the potential drop across a resistance carrying a given current.
- Determine how non-Ohmic devices work.
- Discuss semiconductor theory.
- Identify the basic electronics components (diode, transistor).
- Recognize the basic operation of diode and transistor.
- Analyze an analog electronic circuit.
- Design and build an analog electronic circuit.
- Recognize useful applications of circuits.
- Design basic digital circuits.
- Measure the capacitance of a parallel plate capacitor.
- Predict the current flowing onto or off of a charging or discharging capacitor as a function of time.
- Calculate the capacitance of a parallel plate capacitor based on its design characteristics.
- Determine the total capacitance of capacitors connected in series, in parallel or in mixed combinations.
- Solve RC circuit problems.
- Understand how to use ammeters, voltmeters, galvanometers and Digital Multi-Meter.

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 EMFs [as well as why this is so!].
- Show that if a cell is reversed it subtracts from the total EMF [as well as why this is so!].
- Explain why adding electrochemical cells in parallel, has no effect on the resulting EMF [as well as why this is so!].
- Describe the structural differences between ammeters and voltmeters.
- Use ammeters and voltmeters correctly in an electrical circuit.
- Explain what affect ammeters and voltmeters will have on a circuit if they are used incorrectly.

- Correctly measure the current flow through and the voltage across a circuit.
- Draw the schematic symbols for ammeters and light bulbs.
- Assemble circuits where light bulbs 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 the ammeter-voltmeter method.
- 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/Rt = 1/R1 + 1/R2 + 1/Rn.
- 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.
- Recognize the schematic symbol for a rheostat.
- Measure the resistance of an unknown resistor using a Wheatstone Bridge.
- Determine the relationship between the resistance of a conducting wire and the wire's temperature.
- Measure the resistivity of a conducting wire.
- Use a rheostat to control the voltage being applied to a light bulb.
- Recognize the schematic symbols for both a galvanometer and an adjustable resistor.
- Measure the power generated in an electrical circuit.
- Recognize the schematic symbol for a rheostat.
- Use Joule's Law to calculate the heat energy produced by an electrical circuit.
- Determine the efficiency with which power is delivered to the load in a circuit.
- State the conditions under which maximum power is delivered to the load.
- Calculate the power delivered to the load in a circuit.

- Explain the atomic structure of a typical semiconductor.
- Explain how doping affects the nature of semiconductors.
- Explain how a semiconductor junction can be used to control the flow of current through a circuit.
- Describe the difference between forward biased and reversed biased PN junctions.
- Measure the resistance of a semiconductor as a function of the applied external voltage.
- Explain how a vacuum tube diode works.
- Explain how a transistor can be used to amplify and control current flow.
- 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.
- Measure the capacitance of a parallel plate capacitor.
- Predict the current flowing onto or off of a charging or discharging capacitor as a function of time.
- Calculate the capacitance of a parallel plate capacitor based on its design characteristics.
- Determine the total capacitance of capacitors connected in series, in parallel or in mixed combinations.
- Use digital multimeters, oscilloscopes, breadboards and function generators.

Formative Assessment:

- Daily quizzes maybe 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 or Major Assessments:

Electric Circuit Problem Set: Using the given mathematical representations, students identify and describe how currents flow in a circuit, how capacitors store electric energy 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 RC circuits and the time constant for charging and discharging them.

RC Circuit Lab: This laboratory experiment is designed to investigate the behavior of capacitor responses of RC circuits, the basis for most electronic timing circuits. Data will be recorded on a Labquest.

Lightbulb Evaluation: Students will evaluate and take data on three different types of lightbulbs: an incandescent, compact fluorescent, and an LED. Each lightbulb is rated at 60 W. Students will submit a report based on evidence and data to which light bulb they prefer in which settings in their daily life.

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:

- RC Circuit lab
- Report of Evaluation of Lightbulbs (Incandescent, Compact Fluorescent, and LED)

Instructional Materials:

- Textbook (Honors: College Physics: A Strategic Approach (3rd Edition) by Randall D. Knight, Brian Jones, Stuart Field (2014); Level I: Pearson Physics by James Walker (2013); Level II: 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
- Various Capacitors
- Various LEDs
- Alligator clips
- Voltage sources (batteries or power supplies)

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

Technology Connections:

Websites:

- http://www.physicsclassroom.com/Class/index.cfm
- http://www.walter-fendt.de/ph14e/ohmslaw.htm
- http://www.phy.ntnu.edu.tw/~hwang/electronics/multimeter.html
- http://phet.colorado.edu/simulations/sims.php?sim=Circuit_Construction_Kit_DC_Only
- http://phet.colorado.edu/simulations/sims.php?sim=Resistance_in_a_Wire
- http://phet.colorado.edu/simulations/sims.php?sim=BatteryResistor_Circuit
- http://phet.colorado.edu/simulations/sims.php?sim=Conductivity
- http://phet.colorado.edu/simulations/sims.php?sim=Circuit_Construction_Kit_ACDC
- http://phet.colorado.edu/simulations/sims.php?sim=Ohms_Law
- http://phet.colorado.edu/simulations/sims.php?sim=Resistance_in_a_Wire
- http://phet.colorado.edu/simulations/sims.php?sim=Battery_Voltage
- http://www.article19.com/shockwave/oz.htm
- http://www.electronics-tutorials.ws/index.html
- http://phet.colorado.edu/en/simulation/capacitor-lab
- http://phet.colorado.edu/en/simulation/battery-resistor-circuit
- http://jersey.uoregon.edu/vlab/Voltage/index.html
- http://jersey.uoregon.edu/vlab/circuit/Circuit.html
- http://www.walter-fendt.de/ph14e/combrlc.htm

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.

Unit 6: 21st Century Physics (10 Days)

Why Is This Unit Important?

Physicists have been trying to figure out the world around them for centuries. Our society has inherited a rich intellectual heritage from this ongoing effort. The accumulated knowledge, the mathematical framework, and the concepts that we have inherited from giants like Galileo, Newton and Einstein are traditionally taught in a roughly historical sequence. It takes most people many years to make the progression from mechanics (forces, masses, and accelerations) to electromagnetism (fields, charges and potentials) to quantum mechanics (propagating waves of probability) to the current research frontier of physics. Most people claw their way to the boundary of modern knowledge only after a few years of graduate study. This is an opportunity to explore the physics of today in and gain an appreciation of what is going on in the research labs at universities currently. The big idea explored in this unit:

- Physics has developed quantification systems to describe, analyze and predict phenomena. One of these systems is effective when dealing with extremely large scales, while another is effective at extremely small scales. When applied jointly to phenomena that have factors at both ends (extremely large scales and extremely small scales), the two systems together yield nonsensical results. One of the major goals of physics is to develop a system applicable to all scales.

Disciplinary Core Ideas:

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

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 the current state of physics research
- Planning and carrying out investigations at the edge of physics
- Analyzing and interpreting data from either a research paper or an in-class experiment
- Developing and using models to explain our current understanding of physics

Cross Cutting Concepts:

- Patterns in the data lead to an understanding of physics
- Standard units are used to measure and describe physical quantities
- 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:

- There are enormous scale differences in our universe and at different scales, different forces dominate and different models better explain phenomena.
- There are size dependent effects of nano-sized materials that are not observed in bulk material; i.e., the object’s physical and chemical properties are dominated by surface interactions.
- New tools for observing and manipulating matter increase our ability to investigate and innovate.

Essential Questions:

- What are the limits of physics in the world today?
- How can structures of nanometer-sized dimensions be built and examined?
- What are the possible applications and uses of these structures?

Acquired Knowledge:

- Define nano-science as the study of the fundamental principles of structures
- Have at least one dimension lying roughly between 1 and 100 nanometers.
- Compare and contrast the size of atoms, ions and molecules to the size of nanoparticles.
- Identify structures that are appropriately measured in nanometers.
- Compare and contrast nanoparticle samples to atomic and macro-level samples in terms of the particle size, number of atoms and operational model.
- Explain the importance of nano-science research and technology.
- Recognize the interdisciplinary nature of nano-science.
- Recognize that an extendable nano-structure's physical and chemical properties are dominated by surface interactions.
- Identify the requirements of nano-science and nano-technology, including: new production methods, new measurement instruments and a clean room environment for nano-scale research and technology.
- Identify elements that can form discrete nanoparticles.
- Compare and contrast the properties of several allotropes of carbon (i.e., graphite, diamond, fullerenes).
- Explore the potential applications of carbon nanoparticles and nano-technology.

Assessments:

Formative Assessment:

- A review of current research papers will be done by the class.
- Career Exploration: Design Engineer
- Famous Design Engineers Research Project

Summative Assessment:

- A project that looks to recreate a physics experiment found in recent research.

Benchmark Assessment:

- A project that looks to recreate a physics experiment found in recent research.

Instructional Materials/Teacher Resources:

- College Physics. Randall Knight et.al. Pearson/ Prentice Hall, 2016
- Scientific calculator
- Computers with internet access, word processor and a spreadsheet
- Projector for teacher's computer or a SmartBoard
- Multimeter
- Differential voltage probe
- Voltage probe
- Current probe
- Force Sensor
- Labquest or science workshop interface with a computer

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

Resources:

- Scientific calculator
- Multimeter
- Differential voltage probe
- Voltage probe
- Current probe
- Force Sensor
- Labquest or Science Workshop Interface with a computer
- Computer with Word processor, Spreadsheet, internet access

Accommodations and Extensions (Special Education, ELL, Gifted Learners):

Enrichment

- Research into the production of additional nanotech materials

Supplement

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

Websites

- https://nanohub.org/resources/animations
- http://www.nanowerk.com/n_neatstuff.php
- http://www.nano.gov/
- http://www.nanotech-now.com/information.htm
- http://www.nano.gatech.edu/
- https://perimeterinstitute.ca/

Sample Standards Integration

<u>**Career Readiness, Life Literacies, and Key Skills**</u> **9.4.12.CI.1:** For example, in Unit 1, **Energy Transforming Device:** Students design a system of devices that converts one form of energy into another form of energy. They will use various forms of energy discussed during the course (e.g. Rube Goldberg Apparatus) **9.4.12.CT.2:** For example, in Unit 3, **Hot Air Balloon:** Students design a hot air balloon powered by a candle and take a video of it flying and write a report on how it works.
<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 6 Where students research, analyze and replicate famous physics experiments.
LGBT and Disabilities Law: In Unit 10 the Famous Design Engineers 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: Design 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 activities throughout the course. For example in:

- Unit 3: **Newton's law of Cooling Lab:** A container of hot liquid at temperature, *T*, placed in a room of lower temperature *Troom*, will result in an exchange of heat from the hot water to the room. The water will eventually cool to the same temperature as the room. You observe this cooling process every time you wait for a hot drink to cool. In this experiment students will examine the cooling of a hot liquid, with the goal of creating a model that describes the process. They can also predict the time it takes for the hot liquid to cool to room temperature.
- Unit 4: Write a research paper determining if the human body functions as a closed or open thermodynamic system.

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 activities throughout the course. For example in:

- Unit 1 **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.
- Unit 2: **Fluids Problem Set:** Students use the computational model to calculate how pressure is exerted in and on a fluid that is static and in motion. The concept of buoyance is modeled as a result of pressure. Students develop models in which they identify and describe the components of the system and the surroundings. Students work with Bernoulli's law to study dynamic fluids.