As per board policy 105, the K-12 science curriculum scope and sequence was approved by the board on May 21, 2018. In the curriculum development and unit refinement process we identified the need for several revisions.

**Elementary Resource Review Process**

During the 2018-19 school year, we reviewed three Next Generation Science Standards (NGSS) aligned resources to support our elementary science curriculum: Amplify, FOSS, and Smithsonian. As a part of our review process, we adapted our resource review rubric to reflect science teaching practices that align with the NGSS, participated in a resource review with each vendor, and consulted with Dr. Carla Zembal-Saul, PSU science education professor and Kahn chair for STEM education throughout our process. Although each resource included several key components we were looking for on our rubric, none of the reviewed resources met enough of the indicators to recommend further consideration.

The following summaries represent our overall evaluation of each resource:

**Smithsonian**

We stopped our review of Smithsonian based on its stance towards learners which appears to be inconsistent with our vision of supporting diverse learners. Many of the suggestions for diverse learners were wildly inappropriate or unrealistic. In addition, Smithsonian lacks support for teachers to understand and utilize a sense making stance in science teaching and learning. Smithsonian does not appear to support equity of access among all learners. It appears to be more teacher directed with students following directions, like a recipe. Smithsonian does not cultivate curiosity; it appears more like the scientific method. Finally, if there are this many concerns with grades 3 and 4 and grades K, 1, 2 and 5 are not developed yet, we don’t have enough evidence to support this resource moving forward.

**FOSS**

The comprehensive nature of this program, 180 lessons for an hour each, is not feasible in our schedule. The assessments are not authentic or experiential. In some cases, the post-assessment was eight pages long. There is not a clear content storyline or CER so
Amplify
Amplify is teacher directed and scripted. There is a heavy emphasis on reading about science rather than learning science through experiences and using reading as a support rather than as a science delivery mechanism. The teacher manual is challenging to follow in its monochromatic format. Student experiences are worksheet driven. Explorations are canned and not reflective of the messy learning in authentic science. There were limited opportunities available for speaking, listening, and sense making. The vocabulary is introduced through reading rather than experiences used to develop vocabulary understanding.

The elementary science team recommended creating our own content storylines, much like the middle school has done as a part of its science implementation process. “A storyline is a coherent sequence of lessons, in which each step is driven by students' questions that arise from their interactions with phenomena. A student's goal should be to explain the overarching phenomenon by the end of the unit. At each step, students make progress on the classroom's questions through science and engineering practices, to figure out a piece of a science idea. Each piece they figure out adds to the developing explanation, model, or designed solution. Each step may also generate questions that lead to the next step in the storyline. Together, what students figure out helps explain the unit's phenomena or solve the problems they have identified. A storyline provides a coherent path toward building disciplinary core idea and crosscutting concepts, piece by piece, anchored in students' own questions” (NGSS Content Storylines).

In the spring our science team created a content storyline template so we can ensure coherence across and between grade levels. The template is grounded in research from the NGSS and aligns with the content storylines in use in our middle schools. This summer grade level curriculum teams began creating our content storylines, some of which have already been created through our collaboration with PSU and our PDS partnership. SCASD teachers co-teach the science methods course and our leaders in the development and use of content storylines in their practice. In the fall, non-committee members will review the content storylines we have developed and offer feedback for any revisions. We are proposing that committee and non-committee members field test the unit in the spring. Field testing the content storyline process will provide valuable feedback to the science writers as we continue creating content storylines for implementation in 2019-20.

Proposed elementary revisions
As with our math curriculum, once we evaluated resources and in the case of science, began creating our content storylines, it became clear that changes to the approved curriculum scope and sequence needed to be made to reconcile it with our content storyline development process. Those changes are spelled out in our scope and sequence document so you can see where standards have been changed or moved and
where names of units have changed or shifted. In general, we removed a PA standard if it was a repeat of a NGSS standard. All grades have three units, usually with each unit being an earth science, life science, or physical science focus. Grade five is the only grade with two units because we included the physical science standards with the other two units because they supported the concepts in those units and contributed to the overall content storyline.

Planning for Implementation
We will return to the Board with a proposal that supports professional development with our new science curriculum and content storylines. Our inservice days next year will partially focus on science and will be led by our science team and our PSU consultants, who will be paid through a contract we will bring to the Board.

Proposed secondary revisions
Mainly, the revisions are due to moving a standard and revising unit titles to clarify the focus of the unit. The revisions we are proposing:

- In 7th grade, we would like to move one standard from Unit 3: Why Water is Special to the 8th-grade unit Climate Change for better content alignment.

- Unit title change: we would like to revise the title of the 7th-grade unit from Weather, Hurricanes, and Tornadoes, Oh My! to Hurricanes and Why Water is Special.

- We added the unit Hurricanes and Why Water is Special to 7th grade due to accidental omission when the scope and sequence was approved in May of 2018. This unit was not copied and pasted into the document as intended.
# Table of Contents

Science Mission Statement .........................................................................................3
Grade K ....................................................................................................................3-4
Grade 1 ...................................................................................................................5
Grade 2 ...................................................................................................................6-7
Grade 3 ...................................................................................................................8-10
Grade 4 ..................................................................................................................11-13
Grade 5 ..................................................................................................................14-15
Grades K-5 Nature of Science Scope and Sequence ..............................................16-18
Grade 6 ..................................................................................................................19-20
Grade 7 ..................................................................................................................21-23
Grade 8 ..................................................................................................................24-25
High School Sciences
  Earth Systems Science .........................................................................................26-33
  Biology ...............................................................................................................34-54
  Chemistry .........................................................................................................55-69
  Physics .............................................................................................................70-112
  Environmental Science ....................................................................................113-114
Science Mission Statement
The goal of science education is to prepare students to be responsible citizens in an increasingly complex and dynamic world. The State College science curriculum provides students with the foundations to understand the inner workings of this world using scientific processes and concepts from all fields of endeavor: earth science, biology, chemistry, and physics. This multi-disciplinary approach, based around the Next Generation Science Standards, promotes curiosity and builds content knowledge along with core science practices to develop scientifically literate citizens.

* The performance expectations/standards marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.
Numerical standards notations are quoted from the Next Generation Science Standards (NGSS)
PA standards are indicated with a PA and are quoted from the PA Science Curriculum Framework.
EC indicates an assessed area on the Science PSSA, Eligible Content.

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1 What’s the Weather Today? Tomorrow? The Next Day? | K-PS3-1 Make observations to determine the effect of sunlight on Earth’s surface.
K-ESS2-1 Use and share observations of local weather conditions to describe patterns over time.
K-ESS3-2 Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather.
K-PS3-2 Use tools and materials to design and build a structure that will reduce the warming effect of sunlight on an area. (taught in STEM) |
| Unit 2 Move It: Forces and Motions | K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
K-PS2-2 Analyze data to determine if a design solution, [created from a set of small pieces] works as intended to change the speed or direction of an object with a push or a pull.* (also in STEM)
EC S4.C.3.1.2 Compare the relative movement of objects or describe types of motion that are evident (e.g., bouncing ball, moving in a straight line, back and forth, merry-go-round).
S4.C.3.1.3 Describe the position of an object by locating it relative to |
another object or a stationary background (e.g., geographic direction, left, up).

| Unit 3 Living Together: Animals, Plants, and Their Environment | PA Observe and describe structures of organisms and functions of the structures.  
K-LS1-1 Use observations to describe patterns of what plants and animals (including humans) need to survive.  
K-ESS2-2 Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.  
K-ESS3-1 Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live. |
**Grade 1 Course Description**
In first grade students will formulate answers to questions such as: “What happens when materials vibrate? What happens when there is no light? What are some ways plants and animals meet their needs so that they can survive and grow? How are parents and their children similar and different? What objects are in the sky and how do they seem to move?” Students are expected to develop understanding of the relationship between sound and vibrating materials as well as between the availability of light and ability to see objects. The idea that light travels from place to place can be understood by students at this level through determining the effect of placing objects made with different materials in the path of a beam of light. Students are also expected to develop understanding of how plants and animals use their external parts to help them survive, grow, and meet their needs as well as how behaviors of parents and offspring help the offspring survive. The understanding is developed that young plants and animals are like, but not exactly the same as, their parents. Students are able to observe, describe, and predict some patterns of the movement of objects in the sky. In the first grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, and obtaining, evaluating, and communicating information. Students are expected to use these practices to demonstrate understanding of the core ideas. (From the NGSS)

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
</table>
| **Unit 1 Can You See It? Can you Hear It? Light and Sound** | 1-PS4-1 Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.  
1-PS4-2 Make observations to construct an evidence-based account that objects in darkness can be seen only when illuminated.  
1-PS4-3 Plan and conduct investigations to determine the effect of placing objects made with different materials in the path of a beam of light. (include mirrors) |
| **Unit 2 What’s Up? Sun, Moon, and Stars** | 1-ESS1-1 Use observations of the sun, moon, and stars to describe patterns that can be predicted.  
1-ESS1-2 Make observations at different times of year to relate the amount of daylight to the time of year.  
PA Use scientific tools such as binoculars or telescopes to enhance observations. |
| **Unit 1 It’s Alive! A Close Look at Plants and Animals** | PA Observe and categorize living and nonliving things by external characteristics.  
PA Classify plants and animals according to physical characteristics they share.  
PA Make observations and describe the different parts of organisms that help them survive, grow, and meet their needs.  
PA Design a model that replicates the function of an organism’s structure. (also in STEM)  
PA Observe and compare the stages of life cycles of organisms.  
1-LS1-2 Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.  
1-LS3-1 Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.  
EC S4.B.1.1.5 Describe life cycles of different organisms (e.g., moth, grasshopper, frog, seed-producing plant). |
Grade 2 Course Description
In second grade, students will formulate answers to questions such as: “What is typical weather in different parts of the world and during different times of the year? How can the impact of weather-related hazards be reduced? What are the different kinds of land and bodies of water? How are materials similar and different from one another, and how do the properties of the materials relate to their use? What do plants need to grow? How many types of living things live in a place?” Students are expected to develop an understanding of what plants need to grow and how plants depend on animals for seed dispersal and pollination. Students are also expected to compare the diversity of life in different habitats. An understanding of observable properties of materials is developed by students at this level through analysis and classification of different materials. Students are able to apply their understanding of the idea that wind and water can change the shape of the land to compare design solutions to slow or prevent such change. Students are able to use information and models to identify and represent the shapes and kinds of land and bodies of water in an area and where water is found on Earth. In the second grade performance expectations, students are expected to demonstrate grade appropriate proficiency in developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. Students are expected to use these practices to demonstrate understanding of the core ideas. (From the NGSS)

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
</table>
| **Unit 1 Look No Hands!** | 2-PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.  
2-PS1-2 Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.  
3-PS2-3 Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. |
| **Unit 2 What is the Mystery Substance?** | 2-PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.  
PA Observe, describe, and classify matter by properties and uses (e.g., size, shape, weight, solid, liquid, gas).  
2-PS1-2 Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.* (also in STEM)  
2-PS1-3 Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.  
2-PS1-4 Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.  
PA Plan and carry out investigations to test the idea that warming some materials causes them to change from solid to liquid and cooling causes them to change from liquid to solid.  
EC S4.C.1.1.1 Use physical properties [e.g., mass, shape, size, volume, color, texture, magnetism, state (i.e., solid, liquid, and gas), conductivity (i.e., electrical and heat)] to describe matter.  
EC S4.C.1.1.2 Categorize/group objects using physical characteristics.  
S4.D.1.3.2 Explain how water goes through phase changes (i.e., evaporation, condensation, freezing, and melting). |
| Unit 3 What Are Green Invaders? | 2-LS2-1 Plan and conduct an investigation to determine if plants need sunlight and water to grow.  
PA Plan and carry out investigations to test whether plants from different settings have different needs for water, sunlight, and type of soil.  
2-LS2-2 Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.*  
PA Obtain, evaluate, and communicate information that in any particular environment, some kinds of organisms survive well and some do not.  
2-LS4-1 Make observations of plants and animals to compare the diversity of life in different habitats.  
PA Construct an explanation about why living things can only survive where their needs are met.  
EC S4.B.1.1.3 Describe basic needs of plants and animals (e.g., air, water, food). |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 2 Oh No It's a Snow Storm changed to Magnets</td>
<td>3-ESS3-1 Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard. (in STEM)</td>
</tr>
</tbody>
</table>
**Grade 3 Course Description**

In third grade, students will formulate answers to questions such as: “How do organisms vary in their traits? How do internal and external structures support the survival, growth, behavior, and reproduction of plants and animals? How are plants, animals, and environments of the past similar or different from current plants, animals, and environments? What happens to organisms when their environment changes? How do equal and unequal forces on an object affect the object? How can magnets be used?” Students are able to organize and use data to describe typical weather conditions expected during a particular season. By applying their understanding of weather-related hazards, students are able to make a claim about the merit of a design solution that reduces the impacts of such hazards. Students are expected to develop an understanding of the similarities and differences of organisms’ life cycles. An understanding that organisms have different inherited traits, and that the environment can also affect the traits that an organism develops, is acquired by students at this level. In addition, students are able to construct an explanation using evidence for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing. Students are expected to develop an understanding of types of organisms that lived long ago and also about the nature of their environments. Third graders are expected to develop an understanding of the idea that when the environment changes some organisms survive and reproduce, some move to new locations, some move into the transformed environment, and some die. Students are able to determine the effects of balanced and unbalanced forces on the motion of an object and the cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. They are then able to apply their understanding of magnetic interactions to define a simple design problem that can be solved with magnets. In the third grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in asking questions and defining problems; developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. Students are expected to use these practices to demonstrate understanding of the core ideas. (From the NGSS)

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1 How Have Cockroaches Survived Millions of Years? | 3-LS1-1 Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.  
3-LS3-1 Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.  
3-LS3-2 Use evidence to support the explanation that traits can be influenced by the environment.  
PA Use evidence to compare characteristics inherited from parents, characteristics caused by the environment, and those resulting from both.  
PA Use evidence from fossil records to construct an explanation of the relationship between types of organisms living today and types of organisms that lived in the past.  
3-LS4-2 Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.  
4-LS1-2 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.  
4-LS1-2 Use a model to describe that animals receive different types of |
information through their senses, process the information in their brain, and respond to the information in different ways.
EC S4.B.2.2.1 Identify physical characteristics (e.g., height, hair color, eye color, attached earlobes, ability to roll tongue) that appear in both parents and could be passed onto offspring.
EC S4.B.2.1.1 Identify characteristics for plant and animal survival in different environments (e.g., wetland, tundra, desert, prairie, deep ocean, forest).
EC S4.B.2.1.2 Explain how specific adaptations can help a living organism survive (e.g., protective coloration, mimicry, leaf sizes and shapes, ability to catch or retain water).

| Unit 2 Home Sweet Home | 3-LS2-1 Construct an argument that some animals form groups that help members survive.
3-LS4-3 Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.
3-LS4-4 Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.* (also in STEM)
3-ESS2-1 Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season. (from 2nd grade Snowstorm)
3-ESS2-2 Obtain and combine information to describe climates in different regions of the world. (from 2nd grade Snowstorm)
4-LS1-1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.
4-LS1-2 Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.
EC S4.B.1.1.1 Identify life processes of living things (e.g., growth, digestion, respiration).
EC S4.B.1.1.2 Compare similar functions of external characteristics of organisms (e.g., anatomical characteristics: appendages, type of covering, body segments).
EC S4.B.1.1.4 Describe how different parts of a living thing work together to provide what the organism needs (e.g., parts of plants: roots, stems, leaves).
EC S4.B.2.1.1 Identify characteristics for plant and animal survival in different environments (e.g., wetland, tundra, desert, prairie, deep ocean, forest).
EC S4.B.2.1.2 Explain how specific adaptations can help a living organism survive (e.g., protective coloration, mimicry, leaf sizes and shapes, ability to catch or retain water).
EC S4.B.3.2.1 Describe what happens to a living thing when its habitat is changed.
EC S4.B.3.2.2 Describe and predict how changes in the environment (e.g., fire, pollution, flood, building dams) can affect systems. |
| EC S4.B.3.2.3 Explain and predict how changes in seasons affect plants, animals, or daily human life (e.g., food availability, shelter, mobility). | Unit 3
Fantastic Force: What Happens When Your Forces Are Unbalanced? | 3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. 3-PS2-2 Make observations and/or measurements of an object’s motion to provide evidence that a pattern can be used to predict future motion. 3-PS2-3 Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. 3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets.* (also in STEM) EC S4.C.3.1.1 Describe changes in motion caused by forces (e.g., magnetic, pushes or pulls, gravity, friction). EC S4.C.3.1.2 Compare the relative movement of objects or describe types of motion that are evident (e.g., bouncing ball, moving in a straight line, back and forth, merry-go-round). EC S4.C.3.1.3 Describe the position of an object by locating it relative to another object or a stationary background (e.g., geographic direction, left, up). |
| EC S4.D.1.3.4 Explain the role and relationship of a watershed or a wetland on water sources (e.g., water storage, groundwater recharge, water filtration, water source, water cycle). | | EC S4.D.2.1.2 Identify weather patterns from data charts or graphs of the data (e.g., temperature, wind direction, wind speed, cloud types, precipitation). (from 2nd grade Snowstorm) |
Grade 4 Course Description
In fourth grade students will formulate answers to questions such as: “What are waves and what are some things they can do? How can water, ice, wind and vegetation change the land? What patterns of Earth’s features can be determined with the use of maps? What is energy and how is it related to motion? How is energy transferred? How can energy be used to solve a problem?” Students are able to use a model of waves to describe patterns of waves in terms of amplitude and wavelength, and that waves can cause objects to move. Students are expected to develop understanding of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. They apply their knowledge of natural Earth processes to generate and compare multiple solutions to reduce the impacts of such processes on humans. In order to describe patterns of Earth’s features, students analyze and interpret data from maps. Fourth graders are expected to develop an understanding that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. By developing a model, they describe that an object can be seen when light reflected from its surface enters the eye. Students are able to use evidence to construct an explanation of the relationship between the speed of an object and the energy of that object. Students are expected to develop an understanding that energy can be transferred from place to place by sound, light, heat, and electric currents or from object to object through collisions. They apply their understanding of energy to design, test, and refine a device that converts energy from one form to another. In the fourth grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. Students are expected to use these practices to demonstrate understanding of the core ideas. (From the NGSS)

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1 Energy on the Move</td>
<td>Forms of Energy and Energy Transfer</td>
</tr>
<tr>
<td></td>
<td>4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.</td>
</tr>
<tr>
<td></td>
<td>PA Develop a model using examples to explain differences between renewable and non-renewable sources of energy.</td>
</tr>
<tr>
<td></td>
<td>PA Research multiple sources to describe ways that energy and fuels are derived from natural resources and their impact.</td>
</tr>
<tr>
<td></td>
<td>EC S4.C.2.1.1 Identify energy forms, energy transfer, and energy examples (e.g., light, heat, electrical).</td>
</tr>
<tr>
<td></td>
<td>EC S4.C.2.1.2 Describe the flow of energy through an object or system (e.g., feeling radiant heat from a light bulb, eating food to get energy, using a battery to light a bulb or run a fan).</td>
</tr>
</tbody>
</table>

Energy as Electricity
4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. |
PA Construct serial and parallel circuits and describe the path of electrons in the circuit. |
PA Demonstrate and explain open and closed circuits utilizing switches. |
PA Investigate and describe conductors and insulators. |
PA Carry out an investigation to provide evidence that energy is transferred from place to place by sound, light, electric currents, interacting magnets, and moving or colliding objects. |
EC S4.C.2.1.3 Recognize or illustrate simple direct current series and parallel circuits composed of batteries, light bulbs (or other common
<table>
<thead>
<tr>
<th>Energy &amp; Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.</td>
</tr>
<tr>
<td>PA Construct an explanation using data why an object subjected to multiple pushes and pulls might stay in one place or move.</td>
</tr>
<tr>
<td>PA Use evidence to construct an explanation for the relationship between speed, energy, and motion.</td>
</tr>
</tbody>
</table>

| EC S4.C.3.1.1 Describe changes in motion caused by forces (e.g., magnetic, pushes or pulls, gravity, friction). (in 3rd grade) |
| EC S4.C.3.1.2 Compare the relative movement of objects or describe types of motion that are evident (e.g., bouncing ball, moving in a straight line, back and forth, merry-go-round). |
| S4.C.3.1.3 Describe the position of an object by locating it relative to another object or a stationary background (e.g., geographic direction, left-up). (moved to K - Forces unit) |

| Removed Waves (taught in secondary) |
| Waves |
| 4-PS4-1 Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. |
| PA Identify the patterns of waves by observing their motion in water. |
| PA Provide evidence that waves transfer energy to objects as a wave passes. |
| PA Plan data collection method and make observations to provide evidence that waves transfer energy to objects. |
| PA Use a model to describe the amplitude and wavelength of waves. |
| EC S4.C.2.1.4 Identify characteristics of sound (e.g., pitch, loudness, reflection): |

| Unit 2 Earth’s Place in Space |
| Added to address the astronomy standards in fourth grade and are assessed on the fourth grade PSSA. |
| 5-ESS1-1 Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth. |
| 5-ESS1-2 Represent data in graphical displays to reveal patterns of daily changes in the length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky. |
| EC S4.D.3.1.2 Explain how the motion of the Sun-Earth-Moon system relates to time (e.g., days, months, years). |
| EC S4.D.3.1.3 Describe the causes of seasonal change as they relate to the revolution of the Earth and the tilt of Earth’s axis. |
| EC S4.D.2.1.1 Identify basic cloud types (i.e., cirrus, cumulus, stratus, and cumulonimbus) and make connections to basic elements of weather (e.g., changes in temperature, precipitation). (Was in grade 2 Snowstorm) |
| EC S4.D.2.1.2 Identify weather patterns from data charts or graphs of the data (e.g., temperature, wind direction, wind speed, cloud types, precipitation). |
| EC S4.D.2.1.3 Identify appropriate instruments (i.e., thermometer, rain gauge, weather vane, anemometer, and barometer) to study weather and what they measure. |
| PA Investigate and represent the various forms of water in their local |

loads), wire, and on/off switches.
| Unit 3 Uncovering Evidence from Our Past | 2-ESS1-1 Use information from several sources to provide evidence that Earth events can occur quickly or slowly. *(Was in grade 5 cycle of life)*  
2-ESS2-1 Compare multiple solutions designed to show or prevent wind or water from changing the shapes of land.* *(Was in grade 5 cycle of life)*  
3-LS4-1 Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago. *(Was in Grade 3 Home Sweet Home)*  
4-ESS1-1 Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape [and environment] over time.  
PA Use fossils as evidence to infer that some rocks were formed from the remains of once living organisms. *(covered in NGSS standard)*  
PA Use evidence from fossil records to construct an explanation of the relationship between types of organisms living today and types of organisms that lived in the past. *(covered in NGSS standard)*  
4-ESS2-1 Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation (heating, cooling, volume of water, speed of wind, deposition, slopes, angles, etc.).  
PA Make observations and document how living things affect the physical characteristics in different regions.  
4-ESS2-2 Analyze and interpret data from maps to describe patterns of Earth’s features.  
PA Identify various types of water environments in PA.  
PA Analyze and interpret data from maps to describe Earth’s features (e.g., mountains, valleys, caves, sinkholes, lakes, rivers, peninsulas, lentic/lotic water systems, etc.). *(covered in NGSS standard)*  
EC S4.D.1.1.1 Describe how prominent Earth features in PA (e.g., mountains, valleys, caves, sinkholes, lakes, rivers) were formed.  
EC S4D.1.1.2 Identify various Earth structures (e.g., mountains, watersheds, peninsulas, lakes, rivers, valleys) through the use of models.  
EC S4.D.1.1.3 Describe the composition of soil as weathered rock and decomposed organic remains.  
EC S4D.1.3.1 Describe types of freshwater and saltwater bodies (e.g., lakes, rivers, wetlands, oceans).  
EC S4.D.1.3.3 Describe or compare lentic systems (i.e., ponds, lakes, and bays) and lotic systems (i.e., streams creeks, and rivers).  
EC S4.B.3.1.1 Describe the living and nonliving components of a local ecosystem (e.g., lentic and lotic systems, forest, cornfield, grasslands, city park, playground).  
EC S4.B.3.1.2 Describe interactions between living and nonliving components (e.g. plants - water, soil, sunlight, carbon dioxide, temperature; animals - food, water, shelter, oxygen, temperature) of a local ecosystem.  
EC S4.D.1.2.1 Identify products and by-products of plants and animals for human use (e.g. food, clothing, building materials, paper products).  
EC S4.D.1.2.2 Identify the types and uses of Earth materials for renewable, nonrenewable, and reusable products (e.g., human-made products: concrete, paper, plastics, fabrics).  
EC S3.D.1.2.3 Recognize ways that humans benefit from the use of water |
Grade 5 Course Description
In fifth grade, students will formulate answers to questions such as: “When matter changes, does its weight change? How much water can be found in different places on Earth? Can new substances be created by combining other substances? How does matter cycle through ecosystems? Where does the energy in food come from and what is it used for?” Students are able to describe that matter is made of particles too small to be seen through the development of a model. Students develop an understanding of the idea that regardless of the type of change that matter undergoes, the total weight of matter is conserved. Students determine whether the mixing of two or more substances results in new substances. Through the development of a model using an example, students are able to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. They describe and graph data to provide evidence about the distribution of water on Earth. Students develop an understanding of the idea that plants get the materials they need for growth chiefly from air and water. Using models, students can describe the movement of matter among plants, animals, decomposers, and the environment and that energy in animals’ food was once energy from the sun. In the fifth grade performance expectations, students are expected to demonstrate grade-appropriate proficiency in developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, engaging in argument from evidence, and obtaining, evaluating, and communicating information; and to use these practices to demonstrate understanding of the core ideas. (From the NGSS)

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1 Think Beyond the Sink: Water Consumption and Conservation Our Amazing Earth</td>
<td>5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. (PA This could include the influence of atmosphere on landforms and ecosystems through weather and climate, mountain ranges on winds and clouds, etc.) PA Investigate movement of water in the Earth’s systems and research and develop models for the cycling of water. PA Through the creation of a model, explain that the chemical and physical processes that cycle earth materials and form rocks. (4th grade Changing Earth) PA Utilizing observations and data, explain the patterns of weather in a given location. 5-ESS2-2 Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth. 5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment. PA Research and communicate how communities are using science to protect resources and environments. PA Investigate and represent the various forms of water in their local environment. 2-ESS1-1 Use information from several sources to provide evidence that Earth events can occur quickly or slowly. 2-ESS2-1 Compare multiple solutions designed to show or prevent wind or water from changing the shapes of land.—MOVED to fourth grade, Our Changing Earth</td>
</tr>
<tr>
<td>2-ESS2-2 Develop a model to represent the shapes and kinds of land and bodies of water in an area.</td>
<td></td>
</tr>
<tr>
<td>2-ESS2-3 Obtain information to identify where water is found on Earth and that it can be solid or liquid.</td>
<td></td>
</tr>
<tr>
<td>PA Investigate and represent the various forms of water in their local environment.</td>
<td></td>
</tr>
<tr>
<td>5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen. <em>(Was in 5th grade Why Matter Matters)</em></td>
<td></td>
</tr>
<tr>
<td>5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. <em>(Was in 5th grade Why Matter Matters)</em></td>
<td></td>
</tr>
<tr>
<td>PA Plan and carry out investigations to determine the effect on the total mass of a substance when the substance changes shape, phase, and/or is dissolved. <em>(Was in 5th grade Why Matter Matters)</em></td>
<td></td>
</tr>
<tr>
<td>5-PS1-4 Conduct an investigation to determine whether the mixing of two or more substances results in new substances. <em>(Was in 5th grade Why Matter Matters)</em></td>
<td></td>
</tr>
<tr>
<td>PA Investigate the interaction of two or more substances to provide evidence that when different substances are mixed, one or more new substances with different properties may or may not be formed. <em>(Was in 5th grade Why Matter Matters)</em></td>
<td></td>
</tr>
</tbody>
</table>

### Unit 2 Composing and Decomposing: The Building Blocks of Life

**Cycle of Life: In One End and Out the Other**

**Why Matter Matters** *(Removed this unit and added the physical science standards to the other units.)*

<p>| 5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen. <em>(Was in 5th grade Why Matter Matters)</em> |
| 5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. <em>(Was in 5th grade Why Matter Matters)</em> |
| 5-PS1-3 Make observations and measurements to identify materials based on their properties. <em>(Was in 5th grade Why Matter Matters)</em> |
| 5-PS3-1 Use models to describe that energy in animals’ food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun. |
| 5-LS1-1 Support an argument that plants get the materials they need for growth chiefly from air and water. |
| 5-LS2-1 Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment. |
| PA Construct and communicate models of food webs that demonstrate the transfer of matter and energy among organisms within an ecosystem. |
| PA Ask researchable questions about the ways organisms obtain matter and energy across multiple and varied ecosystems. |
| PA Use models to trace the cycling of particles of matter between the air and soil and among plants, animals, and microbes. |
| PA Use models to describe how decomposition eventually restores (recycles) some materials back to the soil for plants to use. |
| PA Describe a healthy ecosystem as a system in terms of the components and interactions. |</p>
<table>
<thead>
<tr>
<th>Assessment Anchor</th>
<th>Eligible Content</th>
<th>Grades and Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reasoning and Analysis</strong>&lt;br&gt;S4.A.1.1 Identify and explain the application of scientific, environmental, or technological knowledge to possible solutions to problems.</td>
<td>S4.A.1.1.1 Distinguish between a scientific fact and an opinion, providing clear explanations that connect observations and results (e.g., a scientific fact can be supported by making observations).</td>
<td>K - 1, 2, 3 (first part of standard)&lt;br&gt;1 - ELA cur.,1,2, 3&lt;br&gt;2 - ELA cur.&lt;br&gt;3 - ELA cur.&lt;br&gt;4 - ELA cur.&lt;br&gt;5 - ELA cur.,1,2,3</td>
</tr>
<tr>
<td><strong>Reasoning and Analysis</strong>&lt;br&gt;S4.A.1.3 Recognize and describe change in natural or human-made systems and the possible effects of those changes.</td>
<td>S4.A.1.1.2 Identify and describe examples of common technological changes past to present in the community (e.g., energy production, transportation, communications, agriculture, packaging materials) that have either positive or negative impacts on society or the environment.</td>
<td>K - None&lt;br&gt;1 - None&lt;br&gt;2 - 3&lt;br&gt;3 - None&lt;br&gt;4 - None&lt;br&gt;5 - 1, 3</td>
</tr>
<tr>
<td><strong>Reasoning and Analysis</strong>&lt;br&gt;S4.A.1.3 Recognize and describe change in natural or human-made systems and the possible effects of those changes.</td>
<td>S4.A.1.3.1 Observe and record change by using time and measurement.</td>
<td>K - 2&lt;br&gt;1 - 1, 2&lt;br&gt;2 - 2&lt;br&gt;3 - None&lt;br&gt;4 - 1, 3&lt;br&gt;5 -1, 2, 3</td>
</tr>
<tr>
<td><strong>Reasoning and Analysis</strong>&lt;br&gt;S4.A.1.3 Recognize and describe change in natural or human-made systems and the possible effects of those changes.</td>
<td>S4.A.1.3.2 Describe relative size, distance, or motion.</td>
<td>K - 2&lt;br&gt;1 - 1, 2&lt;br&gt;2 - None&lt;br&gt;3 - 3&lt;br&gt;4 - 1, 3&lt;br&gt;5 - 1, 2, 3</td>
</tr>
<tr>
<td><strong>Reasoning and Analysis</strong>&lt;br&gt;S4.A.1.3 Recognize and describe change in natural or human-made systems and the possible effects of those changes.</td>
<td>S4.A.1.3.3 Observe and describe the change to objects caused by temperature change or light.</td>
<td>K - 1, 2&lt;br&gt;1 - 1, 2, 3&lt;br&gt;2 - 1&lt;br&gt;3 - None&lt;br&gt;4 - 1, 3&lt;br&gt;5 - 1, 2, 3</td>
</tr>
<tr>
<td><strong>Reasoning and Analysis</strong>&lt;br&gt;S4.A.1.3 Recognize and describe change in natural or human-made systems and the possible effects of those changes.</td>
<td>S4.A.1.3.4 Explain what happens to a living organism when its food supply, access to water, shelter, or space is changed (e.g., it might die, migrate, change behavior, eat something else).</td>
<td>K - 1&lt;br&gt;1 - 1&lt;br&gt;2 - 3&lt;br&gt;3 - 2&lt;br&gt;4 - 3&lt;br&gt;5 - 1, 3</td>
</tr>
<tr>
<td><strong>Reasoning and Analysis</strong>&lt;br&gt;S4.A.1.3 Recognize and describe change in natural or human-made systems and the possible effects of those changes.</td>
<td>S4.A.1.3.5 Provide examples, predict, or describe how everyday human activities (e.g., solid waste production, food production and consumption, transportation, water consumption, energy production and use) may change the environment.</td>
<td>K - None&lt;br&gt;1 - None&lt;br&gt;2 - None&lt;br&gt;3 - None&lt;br&gt;4 - 3&lt;br&gt;5 - 1 and 3</td>
</tr>
<tr>
<td>Processes, Procedures, and Tools of Scientific Investigations</td>
<td>S4.A.2.1 Apply skills necessary to conduct an experiment or design a solution to solve a problem.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>
| **S4.A.2.1.1** Generate questions about objects, organisms, or events that can be answered through scientific investigations. | K - 1, 2, 3  
1 - 1, 2, 3  
2 - 1, 2, 3  
3 - 1, 2, 3  
4 - 1, 2, 3  
5 - 1, 2, 3 |
| **S4.A.2.1.2** Design and describe an investigation (a fair test) to test one variable. | K - 1, 2, 3  
1 - 1, 2, 3  
2 - 1, 2, 3  
3 - 1, 2, 3  
4 - 1, 2, 3  
5 - 2 |
| **S4.A.2.1.3** Observe a natural phenomenon (e.g., weather changes, length of daylight/night, movement of shadows, animal migrations, growth of plants), record observations, and then make a prediction based on those observations. | K - 1, 2, 3  
1 - 1, 2, 3  
2 - 1, 2, 3  
3 - 1, 2, 3  
4 - 1  
5 - 1, 3 |
| **S4.A.2.1.4** State a conclusion that is consistent with the information/data. | K - 1, 2, 3  
1 - 1, 2, 3  
2 - 1, 2, 3  
3 - 1, 2, 3  
4 - 1, 2, 3  
5 - 1, 2, 3 |

<table>
<thead>
<tr>
<th>Processes, Procedures, and Tools of Scientific Investigations</th>
<th>S4.A.2.2 Identify appropriate instruments for a specific task and describe the information the instrument can provide.</th>
</tr>
</thead>
</table>
| **S4.A.2.2.1** Identify appropriate tools or instruments for specific tasks and describe the information they can provide (e.g., measuring: length - ruler, mass - balance scale, volume - beaker, temperature - thermometer; making observations: hand lens, binoculars, telescope). | K -1, 2, 3  
1 - 1, 2, 3  
2 - 2  
3 - None  
4 - 1, 3  
5 - 1, 2, 3 |

<table>
<thead>
<tr>
<th>Systems, Models, and Patterns</th>
<th>S4.A.3.1 Identify systems and describe relationships among parts of a familiar system (e.g., digestive system, simple machines, water cycle).</th>
</tr>
</thead>
</table>
| **S4.A.3.1.1** Categorize systems as either natural or human-made (e.g., ballpoint pens, simple electrical circuits, plant anatomy, water cycle). | K - None  
1 - None  
2 - None  
3 - None  
4 - ??  
5 - 1, 3 |
| **S4.A.3.1.2** Explain a relationship between the living and nonliving components in a system (e.g., food web, terrarium). | K - 1  
1 - 1  
2 - 3  
3 - 2  
4 - ?? |
<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
<th>Benchmark(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4.A.3.1.3</td>
<td>Categorize the parts of an ecosystem as either living or nonliving and describe their roles in the system.</td>
<td>K - 1 (first part of standard) 1 - 1 (first part of standard) 2 - 3 3 - 2 4 - ?? 5 - 1, 3</td>
</tr>
<tr>
<td>S4.A.3.1.4</td>
<td>Identify the parts of the food and fiber systems as they relate to agricultural products from the source to the consumer.</td>
<td>K - None 1 - None 2 - None 3 - None 4 - ?? 5 - 1, 2, 3</td>
</tr>
<tr>
<td>S4.A.3.2.1</td>
<td>Identify what different models represent (e.g., maps show physical features, directions, distances; globes represent Earth; drawings of watersheds depict terrain; dioramas show ecosystems; concept maps show relationships of ideas).</td>
<td>K - None 1 - None 2 - None 3 - None 4 - ?? 5 - 1, 2, 3</td>
</tr>
<tr>
<td>S4.A.3.2.2</td>
<td>Use models to make observations to explain how systems work (e.g., water cycle, Sun-Earth-Moon system).</td>
<td>K - None 1 - 2 2 - 2 3 - None 4 - 1 5 - 1, 2, 3</td>
</tr>
<tr>
<td>S4.A.3.2.3</td>
<td>Use appropriate, simple modeling tools and techniques to describe or illustrate a system (e.g., two cans and string to model a communications system, terrarium to model an ecosystem).</td>
<td>K - None 1 - 3 2 - None 3 - 2 4 - 1 5 - 1, 2, 3</td>
</tr>
<tr>
<td>S4.A.3.3.1</td>
<td>Identify and describe observable patterns (e.g., growth patterns in plants, weather, water cycle).</td>
<td>K - 1, 2, 3 1 - 1, 2, 3 2 - 2 3 - None 4 - 1 5 - 1, 2, 3</td>
</tr>
<tr>
<td>S4.A.3.3.2</td>
<td>Predict future conditions/events based on observable patterns (e.g., day/night, seasons, sunrise/sunset, lunar phases).</td>
<td>K - 1, 2, 3 1 - 1, 2, 3 2 - 2 3 - None 4 - 1 5 - 1, 2, 3</td>
</tr>
</tbody>
</table>
Middle School Science Courses

**Grade 6 Course Description** - This course of study is designed for students at any ability level. Using the Next Generation Science Standards (NGSS), students will develop an understanding of “What Constitutes Life” and “Their Place in the Solar System” while incorporating physical science concepts of matter and forces. To help students better understand the science concepts embedded in these units, the appropriate NGSS Science Practices and Crosscutting Concepts will be applied. Emphasis is given to the development of quantitative skills necessary for scientific measurement and establishing evidence based explanations and conceptual models. Throughout the course students will develop good reading skills, motivation, perseverance and the ability to share thinking both verbally and in written form. The course includes hands-on/minds-on and STEM related activities, as well as laboratory experiences correlated with large and small group work.

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>My Place in Space</td>
<td>NGSS&lt;br&gt;MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.&lt;br&gt;MS-PS2-3.Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.&lt;br&gt;MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.&lt;br&gt;MS-PS2-5 Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.&lt;br&gt;MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.&lt;br&gt;MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.&lt;br&gt;MS-PS3-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*&lt;br&gt;MS-PS3-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.&lt;br&gt;MS-ESS1-1 Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.&lt;br&gt;MS-ESS1-2 Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.&lt;br&gt;MS-ESS1-3 Analyze and interpret data to determine scale properties of objects in the solar system.</td>
</tr>
<tr>
<td>PA Stds</td>
<td>S8.D.3.1.1 Describe patterns of earth’s movements (i.e., rotation and</td>
</tr>
<tr>
<td>revolution) in relation to the moon and sun (i.e., phases, eclipses, and tides)</td>
<td>S8.D.3.1.2 Describe the role of gravity as the force that governs the movement of the solar system and universe.</td>
</tr>
<tr>
<td>S8.D.3.1.3 Compare and contrast characteristics of celestial bodies found in the solar system (e.g., moons, asteroids, comets, meteors, inner and outer planets).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What is Life?</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS-LS1-1</strong> Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.</td>
<td><strong>MS-LS1-2</strong> Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.</td>
</tr>
<tr>
<td><strong>MS-LS1-3</strong> Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.</td>
<td><strong>MS-LS1-6</strong> Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.</td>
</tr>
<tr>
<td><strong>MS-LS1-7</strong> Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.</td>
<td><strong>MS-LS1-8</strong> Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.</td>
</tr>
<tr>
<td><strong>MS-LS3-2</strong> Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.</td>
<td><strong>PA Stds</strong></td>
</tr>
<tr>
<td><strong>S8.B.1.1.1</strong> Describe the structures of living things that help them function effectively in specific ways (e.g., adaptations, characteristics).</td>
<td><strong>S8.B.1.1.2</strong> Compare similarities and differences in internal structures of organisms (e.g., invertebrate/vertebrate, vascular/nonvascular, single-celled/multi-celled) and external structures (e.g., appendages, body segments, type of covering, size, shape).</td>
</tr>
<tr>
<td><strong>S8.B.1.1.3</strong> Apply knowledge of characteristic structures to identify or categorize organisms (i.e., plants, animals, fungi, bacteria, and protista).</td>
<td><strong>S8.B.1.1.4</strong> Identify the levels of organization from cell to organism and describe how specific structures (parts), which underlie larger systems, enable the system to function as a whole.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Why is There Life on Earth?</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS-PS1-1</strong> Develop models to describe the atomic composition of simple molecules and extended structures.</td>
<td><strong>MS-PS3-3</strong> Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*</td>
</tr>
<tr>
<td><strong>MS-LS1-6</strong> Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.</td>
<td><strong>MS-LS1-7</strong> Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.</td>
</tr>
<tr>
<td>MS-LS1-4</td>
<td>Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.</td>
</tr>
<tr>
<td>MS-LS3-2</td>
<td>Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.</td>
</tr>
</tbody>
</table>

Incorporates previous Eligible Content.
Grade 7 Course Description - This course of study is designed for students at any ability level. Using the Next Generation Science Standards (NGSS), students will develop an understanding of energy, the particulate nature of matter, weather, plate tectonics, and their effects on the environment. To help students better understand the science concepts embedded in these units, the appropriate NGSS Science Practices and Crosscutting Concepts will be applied. Emphasis is given to the development of quantitative skills necessary for scientific measurement and establishing evidence based explanations and conceptual models. Throughout the course students will develop good reading skills, motivation, perseverance and the ability to share thinking both verbally and in written form. The course includes hands-on/minds-on and STEM related activities, as well as laboratory experiences correlated with large and small group work.

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Energy - It's time to    | **NGSS**  
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.  
MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.  
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.  
MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*  
MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.  
**PA Stds**  
S8.C.2.1.1 Distinguish among forms of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) and sources of energy (i.e., renewable and nonrenewable energy).  
PA S8.C.2.1.2 Explain how energy is transferred from one place to another through convection, conduction, or radiation.  
PA S8.C.2.1.3 Describe how one form of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) can be converted into a different form of energy. |
| Under Pressure           | **NGSS**  
MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.  
MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. |
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Weather, Hurricanes, Tornado’s, Oh My! Hurricanes and Why Water is Special

NGSS

MS-PS4-1: Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
MS-ESS2-1: Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.
MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.
MS-ESS2-4: Develop a model to describe the cycling of water through Earth’s systems driven by energy from the sun and the force of gravity.
MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.
MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

I Felt the Earth Move Under My Feet.

NGSS

MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth’s mineral, energy, and groundwater resources are the result of past and current geoscience processes.
MS-ESS2-3. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.
MS-ESS2-1. Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.
MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.

PA Stds
S8.D.1.1.1 Explain the rock cycle as changes in the solid earth and rock types (igneous – granite, basalt, obsidian, pumice; sedimentary – limestone, sandstone, shale, coal; and metamorphic – slate, quartzite, marble, gneiss).
S8.D.1.1.2 Describe natural processes that change Earth’s surface (e.g., landslides, volcanic eruptions, earthquakes, mountain building, new land
being formed, weathering, erosion, sedimentation, soil formation).
S8.D.1.1.3 Identify soil types (i.e., humus, topsoil, subsoil, loam, loess, and parent material) and their characteristics (i.e., particle size, porosity, and permeability) found in different biomes and in Pennsylvania, and explain how they formed.

| I Will Survive | NGSS
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS-LS2-1.</strong> Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.</td>
<td><strong>S8.D.1.3.2</strong> Compare and contrast characteristics of freshwater and saltwater systems on the basis of their physical characteristics (i.e., composition, density, and electrical conductivity) and their use as natural resources.</td>
</tr>
<tr>
<td><strong>MS-LS2-2.</strong> Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.</td>
<td><strong>S8.D.1.3.3</strong> Distinguish among different water systems (e.g., wetland systems, ocean systems, river systems, watersheds) and describe their relationships to each other as well as to landforms.</td>
</tr>
<tr>
<td><strong>MS-LS2-3.</strong> Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.</td>
<td><strong>S8.D.1.3.4</strong> Identify the physical characteristics of a stream and how these characteristics determine the types of organisms found within the stream environment (e.g., biological diversity, water quality, flow rate, tributaries, surrounding watershed).</td>
</tr>
<tr>
<td><strong>MS-LS2-4.</strong> Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.</td>
<td><strong>S8.B.3.1.1</strong> Explain the flow of energy through an ecosystem (e.g., food chains, food webs).</td>
</tr>
<tr>
<td><strong>MS-LS2-5.</strong> Evaluate competing design solutions for maintaining biodiversity and ecosystem services.*</td>
<td><strong>S8.B.3.1.2</strong> Identify major biomes and describe abiotic and biotic components (e.g., abiotic: different soil types, air, water sunlight; biotic: soil microbes, decomposers).</td>
</tr>
<tr>
<td><strong>MS-ESS2-2.</strong> Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.</td>
<td><strong>S8.B.3.1.3</strong> Explain relationships among organisms (e.g., producers/consumers, predator/prey) in an ecosystem</td>
</tr>
<tr>
<td></td>
<td><strong>S8.B.3.3.1</strong> Explain how human activities may affect local, regional, and global environments.</td>
</tr>
<tr>
<td></td>
<td><strong>S8.B.3.3.2</strong> Explain how renewable and nonrenewable resources provide for human needs (i.e., energy, food, water, clothing, and shelter).</td>
</tr>
<tr>
<td></td>
<td><strong>S8.B.3.3.3</strong> Describe how waste management affects the environment (e.g., recycling, composting, landfills, incineration, sewage treatment).</td>
</tr>
</tbody>
</table>
Grade 8 Course Description - This course of study is designed for students at any ability level. Using the Next Generation Science Standards (NGSS) and the theme of “Change”, students will develop an understanding of Chemical Changes, Changes to Organisms and the Earth over Time, and Climate Change. To help students better understand the science concepts embedded in these units, the appropriate NGSS Science Practices and Crosscutting Concepts will be applied. Emphasis is given to the development of quantitative skills necessary for scientific measurement and establishing evidence based explanations and conceptual models. Throughout the course students will develop good reading skills, motivation, perseverance and the ability to share thinking both verbally and in written form. The course includes hands-on/minds-on and STEM related activities, as well as laboratory experiences correlated with large and small group work.
<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Chemical Changes           | **NGSS**  
  MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.  
  MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.  
  MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.  
  MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.  
  MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*  
  MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*  
  MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.  
  MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.  
  **PA Stds**  
  S8.C.1.1.1 Explain the differences among elements, compounds, and mixtures.  
  S8.C.1.1.2 Use characteristic physical or chemical properties to distinguish one substance from another (e.g., density, thermal expansion/contraction, freezing/melting points, streak test).  
  S8.C.1.1.3 Identify and describe reactants and products of simple chemical reactions. |
| Evolution and Geologic Time| **NGSS**  
  MS-ESS1-4. Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.  
  MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.  
  MS-LS4-3. Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.  
  MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.  
  MS-LS3-1. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. |
function of the organism.

**MS-LS4-4.** Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals’ probability of surviving and reproducing in a specific environment.

**MS-LS4-5.** Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

**MS-LS4-6.** Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

**PA Stds**

- **S8.D.1.1.4** Explain how fossils provide evidence about plants and animals that once lived throughout Pennsylvania’s history (e.g., fossils provide evidence of different environments).
- **S8.B.2.1.1** Explain how inherited structures or behaviors help organisms survive and reproduce in different environments.
- **S8.B.2.1.2** Explain how different adaptations in individuals of the same species may affect survivability or reproductive success.
- **S8.B.2.1.3** Explain that mutations can alter a gene and are the original source of new variations.
- **S8.B.2.1.4** Describe how selective breeding or biotechnology can change the genetic makeup of organisms.
- **S8.B.2.1.5** Explain that adaptations are developed over long periods of time and are passed from one generation to another.
- **S8.B.2.2.1** Identify and explain differences between inherited and acquired traits.
- **S8.B.2.2.2** Recognize that the gene is the basic unit of inheritance, that there are dominant and recessive genes, and that traits are inherited.

### Climate Change

**NGSS**

- **MS-ESS2-1.** Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.
- **MS-ESS2-6.** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
- **MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s systems.
- **MS-ESS3-5.** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
- **MS-ESS2-5:** Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

**PA Stds**

- **S8.D.2.1.2** Identify how global patterns of atmospheric movement influence regional weather and climate.
High School Science Courses

<table>
<thead>
<tr>
<th>Earth Systems Science - Earth Systems Science 1 and Advanced Earth Systems Science 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Earth Systems Science 1 Course Description</strong> - The class provides an investigation of the Earth systems as they relate to the topics of astronomy, geology, oceanography, and meteorology. Students will explore the interactions among these components in order to explain Earth’s dynamics, Earth’s evolution, global change and Earth’s place within the universe. Students who take this course will utilize their mathematics knowledge with the guidance of the teachers. Students who pass this course may not elect to take Advanced Earth Systems Science at a later date. Evaluation of the students is based on tests, quizzes, laboratory exercises, homework and special assignments. <strong>Adv. Earth Systems Science 1 Course Description</strong> - This course is recommended for students who have above average skills in mathematics (completion of Algebra 1) and who plan on pursuing a career in the fields of science and engineering. The class provides an in-depth look at the Earth systems, as they relate to the topics of astronomy, geology, oceanography, and meteorology. The nature of this advanced course is such that students study the topics in greater detail at a pace that provides for further enrichment. Students who take this course will utilize their knowledge of mathematics and apply to specific earth science concepts. Students will be expected to demonstrate independent, higher order thinking and problem-solving skills, as measured through assessments, laboratory exercises, data analysis, homework assignments, special assignments and class discussions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit Title</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Science Methodology</td>
<td>NGSS&lt;br&gt;HS - ESS1-4 (Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.)&lt;br&gt;HS - ESS1-5 (Empirical evidence is needed to identify patterns.)&lt;br&gt;PA Stds&lt;br&gt;3.3.10.A8 (Compare and contrast scientific theories, identify questions and concepts that guide scientific investigations, explain the importance of accuracy and precision in making valid measurements.)&lt;br&gt;3.1.10.D.1. Apply dimensional analysis and scale as a ratio.3.1.10.D.2. Convert one scale to another.&lt;br&gt;Eligible Content&lt;br&gt;BIO.B.3.3.1 Distinguish between the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.</td>
</tr>
<tr>
<td>Unit 2: Earth’s Place in the Universe</td>
<td>NGSS&lt;br&gt;HS - ESS1-1 (Develop a model based on evidence to illustrate the lifespan of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.)&lt;br&gt;HS - ESS1-2 Construct an explanation of the Big Band Theory based on the astronomical evidence of light spectra, motion of distant galaxies, and...</td>
</tr>
</tbody>
</table>
### Unit 3: Earth’s Systems

**NGSS**
- HS-ESS1-5 Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.
- HS-ESS2-1 Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.
- HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.
- HS-ESS2-5 Investigate the properties of water and its effects on Earth materials and surface properties.

**PA Stds**
- 3.5.10.A. Relate earth features and processes that change the earth.
- 3.5.10.B. Explain sources and uses of earth resources.

**Eligible Content:**
- BIO.B.4.2.3 - Describe how matter recycles through an ecosystem (i.e., water cycle, carbon cycle, oxygen cycle and nitrogen cycle - using the intro to soil to construct the conversation)
- BIO.B.4.2.4: Describe how ecosystems change in response to natural and human disturbances (e.g. climate changes, introduction of nonnative species, pollution, fires).

### Unit 4: Earth’s Processes and Human Activity

**NGSS**
- HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in the climate have influenced human activity.
- HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth’s system.
- HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
- HS-ESS2-7: Construct an argument based on evidence about the simultaneous co-evolution of Earth’s systems and life on Earth.

**PA Stds**
3.1.10.A.2. Describe the interrelationships among inputs, processes, outputs, feedback and control in specific systems.
3.1.10.B. Describe concepts of models as a way to predict and understand science and technology.
3.1.10.E. Describe patterns of change in nature, physical and man made systems.

Eligible Content:
BIO B.3.1.2 Describe the factors that can contribute to the development of new species (e.g. geology as an isolating mechanism)
BIO B.3.2.1 Interpret evidence supporting the theory of evolution (i.e. fossils)

---

**Earth Systems Science - Advanced Astronomy**

**Course Description** - This is a semester course designed for college-bound students seeking in-depth experiences in the Earth Systems Sciences. Emphasis is placed on understanding the physical environment through an increased awareness of the processes of science. A historical introductory unit combined with planetarium exercises will begin the search for natural laws that eventually will allow lessons to focus on planets, stars, galaxies and cosmology. This course of study builds on the astronomy concepts covered in all Earth Systems Science courses.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Backyard Astronomy | NGSS  
HS-ESS1-1 (Develop a model based on evidence to illustrate the lifespan of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.) Cross-cutting concept - Scientific Knowledge Assumes an Order Consistency in Natural Systems  
HS-ESS1-4 (Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.) Cross-cutting concept - Scientific Knowledge Assumes an Order Consistency in Natural Systems  
PA Stds  
S11.A.2.2.2: Explain how technology (e.g., GPS, spectroscope, scanning electron microscope, pH meter, probe, interface, imaging technology, telescope) is used to extend human abilities and precision.  
S11.A.3.3.3: Analyze physical patterns of motion to make predictions or draw conclusions (e.g., solar system, tectonic plates, weather systems, atomic motion, waves). |
| Unit 2: Tools and Development of Astronomy | NGSS:  
|-----------------------------------------|----------------------------------|
|                                         | HS-ESS1-2: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.  
|                                         | HS-ESS1-4: Use mathematical of computational representations to predict the motion of orbiting objects in the solar system.  

| Unit 3: Living and Working Space | NGSS:  
|----------------------------------|----------------------------------|
|                                  | 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.  
|                                  | ETS1.B: Developing Possible Solutions  
|                                  | When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)  
|                                  | HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.  
|                                  | HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*  
|                                  | HS-ESS3-3 Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.  
|                                  | HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.  
|                                  | HS-ESS1-2 Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.  

| Unit 4: Stars | NGSS  
|--------------|----------------------------------|
| HS-ESS1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.  
| HS-ESS1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements.  

| Unit 5: Galaxies and Cosmology | NGSS  
|----------------------------------|----------------------------------|
| HS-ESS1-2 Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.  

**Earth Systems Science - Advanced Geology**

**Course Description** - This semester course is designed for college-bound students seeking in-depth experiences in Earth Systems Science. Emphasis is placed on understanding the physical environment.
through an increased awareness of the processes of science. Areas covered include composition and deformation of the Earth’s crust, mineralology and petrography; sedimentology and stratigraphy; interpretation of topographical maps and aerial photographs; weathering and the development of landforms caused by mass-wasting, streams, groundwater, wind and glaciers; structural geology and reading geologic maps.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| **Unit 1: Rocks and Minerals**| **NGSS:**  
HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.  
HS-ESS1-6 - Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history.  
HS-ESS2-1 - Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. |
| **Unit 2: Landforms**         | **NGSS**  
HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.  
HS-ESS1-6 - Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history.  
HS-ESS1-5 - Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.  
HS-ESS2-3 - Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection.  
HS-ESS2-5 - Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. |
| **Unit 3: Historical Geology** | **NGSS**  
HS-ESS1-6 - Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history.  
HS-ESS1-5 - Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.  
HS-ESS2-1 - Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.  
HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.  
HS-ESS2-3 - Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection. |
| **Unit 4: Structural Geology** | **NGSS**  
HS-ESS1-6 - Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth’s formation and early history. |
### Earth Systems Science - Advanced Meteorology

**Course Description** - This semester course, along with other advanced Earth Science electives, is designed for college-bound students seeking in-depth experiences in Earth Science. Emphasis is placed on understanding the physical environment through an increased awareness of the processes of science. Areas covered include structures and composition of the atmosphere, heating of the atmosphere, atmospheric motion, storms, hazardous weather and weather prediction and modification. Evaluation is based on tests, quizzes, laboratory activities and projects. This course of study builds on the meteorology concepts covered in all Earth System Science courses.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit 1: Properties of the Atmosphere</strong></td>
<td>NGSS:</td>
</tr>
<tr>
<td></td>
<td>HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.</td>
</tr>
<tr>
<td></td>
<td>HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.</td>
</tr>
<tr>
<td><strong>Unit 2: Stability and System Development</strong></td>
<td>NGSS:</td>
</tr>
<tr>
<td></td>
<td>HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.</td>
</tr>
<tr>
<td></td>
<td>HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.</td>
</tr>
<tr>
<td></td>
<td>Eligible Content:</td>
</tr>
<tr>
<td></td>
<td>BIO.B.4.2.3 - Describe how matter recycles through an ecosystem (i.e., water cycle, carbon cycle, oxygen cycle and nitrogen cycle - using the intro to soil to construct the conversation)</td>
</tr>
<tr>
<td></td>
<td>BIO.B.4.2.4: Describe how ecosystems change in response to natural and human disturbances (e.g. climate changes, introduction of nonnative species, pollution, fires).</td>
</tr>
</tbody>
</table>
| Unit 3: Mid-latitude cyclones and severe weather forecasting | NGSS  
HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth’s systems result in changes in climate.  
HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth’s systems.  

PA Stds  
3.5.10.A. Relate earth features and processes that change the earth.  
3.5.10.B. Explain sources and uses of earth resources.  

Eligible Content:  
BIO.B.4.2.3 - Describe how matter recycles through an ecosystem (i.e., water cycle, carbon cycle, oxygen cycle and nitrogen cycle - using the intro to soil to construct the conversation)  
BIO.B4.2.4: Describe how ecosystems change in response to natural and human disturbances (e.g. climate changes, introduction of nonnative species, pollution, fires. |
| --- | --- |
| Unit 4: Tropical Cyclones, Heat waves, and Drought | NGSS  
HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth’s systems result in changes in climate.  
HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth’s systems.  

Eligible Content:  
BIO.B.4.2.3 - Describe how matter recycles through an ecosystem (i.e., water cycle, carbon cycle, oxygen cycle and nitrogen cycle - using the intro to soil to construct the conversation)  
BIO.B4.2.4: Describe how ecosystems change in response to natural and human disturbances (e.g. climate changes, introduction of nonnative species, pollution, fires. |

---

Earth Systems Science - Advanced Oceanography

**Course Description:** This semester course, along with other advanced Earth Science electives, is designed for college-bound students seeking in-depth experiences in Earth Science. Emphasis is placed on understanding the physical environment through an increased awareness of the processes of science. Areas covered include the impact of oceans on everyday life; methods of oceanographic research; chemistry, salinity, temperature and motion of water; submarine and coastal landforms; erosion and deposition of ocean sediments; marine ecology; and oceans as a resource.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Intro to Oceans and Instrumentation | NGSS:  
HS-ESS1-4 Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.  
HS-ESS1-5 Empirical evidence is needed to identify patterns. |
<table>
<thead>
<tr>
<th>Unit 2: Sediments</th>
<th>NGSS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-ESS2-5. Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.</td>
<td></td>
</tr>
<tr>
<td>HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.</td>
<td></td>
</tr>
<tr>
<td>HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.</td>
<td></td>
</tr>
<tr>
<td>HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth.</td>
<td></td>
</tr>
<tr>
<td>HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.</td>
<td></td>
</tr>
<tr>
<td>HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*</td>
<td></td>
</tr>
<tr>
<td>HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit 3: Chemistry of Seawater</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.</td>
<td></td>
</tr>
<tr>
<td>HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.</td>
<td></td>
</tr>
<tr>
<td>HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.</td>
<td></td>
</tr>
</tbody>
</table>
| Unit 4: Circulation | HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.  
HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 5: Waves and Coastal Landforms</td>
<td></td>
</tr>
</tbody>
</table>
**NGSS**  
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.  
HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth.  
HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.  
HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.  
HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. |
| Unit 6: Marine Ecology |  
**NGSS**  
HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.  
HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth’s surface can create feedbacks that cause changes to other Earth systems.  
HS-ESS2-7. Construct an argument based on evidence about the simultaneous coevolution of Earth’s systems and life on Earth.  
HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.  
HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. |
**Biology - Biology 1 and Adv. Biology**

**Biology 1 Course Description:** This course introduces the fundamental principles in the field of biology and provides a foundation for further studies in biology at State High and in the post secondary. Units of study include: Principles of Biology, Chemical Basis of Life, Bioenergetics, Homeostasis and Transport, Cell Growth and Reproduction, Genetics, Theory of Evolution, and Ecology. Laboratory activities are emphasized. This course meets state required biology standards and prepares students for the required Keystone Biology Exam.

**Adv. Biology 1 Course Description:** This course provides an in-depth and rigorous study of fundamental topics within the field of biology with an emphasis on cellular, molecular and environmental concepts. Units of study include: Principles of Biology, Chemical Basis of Life, Bioenergetics, Homeostasis and Transport, Cell Growth and Reproduction, Genetics, Theory of Evolution, and Ecology. Laboratory activities are emphasized. A high level of reading and math computational skills are essential for this course. This course meets the state required biology standards and prepares students for the required Keystone Biology Exam.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Nature of Science and Characteristics of Life | NGSS:  
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems the provide specific functions within multicellular organisms  
HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.  
Keystone Eligible Content  
BIO.A.1. 1 Explain the characteristics common to all organisms.  
BIO.B.2.4 Apply scientific thinking, processes, tools, and technologies |

37
| Unit 2: Chemical Basis for Life | NGSS:  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>
| Keystone Eligible Content | BIO.A.2. 1. Describe how the unique properties of water support life on Earth.  
BIO.A.2. 1.1. Describe the unique properties of water and how these properties support life on Earth (e.g., freezing point, high specific heat, cohesion).  
BIO.A.2. 2. Describe and interpret relationships between structure and function at various levels of biochemical organization (i.e., atoms, molecules, and macromolecules).  
BIO.A.2. 2.1. Explain how carbon is uniquely suited to form biological macromolecules.  
BIO.A.2. 2.2. Describe how biological macromolecules form from monomers.  
BIO.A.2. 2.3. Compare the structure and function of carbohydrates, lipids, proteins, and nucleic acids in organisms.  
BIO.A.2. 3. Explain how enzymes regulate biochemical reactions within a cell.  
BIO.A.2. 3.1. Describe the role of an enzyme as a catalyst in regulating a specific biochemical reaction.  
BIO.A.2. 3.2. Explain how factors such as pH, temperature, and concentration levels can affect enzyme function. |
| Unit 3: Cell Structure, Function, and Transport | NGSS:  
| HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  
HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. |
| Keystone Eligible Content | BIO.A.1.1.1. Describe the characteristics of life shared by all prokaryotic and eukaryotic organisms.  
BIO.A.1.2.2. Describe and interpret relationships between structure and function at various levels of biological organization.  
BIO.A.4.1. Identify and describe the cell structures involved in transport of materials into, out of, and throughout a cell.  
BIO.A.4.1.1: Describe how the structure of the plasma membrane allows it to function as a regulatory structure and/or protective barrier for a cell.  
BIO.A.4.1.2: Compare and contrast the mechanisms that transport materials across the plasma membrane (i.e., passive transport -- diffusion, osmosis, facilitated diffusion; active transport -- pumps, endocytosis, exocytosis). |
| BIO.A.4.1.3 | Describe how endoplasmic reticulum, Golgi apparatus, and other membrane-bound cellular organelles facilitate transport of materials within cells. BIO.A.4. 2. Explain mechanisms that permit organisms to maintain biological balance between their internal and external environments. BIO.A.4.2.1: Explain how organisms maintain homeostasis (e.g., thermoregulation, water regulation, oxygen regulation). |
| Unit 4: Bioenergetics | NGSS: HS-LS-1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. HS-LS-1-6 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-LS-1-7 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-LS-1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. |
| Keystone Eligible Content | BIO.A.3. 1. Identify and describe the cell structures involved in processing energy. BIO.A.3. 1.1. Describe the fundamental roles of plastids (e.g., chloroplasts) and mitochondria in energy transformations. BIO.A.3. 2. Identify and describe how organisms obtain and transform energy for their life processes. BIO.A.3.2.1: Compare and contrast the basic transformation of energy during photosynthesis and cellular respiration. BIO.A.3.2.2: Describe the role of ATP in biochemical reactions. |
| Unit 5: Cell Growth and Reproduction | NGSS: HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population |
| Keystone Eligible Content | BIO.B.1. 1. Describe the three stages of the cell cycle: interphase, nuclear division, cytokinesis. BIO.B.1. 1.1. Describe the events that occur during the cell cycle: interphase, nuclear division (i.e., mitosis or meiosis), cytokinesis. BIO.B.1. 1.2. Compare the processes and outcomes of mitotic and meiotic nuclear divisions. BIO.B.1.2. Explain how genetic information is inherited. BIO.B.1.2.1. Describe how the process of DNA replication results in the |
| Unit 6: DNA/RNA/Protein Synthesis | NGSS:  
HS-LS1-1 - Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. 
HS-LS1-2 - Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. 
HS-LS1-3 - Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.  

Keystone Eligible Content  
BIO.B.1.2. Explain how genetic information is inherited.  
BIO.B.1.2.1: Describe how the process of DNA replication results in the transmission and/or conservation of genetic information.  
BIO.B.1.2.2: Explain the functional relationships among DNA, genes, alleles, and chromosomes and their roles in inheritance.  
BIO.B.2.1.1: Describe and/or predict observed patterns of inheritance (i.e., dominant, recessive, co-dominance, incomplete dominance, sex-linked, polygenic, and multiple alleles).  
BIO.B.2.1.2: Describe processes that can alter composition or number of chromosomes (i.e., crossing-over, nondisjunction, duplication, translocation, deletion, insertion, and inversion).  
BIO.B.2.2. Explain the process of protein synthesis (i.e., transcription, translation, and protein modification).  
BIO.B.2.2.1: Describe how the processes of transcription and translation are similar in all organisms.  
BIO.B.2.2.2: Describe the role of ribosomes, endoplasmic reticulum, Golgi apparatus, and the nucleus in the production of specific types of proteins.  
BIO.B.2.3. Explain how genetic information is expressed.  
BIO.B.2.3.1: Describe how genetic mutations alter the DNA sequence and may or may not affect phenotype (e.g., silent, nonsense, frame-shift).  
BIO.B.2.4.1: Explain how genetic engineering has impacted the fields of medicine, forensics, and agriculture (e.g., selective breeding, gene splicing, cloning, genetically modified organisms, gene therapy)  

| Unit 7: Genetics | NGSS  
HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.  

Keystone Eligible Content  
BIO.B.2. 1.1. Describe and/or predict observed patterns of inheritance (i.e., dominant, recessive, co-dominance, incomplete dominance, sex-linked, polygenic, and multiple alleles).  
BIO.B.2. 3. Explain how genetic information is expressed.  
BIO.B.2. 4. Apply scientific thinking, processes, tools, and technologies in the study of genetics.  
BIO.B.2. 4.1. Explain how genetic engineering has impacted the fields of |
<table>
<thead>
<tr>
<th>Unit 8: Theory of Evolution</th>
<th>NGSS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS4-1 - Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.</td>
<td></td>
</tr>
<tr>
<td>HS-LS4-2 - Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.</td>
<td></td>
</tr>
<tr>
<td>HS-LS4-3 - Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.</td>
<td></td>
</tr>
<tr>
<td>HS-LS4-4 - Construct an explanation based on evidence for how natural selection leads to adaptation of populations.</td>
<td></td>
</tr>
<tr>
<td>HS-LS4-5 - Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.</td>
<td></td>
</tr>
</tbody>
</table>

Keystone Eligible Content

BIO.B.3. 1. Explain the mechanisms of evolution.
BIO.B.3. 1.1. Explain how natural selection can impact allele frequencies of a population.
BIO.B.3. 1.2. Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).
BIO.B.3. 1.3. Explain how genetic mutations may result in genotypic and phenotypic variations within a population.
BIO.B.3. 2. Analyze the sources of evidence for biological evolution.
BIO.B.3. 2.1. Interpret evidence supporting the theory of evolution (i.e., fossil, anatomical, physiological, embryological, biochemical, and universal genetic code).
BIO.B.3. 3. Apply scientific thinking, processes, tools, and technologies in the study of the theory of evolution.
BIO.B.3. 3.1. Distinguish between the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.

<table>
<thead>
<tr>
<th>Unit 9: Ecology</th>
<th>NGSS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS2-1 - Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</td>
<td></td>
</tr>
<tr>
<td>HS-LS2-2 - Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>HS-LS2-4 - Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.</td>
<td></td>
</tr>
</tbody>
</table>
| HS-LS2-5 - Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere,
hydrosphere, and geosphere.

HS-LS2-6 - Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

HS-LS2-7 - Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*

HS-LS2-8 - Evaluate evidence for the role of group behavior on individual and species’ chances to survive and reproduce.

Keystone Eligible Content

BIO.B.4. 1.1. Describe the levels of ecological organization (i.e., organism, population, community, ecosystem, biome, and biosphere).

BIO.B.4. 1.2. Describe characteristic biotic and abiotic components of aquatic and terrestrial ecosystems.

BIO.B.4. 2. Describe interactions and relationships in an ecosystem.

BIO.B.4. 2.1. Describe how energy flows through an ecosystem (e.g., food chains, food webs, energy pyramids).

BIO.B.4. 2.2. Describe biotic interactions in an ecosystem (e.g., competition, predation, symbiosis).

BIO.B.4. 2.3. Describe how matter recycles through an ecosystem (i.e., water cycle, carbon cycle, oxygen cycle, and nitrogen cycle).

BIO.B.4. 2.4. Describe how ecosystems change in response to natural and human disturbances (e.g., climate changes, introduction of nonnative species, pollution, fires).

BIO.B.4. 2.5. Describe the effects of limiting factors on population dynamics and potential species extinction

Biology - Advanced Botany

Course Description: Botany is the study of plants and their relationship with the environment. This semester course along with other advanced biology electives is designed for college-bound students seeking in-depth experiences in biology. The areas of study include plant diversity, anatomy, hormones, nutrition, transport, and ecology while integrating appropriate concepts in chemistry. In addition, the class will research a variety of plant-based topics including plant-pollinator interactions, growth patterns, invasive species, and GMO crops. This course relies heavily on laboratory activities and requires regular attendance.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Diversity and Life Cycles | NGSS:  
|                       | HS-LS1-2 From Molecules to Organisms: Structures and Processes Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  
|                       | HS-LS2-2 Interactions, Energy, and Dynamics Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.  
|                       | HS-LS2-7 Interactions, Energy, and Dynamics Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.  
|                       | HS-LS4-1 Biological Evolution: Unity and Diversity Communicate scientific                   |
information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

PA Stds
3.1.12.A9 Compare and contrast scientific theories.
Know that both direct and indirect observations are used by scientists to study the natural world and universe. Identify questions and concepts that guide scientific investigations. Formulate and revise explanations and models using logic and evidence. Recognize and analyze alternative explanations and models. Explain the importance of accuracy and precision in making valid measurements. Examine the status of existing theories. Evaluate experimental information for relevance and adherence to science processes. Judge that conclusions are consistent and logical with experimental conditions. Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. Communicate and defend a scientific argument.

3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.
3.1.12.A2 Evaluate how organisms must derive energy from their environment or their food in order to survive.
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.
3.1.10.A1 Explain the characteristics of life common to all organisms.
3.1.10.A3 Compare and contrast the life cycles of different organisms.

Unit 2: Structure, Growth, and Development

NGSS:
HS-LS1-2 From Molecules to Organisms: Structures and Processes Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS2-8 Ecosystems: Interactions, Energy, and Dynamics Evaluate evidence for the role of group behavior on individual and species’ chances to survive and reproduce.
HS-LS4-1 Biological Evolution: Unity and Diversity Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
HS-LS4-2 Biological Evolution: Unity and Diversity Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

PA Stds
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.
3.1.B.A1 Compare and contrast the cellular structures and degrees of complexity of prokaryotic and eukaryotic organisms. Explain that some structures in
eukaryotic cells developed from early prokaryotic cells (e.g., mitochondria, chloroplasts).
3.1.B.A3 Explain how all organisms begin their life cycles as a single cell and that in multicellular organisms, successive generations of embryonic cells form by cell division.
3.1.B.A6 Explain how cells differentiate in multicellular organisms.
3.1.12.B2 Evaluate the process of sexual reproduction in influencing genetic variability in a population

<table>
<thead>
<tr>
<th>Unit 3: Photosynthesis</th>
<th>NGSS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS1-5 From Molecules to Organisms: Structures and Processes Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.</td>
<td></td>
</tr>
<tr>
<td>HS-LS1-6 From Molecules to Organisms: Structures and Processes 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.</td>
<td></td>
</tr>
<tr>
<td>HS-LS1-7 From Molecules to Organisms: Structures and Processes 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.</td>
<td></td>
</tr>
<tr>
<td>HS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.</td>
<td></td>
</tr>
</tbody>
</table>

| PA Stds: |
| 3.1.B.A2 Identify the initial reactants, final products, and general purposes of photosynthesis and cellular respiration. Explain the important role of ATP in cell metabolism. Describe the relationship between photosynthesis and cellular respiration in photosynthetic organisms. |
| 3.1.B.A5 Relate the structure of cell organelles to their function (energy capture and release, transport, waste removal, protein synthesis, movement, etc). |
| 3.1.B.A7 Analyze the importance of carbon to the structure of biological macromolecules. |

<table>
<thead>
<tr>
<th>Unit 4: Plant Nutrition and Transport</th>
<th>NGSS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS1-2 From Molecules to Organisms: Structures and Processes Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
<td></td>
</tr>
<tr>
<td>HS-LS1-3 From Molecules to Organisms: Structures and Processes Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td>
<td></td>
</tr>
<tr>
<td>HS-LS1-6 From Molecules to Organisms: Structures and Processes 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.</td>
<td></td>
</tr>
<tr>
<td>HS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</td>
<td></td>
</tr>
<tr>
<td>HS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics Use mathematical</td>
<td></td>
</tr>
</tbody>
</table>
representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

PA Standards:
3.1.B.A8 - Describe how the unique properties of water support life.

Advanced Placement Essential Knowledge
2.A.1 - All living systems require constant input of free energy.
2.A.3 - Organisms must exchange matter with the environment to grow, reproduce and maintain organization.

<table>
<thead>
<tr>
<th>Unit 5: Biotechnology</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS3-2 Heredity: Inheritance and Variation of Traits</td>
<td>Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.</td>
</tr>
</tbody>
</table>

PA Standards
3.1.12.B4 - Evaluate the societal impact of genetic engineering techniques and applications.
3.1.B.B4 Explain how genetic technologies have impacted the fields of medicine, forensics, and agriculture

Advanced Placement Essential Knowledge
3.A.1 - DNA, and in some cases RNA, is the primary source of heritable information.
4.B.3 - Interactions between and within populations influence patterns of species distribution and abundance.
4.B.3 - Distribution of local and global ecosystems changes over time.

<table>
<thead>
<tr>
<th>Unit 6: Plant Hormones and Responses</th>
<th>NGSS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS1-3 From Molecules to Organisms: Structures and Processes</td>
<td>Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td>
</tr>
<tr>
<td>HS-LS1-2 From Molecules to Organisms: Structures and Processes</td>
<td>Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
</tr>
<tr>
<td>HS-LS3-3 Heredity: Inheritance and Variation of Traits</td>
<td>Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.</td>
</tr>
<tr>
<td>HS-LS3-2</td>
<td>Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.</td>
</tr>
</tbody>
</table>

PA Stds
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.
3.1.12.A6 Analyze how cells in different tissues/organisms are specialized to
**Biology - Advanced Genetics**

**Course Description:** Genetics is the study of genes, gene variation, and heredity. This semester course along with other advanced biology electives is designed for college-bound students seeking in-depth experiences in biology. Topics include cell division, genetics of viruses and bacteria, Mendelian inheritance, chromosomal inheritance, molecular genetics, and DNA technologies while integrating appropriate topics in chemistry. Particular emphasis is placed on development of current biotechnology procedures. This course relies heavily on laboratory activities and requires regular attendance.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit 1: Cell Cycle And Meiosis</strong></td>
<td><strong>NGSS</strong></td>
</tr>
<tr>
<td></td>
<td>HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms</td>
</tr>
<tr>
<td></td>
<td>HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring</td>
</tr>
<tr>
<td></td>
<td>HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors</td>
</tr>
<tr>
<td></td>
<td><strong>PA Stds</strong></td>
</tr>
<tr>
<td></td>
<td>3.1.B.A4 Summarize the stages of the cell cycle. Examine how interactions among the different molecules in the cell cause the distinct stages of the cell cycle which can also be influenced by other signaling molecules. Explain the role of mitosis in the formation of new cells and its importance in maintaining chromosome number during asexual reproduction.</td>
</tr>
<tr>
<td></td>
<td>3.2.10.A Describe the cell cycle and the process and significance of mitosis.</td>
</tr>
<tr>
<td></td>
<td><strong>Advanced Placement Essential Knowledge</strong></td>
</tr>
<tr>
<td></td>
<td>3.A.2 - In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle and mitosis or meiosis plus fertilization</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Unit 2: Mendel and the Chromosomal Basis of Inheritance</strong></th>
<th><strong>NGSS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.</td>
</tr>
<tr>
<td></td>
<td>HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.</td>
</tr>
</tbody>
</table>

**AP Standards Essential Knowledge**

2.B.2 - A variety of intercellular and intracellular signal transmissions mediate gene expression
3.D. 2 - Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.

3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs.
viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

PA Stds
3.1.B.B5  Describe how Mendel’s laws of segregation and independent assortment can be observed through patterns of inheritance. Distinguish among observed inheritance patterns caused by several types of genetic traits (dominant, recessive, codominant, sex-linked, polygenic, incomplete dominance, multiple alleles)
3.1.B.A9  Compare and contrast scientific theories. Know that both direct and indirect observations are used by scientists to study the natural world and universe. Identify questions and concepts that guide scientific investigations. Formulate and revise explanations and models using logic and evidence. Recognize and analyze alternative explanations and models. Explain the importance of accuracy and precision in making valid measurements. Examine the status of existing theories. Evaluate experimental information for relevance and adherence to science processes. Judge that conclusions are consistent and logical with experimental conditions. Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. Communicate and defend a scientific argument.

Advanced Placement Essential Knowledge
3.A.3- The Chromosomal basis of inheritance provides an understanding of the pattern of passage of genes from parent to offspring.
3.A.4 - The inheritance pattern of many traits cannot be explained by simple Mendelian genetics

Unit 3: The Molecular Basis of Inheritance: From Gene to Protein

NGSS
HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells
HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

PA Stds:
3.1.12.B3 - Analyze gene expression at the molecular level. Explain the impact of environmental factors on gene expression.
3.1.12.B4 - Evaluate the societal impact of genetic engineering techniques and applications.

Advanced Placement Essential Knowledge
2.E.1 - Timing and coordination of specific events are necessary for the normal development of organisms, and these events are regulated by a variety of mechanisms.

3.A.1 - DNA, and in some cases RNA, is the primary source of heritable information.

3.C.1 - Changes in genotype can result in changes in phenotype.

3.C.2 - Biological systems have multiple processes that increase genetic variation.

4.A.1 - The subcomponents of biological molecules and their sequence determines the properties of that molecule.

---

**Unit 4: Viruses**

**NGSS**

HS-LS1-2 High School Life Science: Structure and Function

Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

**PA Stds**

3.1.B.A4 - Compare and contrast a virus and a cell. Relate the stages of viral cycles to the cell cycle.

Advanced Placement Essential Knowledge

3.C.3 - Viral replication results in genetic variation and viral infection can introduce genetic variation into the hosts.

---

**Unit 5: Biotechnology**

**NGSS**

HS-LS3-2 Heredity: Inheritance and Variation of Traits

Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

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

**PA Stds**

3.1.12.B3 Analyze gene expression at the molecular level. Explain the impact of environmental factors on gene expression.


3.1.12.B4 - Evaluate the societal impact of genetic engineering techniques and applications.

3.1.B.B4 Explain how genetic technologies have impacted the fields of medicine, forensics, and agriculture.

Advanced Placement Essential Knowledge

3.A.1 - DNA, and in some cases RNA, is the primary source of heritable information.

4.B.3 - Interactions between and within populations influence patterns of species distribution and abundance.

4.B.3 - Distribution of local and global ecosystems changes over time.
**Course Description:** Molecular and cellular biology is the study of biology at the molecular level. This semester course along with other advanced biology electives is designed for college-bound students seeking in-depth experiences in biology. Topics include chemistry of water, organic chemistry, biochemistry, cell diversity, cell membranes, metabolism, and cellular respiration with an emphasis on appropriate chemistry concepts. This course relies heavily on laboratory activities and requires regular attendance.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit 1: Water</strong></td>
<td>NGSS</td>
</tr>
<tr>
<td></td>
<td>HS-PS1-1 Matter and its Interactions Use the periodic table as a model to</td>
</tr>
<tr>
<td></td>
<td>predict the relative properties of elements based on the patterns of</td>
</tr>
<tr>
<td></td>
<td>electrons in the outermost energy level of atoms.</td>
</tr>
<tr>
<td></td>
<td>PA Stds</td>
</tr>
<tr>
<td></td>
<td>3.1.B.A8 Describe how the unique properties of water support life.</td>
</tr>
<tr>
<td></td>
<td>Compare and contrast the unique properties of water to other liquids.</td>
</tr>
<tr>
<td></td>
<td>3.1.B.A9 Compare and contrast scientific theories. Know that both direct</td>
</tr>
<tr>
<td></td>
<td>and indirect observations are used by scientists to study the natural</td>
</tr>
<tr>
<td></td>
<td>world and universe. Identify questions and concepts that guide</td>
</tr>
<tr>
<td></td>
<td>scientific investigations. Formulate and revise explanations and models</td>
</tr>
<tr>
<td></td>
<td>using logic and evidence. Recognize and analyze alternative explanations</td>
</tr>
<tr>
<td></td>
<td>and models. Explain the importance of accuracy and precision in</td>
</tr>
<tr>
<td></td>
<td>making valid measurements. Examine the status of existing theories.</td>
</tr>
<tr>
<td></td>
<td>Evaluate experimental information for relevance and adherence to</td>
</tr>
<tr>
<td></td>
<td>science processes. Judge that conclusions are consistent and</td>
</tr>
<tr>
<td></td>
<td>logical with experimental conditions. Interpret results of experimental</td>
</tr>
<tr>
<td></td>
<td>research to predict new information, propose additional</td>
</tr>
<tr>
<td></td>
<td>investigable questions, or advance a solution. Communicate and defend</td>
</tr>
<tr>
<td></td>
<td>a scientific argument.</td>
</tr>
<tr>
<td></td>
<td>Advanced Placement Essential Knowledge</td>
</tr>
<tr>
<td></td>
<td>4.A.1 - The subcomponents of biological molecules and their sequence</td>
</tr>
<tr>
<td></td>
<td>determine the properties of that molecule.</td>
</tr>
<tr>
<td></td>
<td>2.A.3 - Organisms must exchange matter with the environment to grow,</td>
</tr>
<tr>
<td></td>
<td>reproduce, and maintain organization.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Unit 2: Carbon and the Molecular Diversity of Life</strong></th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HS-LS1-6. Construct and revise an explanation based on evidence for how</td>
</tr>
<tr>
<td></td>
<td>carbon, hydrogen, and oxygen from sugar molecules may combine with</td>
</tr>
<tr>
<td></td>
<td>other elements to form amino acids and/or other large carbon-based</td>
</tr>
<tr>
<td></td>
<td>molecules. Use the periodic table as a model to predict the relative</td>
</tr>
<tr>
<td></td>
<td>properties of elements based on the patterns of electrons in the</td>
</tr>
<tr>
<td></td>
<td>outermost energy level of atoms.</td>
</tr>
<tr>
<td></td>
<td>HS-PS1-5 Matter and its Interactions</td>
</tr>
<tr>
<td></td>
<td>Apply scientific principles and evidence to provide an explanation about</td>
</tr>
<tr>
<td></td>
<td>the effects of changing the temperature or concentration of the reacting</td>
</tr>
<tr>
<td></td>
<td>particles on the rate at which a reaction occurs.</td>
</tr>
<tr>
<td></td>
<td>PA Stds</td>
</tr>
<tr>
<td></td>
<td>3.1.B.A7 Analyze the importance of carbon to the structure of biological</td>
</tr>
<tr>
<td></td>
<td>macromolecules.</td>
</tr>
</tbody>
</table>
| Unit 3: The Biochemistry of Life | Advanced Placement Essential Knowledge  
4.A.1 - The subcomponents of biological molecules and their sequence determine the properties of that molecule.  

NGSS  
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-LS1-1 From Molecules to Organisms: Structures and Processes  
Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.  

PA Stds  
3.1.B.A7 Analyze the importance of carbon to the structure of biological macromolecules. Compare and contrast the functions and structures of proteins, lipids, carbohydrates, and nucleic acids. Explain the consequences of extreme changes in pH and temperature on cell proteins.  
3.1.B.A8 Demonstrate the repeating patterns that occur in biological polymers.  

NGSS  
HS-LS1-2 From Molecules to Organisms: Structures and Processes  
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  
HS-LS1-3 From Molecules to Organisms: Structures and Processes  
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.  

PA Stds  
3.1.B.A5 Relate the structure of cell organelles to their function (energy capture and release, transport, waste removal, protein synthesis, movement, etc). Explain the role of water in cell metabolism. Explain how the cell membrane functions as a regulatory structure and protective barrier for the cell. Describe transport mechanisms across the plasma membrane.  

Advanced Placement Essential Knowledge  
2.B.1 - Cell membranes are selectively permeable due to their structure.  
2.B.2 - Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.  
4.A.2 - The structure and function of subcellular components, and their interactions, provide essential cellular processes.  

| Unit 4: Cellular Structure, Function, and Transport | Advanced Placement Essential Knowledge  
4.A.1 - The subcomponents of biological molecules and their sequence determine the properties of that molecule.  

NGSS  
HS-LS1-2 From Molecules to Organisms: Structures and Processes  
Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  
HS-LS1-3 From Molecules to Organisms: Structures and Processes  
Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.  

PA Stds  
3.1.B.A5 Relate the structure of cell organelles to their function (energy capture and release, transport, waste removal, protein synthesis, movement, etc). Explain the role of water in cell metabolism. Explain how the cell membrane functions as a regulatory structure and protective barrier for the cell. Describe transport mechanisms across the plasma membrane.  

Advanced Placement Essential Knowledge  
2.B.1 - Cell membranes are selectively permeable due to their structure.  
2.B.2 - Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.  
4.A.2 - The structure and function of subcellular components, and their interactions, provide essential cellular processes.  

| Unit 5: Metabolism | PA Stds  
3.1.12.A2 - Evaluate how organisms must derive energy from their environment or their food in order to survive.  
3.1.12.A7 - Evaluate metabolic activities using experimental knowledge of
3.1.B.A2 Explain the important role of ATP in cell metabolism. Explain why many biological macromolecules such as ATP and lipids contain high energy bonds. Explain the importance of enzymes as catalysts in cell reactions.

3.1.B.A5 Relate the structure of cell organelles to their function (energy capture and release, transport, waste removal, protein synthesis, movement, etc).

Explain the role of water in cell metabolism. Identify how factors such as pH and temperature may affect enzyme function.

Advanced Placement Essential Knowledge
2.A.1- All living systems require constant input of free energy.
4.B.1 - Interactions between molecules affect their structure and function.
4.C.1 - Variation in molecular units provides cells with a wider range of functions.

Unit 6: Cellular Respiration

NGSS
HS-LS-1-7 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-LS2-5 Ecosystems: Interactions, Energy, and Dynamics
Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

PA Stds
3.1.B.A2 Identify the initial reactants, final products, and general purposes of photosynthesis and cellular respiration. Explain the important role of ATP in cell metabolism. Describe the relationship between photosynthesis and cellular respiration in photosynthetic organisms.

Explain why many biological macromolecules such as ATP and lipids contain high energy bonds.

Advanced Placement Essential Knowledge
2.A.1- All living systems require constant input of free energy.
2.A.2 - Organisms capture and store free energy of use in biological processes.
<table>
<thead>
<tr>
<th>HS-LS2-2 Interactions, Energy, and Dynamics</th>
<th>Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS2-7 Interactions, Energy, and Dynamics</td>
<td>Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*</td>
</tr>
<tr>
<td>HS-LS4-1 Biological Evolution: Unity and Diversity</td>
<td>Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.</td>
</tr>
<tr>
<td>HS-LS4-5 Biological Evolution: Unity and Diversity</td>
<td>Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.</td>
</tr>
</tbody>
</table>

**PA Stds**

3.1.12.A9 Compare and contrast scientific theories. Know that both direct and indirect observations are used by scientists to study the natural world and universe. Identify questions and concepts that guide scientific investigations. Formulate and revise explanations and models using logic and evidence. Recognize and analyze alternative explanations and models. Explain the importance of accuracy and precision in making valid measurements. Examine the status of existing theories. Evaluate experimental information for relevance and adherence to science processes. Judge that conclusions are consistent and logical with experimental conditions. Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. Communicate and defend a scientific argument.

3.1.12.A2 Evaluate how organisms must derive energy from their environment or their food in order to survive.

3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.

3.1.10.A1 Explain the characteristics of life common to all organisms.

3.1.10.A3 Compare and contrast the life cycles of different organisms.

**Advanced Placement Essential Knowledge**

1.A - Natural Selection is a major mechanism of evolution.

1.C- Life continues to evolve within a changing environment.

2.A.1 - All living systems require constant input of free energy.

2.D.1 - All biological systems from cells and organisms to populations, communities and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.

2.E.1 - Timing and coordination of specific events are necessary for normal development, and these events are regulated.

4.A.5- Communities are composed of populations of organisms that interact in complex ways.

<table>
<thead>
<tr>
<th>Unit 2: Invertebrate Structure and Development</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HS-LS1-2 From Molecules to Organisms: Structures and Processes Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
</tr>
<tr>
<td></td>
<td>HS-LS2-8 Ecosystems: Interactions, Energy, and Dynamics Evaluate evidence for the role of group behavior on individual and species’ chances to survive and</td>
</tr>
</tbody>
</table>
HS-LS4-1 Biological Evolution: Unity and Diversity Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-2 Biological Evolution: Unity and Diversity Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

PA Standards
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.
3.1.B.A1 Compare and contrast the cellular structures and degrees of complexity of prokaryotic and eukaryotic organisms. Explain that some structures in eukaryotic cells developed from early prokaryotic cells (e.g., mitochondria, chloroplasts).
3.1.B.A3 Explain how all organisms begin their life cycles as a single cell and that in multicellular organisms, successive generations of embryonic cells form by cell division.
3.1.B.A6 Explain how cells differentiate in multicellular organisms.

Advanced Placement Essential Knowledge:
4.A.2 - The structure and function of subcellular components, and their interactions, provide essential cellular processes.
2.D.4 - Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
2.E.1 - Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.
2.E.2 - Timing and coordination of physiological events are regulated by multiple mechanisms
3.D.1 - Cell communication processes share common features that reflect a shared evolutionary history.
3.E.1 - Individuals can act on information and communicate it to others.
3.E.2 - Animals have nervous systems that detect external and internal signals, transmit integrate information, and produce responses.
4.A.4 - Organisms exhibit complex properties due to interactions between their constituent parts.
4.B.2. - Cooperative interactions within organisms promote efficiency in the use of energy and matter.
and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

HS-LS2-8 Ecosystems: Interactions, Energy, and Dynamics Evaluate evidence for the role of group behavior on individual and species’ chances to survive and reproduce.

HS-LS4-1 Biological Evolution: Unity and Diversity Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-2 Biological Evolution: Unity and Diversity Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

PA Stds
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.
3.1.B.A1 Compare and contrast the cellular structures and degrees of complexity of prokaryotic and eukaryotic organisms. Explain that some structures in eukaryotic cells developed from early prokaryotic cells (e.g., mitochondria, chloroplasts).
3.1.B.A3 Explain how all organisms begin their life cycles as a single cell and that in multicellular organisms, successive generations of embryonic cells form by cell division.
3.1.B.A6 Explain how cells differentiate in multicellular organisms.

Advanced Placement Essential Knowledge
4.A.2 - The structure and function of subcellular components, and their interactions, provide essential cellular processes.
2.D.4 - Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
2.E.1 - Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.
2.E.2 - Timing and coordination of physiological events are regulated by multiple mechanisms
3.D.1 - Cell communication processes share common features that reflect a shared evolutionary history.
3.E.1 - Individuals can act on information and communicate it to others.
3.E.2 - Animals have nervous systems that detect external and internal signals, transmit integrate information, and produce responses.
4.A.4 - Organisms exhibit complex properties due to interactions between their constituent parts.
4.B.2. - Cooperative interactions within organisms promote efficiency in the use of energy and matter.
<table>
<thead>
<tr>
<th>Unit 4: Major Animal Organ System</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS1-2 From Molecules to Organisms: Structures and Processes Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
<td></td>
</tr>
</tbody>
</table>

**PA Stds:**
- 3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.
- 3.1.10.A1 Explain the characteristics of life common to all organisms.
- 3.1.10.A3 Compare and contrast the life cycles of different organisms.
- 3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.

**Advanced Placement Essential Knowledge:**
- 2.D.4 - Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
- 4.A.2 - The structure and function of subcellular components, and their interactions, provide essential cellular processes.
- 3.E.2 - Animals have nervous systems that detect external and internal signals, transmit integrate information, and produce responses.
- 4.A.4 - Organisms exhibit complex properties due to interactions between their constituent parts.
- 4.B.2. - Cooperative interactions within organisms promote efficiency in the use of energy and matter.

<table>
<thead>
<tr>
<th>Unit 5: Animal Behavior and the Environment</th>
<th>NGSS</th>
</tr>
</thead>
</table>
| HS-LS2-8 Ecosystems: Interactions, Energy, and Dynamics Evaluate evidence for the role of group behavior on individual and species' chances to survive and reproduce. | **PA Stds**
- 3.1.12.A1- Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.

**Advanced Placement Essential Knowledge**
- 2.C.2 - Organisms respond to changes in their environment.
- 2.D.1 - All biological systems from cells and organisms are affected by complex biotic and abiotic interactions involving exchange of matter and free energy.
- 2.D.2 Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.
- 2.D.4 - Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
- 2.E.2 - Timing and coordination of physiological events are regulated by multiple mechanisms
- 3.E.1 - Individuals can act on information and communicate it to others.
- 4.A.4 - Organisms exhibit complex properties due to interactions between their constituent parts.
- 4.A.5 - Communities are composed of populations of organisms that interact in complex ways.

<table>
<thead>
<tr>
<th>Unit 6: Biotechnology</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS3-2 Heredity: Inheritance and Variation of Traits</td>
<td></td>
</tr>
</tbody>
</table>
Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

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

**PA Stds**
3.1.12.B4 - Evaluate the societal impact of genetic engineering techniques and applications.
3.1.B.B4 Explain how genetic technologies have impacted the fields of medicine, forensics, and agriculture

Advanced Placement Essential Knowledge
3.A.1 - DNA, and in some cases RNA, is the primary source of heritable information.
4.B.3 - Interactions between and within populations influence patterns of species distribution and abundance.
4.B.3 - Distribution of local and global ecosystems changes over time.

---

**Biology - Anatomy and Physiology**

**Course Description**: This course will involve students in an in-depth study of the structure and function of the human body. Special attention will be given to the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, immune, respiratory, digestive, lymphatic, urinary and reproductive systems. It will provide a firm foundation for further study in the medical field at the post-secondary level. Students are encouraged to take Anatomy & Physiology with the other Health Professions courses.

**Unit Titles**

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Introduction to Anatomy and</td>
<td><strong>NGSS</strong></td>
</tr>
<tr>
<td>Physiology</td>
<td>HS-L51-2 From Molecules to Organisms: Structures and Processes</td>
</tr>
<tr>
<td></td>
<td>Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
</tr>
<tr>
<td></td>
<td>HS-L51-3 From Molecules to Organisms: Structures and Processes</td>
</tr>
<tr>
<td></td>
<td>Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td>
</tr>
<tr>
<td></td>
<td>HS-L51-7 From Molecules to Organisms: Structures and Processes</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
</tbody>
</table>

**PA Stds**
3.1.10.A1 Explain the characteristics of life common to all organisms.
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to
| Unit 2: Histology | NGSS
| Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. |
| In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. |
| SAS
| 3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms. |
| 3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms. |
| 3.1.12.A6 Analyze how cells in different tissues/ organs are specialized to perform specific functions. |
| 3.1.10.A5 Relate life processes to sub-cellular and cellular structures to their functions. |
| 3.1.10.A6 Identify the advantages of multi-cellularity in organisms. |

| Unit 3: Integumentary System | NGSS
| Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. |
| In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. |
| HS-LS4-1 Biological Evolution: Unity and Diversity - Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. |
| HS-LS4-2 Biological Evolution: Unity and Diversity - Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. |
| SAS
| 3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms. |
| Unit 4: Endocrine System | 3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.  
3.1.10.C1 Explain the mechanisms of biological evolution. |
| --- | --- |
| **NGSS:**  
HS-LS1-2 From Molecules to Organisms: Structures and Processes Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  
HS-LS1-4 In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.  
HS-LS3-3 Heredity: Inheritance and Variation of Traits Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.  
HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. |
| **PA Stds**  
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.  
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.  
3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs. |

| Unit 5: Urinary System | 3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.  
3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs. |
| --- | --- |
| **NGSS:**  
HS-LS1-2 From Molecules to Organisms: Structures and Processes Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. |
| **PA Stds**  
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.  
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.  
3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs.  
3.1.B.A5 Relate the structure of cell organelles to their function (energy capture and release, transport, waste removal, protein synthesis, movement, etc). |
| Unit 6: Digestive System | NGSS:  
HS-LS1-2 From Molecules to Organisms: Structures and Processes  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  

PA Stds  
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.  
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions. |
| --- | --- |
| Unit 7: Skeletal System | NGSS:  
HS-LS1-2 From Molecules to Organisms: Structures and Processes  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  

PA Stds  
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.  
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions. |
| Unit 8: Muscular System | NGSS:  
HS-LS1-2 From Molecules to Organisms: Structures and Processes  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  
HS-LS1-7 From Molecules to Organisms: Structures and Processes  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.  

PA Stds  
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.  
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.  
3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs. |
| Unit 9: Nervous System | NGSS:  
HS-LS1-2 From Molecules to Organisms: Structures and Processes  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. |
<table>
<thead>
<tr>
<th>Unit 10: Cardiovascular System</th>
<th>Unit 11: Respiratory System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NGSS:</strong></td>
<td><strong>NGSS:</strong></td>
</tr>
<tr>
<td>HS-LS1-2 From Molecules to Organisms: Structures and Processes  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
<td>HS-LS1-2 From Molecules to Organisms: Structures and Processes  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.</td>
</tr>
<tr>
<td><strong>PA Stds</strong></td>
<td><strong>PA Stds</strong></td>
</tr>
<tr>
<td>3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.</td>
<td>3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.</td>
</tr>
<tr>
<td>3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.</td>
<td>3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.</td>
</tr>
<tr>
<td>3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.</td>
<td>3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.</td>
</tr>
<tr>
<td>3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs.</td>
<td>3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs.</td>
</tr>
<tr>
<td>3.1.B.A5 Relate the structure of cell organelles to their function (energy capture and release, transport, waste removal, protein synthesis, movement, etc). Explain the role of water in cell metabolism. Explain how the cell membrane functions as a regulatory structure and protective barrier for the cell. Describe transport mechanisms across the plasma membrane.</td>
<td>3.1.B.A5 Relate the structure of cell organelles to their function (energy capture and release, transport, waste removal, protein synthesis, movement, etc). Explain the role of water in cell metabolism. Explain how the cell membrane functions as a regulatory structure and protective barrier for the cell. Describe transport mechanisms across the plasma membrane.</td>
</tr>
</tbody>
</table>
| Unit 12: Reproductive System | NGSS:  
**HS-LS1-2** From Molecules to Organisms: Structures and Processes  Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.  
**HS-LS1-4** In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.  

**PA Stds**  
3.1.12.A1 Relate changes in the environment to various organisms’ ability to compensate using homeostatic mechanisms.  
3.1.12.A5 Analyze how structure is related to function at all levels of biological organization from molecules to organisms.  
3.1.12.A6 Analyze how cells in different tissues/organs are specialized to perform specific functions.  
3.1.10.A8 Investigate the spatial relationships of organisms’ anatomical features using specimens, models, or computer programs.  
3.1.10.B2 Explain the process of meiosis resulting in the formation of gametes. Compare and contrast the function of mitosis and meiosis. |
**Chemistry - Chemistry Matters!**

**Course Description:** This lab-based semester course will explore concepts of chemistry with limited emphasis on mathematics. Chemistry is a science with a very practical outlook. Students will gain a unique perspective on what things are made of and why they behave as they do. Students will investigate topics related to matter, types of energy, gas laws, and how changes in matter results in new materials. This broad-based class is open to all students in 11th and 12th grades who have not taken a full year chemistry course.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| **Unit 1: Recycling: It's not just a good idea, it's the law** | NGSS  
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.  
PA Stds  
PA Std CHEM.A.1.1 Identify and describe how observable and measurable properties can be used to classify and describe matter and energy.  
PA Std CHEM.A.2.3 Explain how periodic trends in the properties of atoms allow for the prediction of physical and chemical properties.  
PA Std CHEM.B.1.3 Explain how atoms form chemical bonds.  
Eligible Content  
CHEM.A.1.1.1 Classify physical or chemical changes within a system in terms of matter and/or energy  
CHEM.A.2.3.1 Explain how the periodicity of chemical properties led to the arrangement of elements on the periodic table.  
CHEM.A.2.1.2 Differentiate between the mass number of an isotope and the average atomic mass of an element.  
CHEM.B.1.3.1 Explain how atoms combine to form compounds through ionic and covalent bonding. |
| **Unit 2: Energy: That's Hot! How to we get energy from fuels?** | NGSS  
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.  
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.  
PA Stds  
PA Std CHEM.A.1.1 Identify and describe how observable and measurable properties can be used to classify and describe matter and energy.  
PA Std CHEM.A.1.4 Relate the physical properties of matter to its atomic or molecular structure.  
PA Std CHEM.B.1.3 Explain how atoms form chemical bonds.  
PA Std CHEM.B.1.4 Explain how models can be used to represent bonding  
PA Std CHEM.B.2.1 Predict what happens during a chemical reaction  
Eligible Content: |
| Unit 3: Solution Chemistry: Power up! What’s in my sports drink? | CHEM.A.1.1.1 Classify physical or chemical changes within a system in terms of matter and/or energy  
CHEM.B.2.1.4 Predict products of simple chemical reactions (e.g., synthesis, decomposition, single replacement, double replacement, combustion).  
CHEM.B.2.1.5 Balance chemical equations by applying the Law of Conservation of Matter  
NGSS  
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.  
PA Stds  
CHEM.A.1.2 Compare the properties of mixtures.  
CHEM.A.1.2.1 Compare properties of solutions containing ionic or molecular solutes (e.g., dissolving, dissociating)  
CHEM.A.1.2.3 Describe how factors (e.g., temperature, concentration, surface area) can affect solubility.  
CHEM.A.1.2.4 Describe various ways that concentration can be expressed and calculated (e.g., molarity, percent by mass, percent by volume). |
| --- | --- |
| Unit 4: Gases: Pressurized! | NGSS:  
HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.  
PA Standard  
CHEM.B.2.2 Explain how the kinetic molecular theory relates to the behavior of gases.  
CHEM.B.2.2.1 Utilize mathematical relationships to predict changes in the number of particles, the temperature, the pressure, and the volume in a gaseous system (i.e., Boyle's law, Charles's law, Dalton's law of partial pressures, the combined gas law, and the ideal gas law). |

**Chemistry - Chemistry 1**

**Course Description**: This course is designed for the student who desires a basic understanding of the fundamentals of chemistry. Experimental, theoretical, and practical aspects of chemistry will be explored with an emphasis on the application and relevance of chemical principles. Topics will include matter, atomic theory, bonding, nomenclature, reactions, the mole, stoichiometry, and solutions.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Lab Safety | Act 116 - Pennsylvania Eye Safety - Regulations Governing the Use and Care of Protective Eye Devices in the Schools of Pennsylvania.  
Provide for the use of eye protective devices by persons engaged in hazardous activities or exposed to known dangers in schools, colleges and universities. |
| Unit 2: Atomic Theory and Nuclear | PA Stds:  
3.3.12.B3. Develop an understanding of Science as Inquiry.  

NGSS:  
HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.  

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.  

PA Stds  
3.2.C.A5. Describe the historical development of models of the atom and how they contributed to modern atomic theory.  

Eligible Content  
CHEM.A.2.1.1 Describe the evolution of atomic theory leading to the current model of the atom based on the works of Dalton, Thomson, Rutherford, and Bohr.  |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 3: Electrons and the Periodic Table</td>
<td></td>
</tr>
</tbody>
</table>
NGSS:  
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements.  

PA Stds:  
3.4.10.A2 Explain the repeating pattern of chemical properties by using the repeating patterns of atomic structure within the periodic table.  

3.2.C.A2. Compare the electron configurations for the first twenty elements of the periodic table.  

Eligible Content  
CHEM.A.2.1.1 Describe the evolution of atomic theory leading to the current model of the atom based on the works of Dalton, Thomson, Rutherford, and Bohr.  

CHEM.A.2.2.1 Predict the ground state electronic configuration and/or orbital diagram for a given atom or ion.  

CHEM.A.2.2.3 Explain the relationship between the electron configuration and the atomic structure of a given atom or ion (e.g., energy levels and/or orbitals with electrons, distribution of electrons in orbitals, shapes of orbitals).  

CHEM.A.2.2.4 Relate the existence of quantized energy levels to atomic emission spectra.  

CHEM.A.2.3.2 Compare and/or predict the properties (e.g., electron affinity, ionization energy, chemical reactivity, electronegativity, atomic radius) of selected elements by using their locations on the periodic table and known trends.  |
| Unit 4: Bonding |  
NGSS:  
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.  

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the |
structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**PA Standards:**

3.2.C.A1 Explain the relationship of an element's position on the periodic table to its atomic number, ionization energy, electronegativity, atomic size, and classification of elements. Use electronegativity to explain the difference between polar and nonpolar covalent bonds.

3.2.C.A2 Explain how atoms combine to form compounds through both ionic and covalent bonding. Predict chemical formulas based on the number of valence electrons. Draw Lewis dot structures for simple molecules and ionic compounds.

CHEM.A.1.1 Identify and describe how observable and measurable properties can be used to classify and describe matter and energy.

**Eligible Content**

CHEM.A.1.1.4 Relate the physical properties of matter to its atomic or molecular structure.

### Unit 5: Nomenclature

**NGSS:**

HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

**PA Standards:**

3.2.C.A10 Predict chemical formulas based on the number of valence electrons. Predict the chemical formulas for simple ionic and molecular compounds.

CHEM.A.1.1.5 Apply a systematic set of rules (IUPAC) for naming compounds and writing chemical formulas (e.g., binary covalent, binary ionic, ionic compounds containing polyatomic ions).

### Unit 6: Reactions

**NGSS:**

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

**PA Stds**


**Eligible Content**

CHEM.B.2.1.3 Classify reactions as synthesis, decomposition, single replacement, double replacement, or combustion.

CHEM.B.2.1.4 Predict products of simple chemical reactions (e.g., synthesis, decomposition, single replacement, double replacement, combustion).
<table>
<thead>
<tr>
<th>CHEM.B.2.1.5</th>
<th>Balance chemical equations by applying the Law of Conservation of Matter.</th>
</tr>
</thead>
</table>
| **Unit 7: The Mole** | 3.2.10.A5 Apply the mole concept to determine number of particles and molar mass for elements and compounds.  
3.2.C.A2 Mole, empirical/molecular formulas  
Use the mole concept to determine number of particles and molar mass for elements and compounds.  
Determine percent compositions, empirical formulas, and molecular formulas. |
| **Unit 8: Stoichiometry** | NGSS:  
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.  
PA Stds  
3.2.C.A2 Use the mole concept to determine number of particles and molar mass for elements and compounds  
3.2.C.A4 Use stoichiometry to predict quantitative relationships in a chemical reaction.  
Eligible Content  
CHEM.B.1.1.1 Apply the mole concept to representative particles (e.g., counting, determining mass of atoms, ions, molecules, and/or formula units).  
CHEM.B.2.1.1 Describe the roles of limiting and excess reactants in chemical reactions.  
CHEM.B.2.1.2 Use stoichiometric relationships to calculate the amounts of reactants and products involved in a chemical reaction. |
| **Chemistry - Advanced Chemistry 1** |  
**Course Description**: This course is designed for students with a strong aptitude for mathematics who plan on pursuing a career in math, engineering or the sciences. Experimental and theoretical aspects of chemistry are explored. Topics will include - measurement, matter, atomic theory, nuclear chemistry, bonding, nomenclature, moles, reactions, stoichiometry, solutions, gas laws, rates & equilibria, acids/bases, and organic chemistry.  
**Unit Titles** | **Standards**  
**Unit 1: Measurement** | NGSS  
HS-PS1-3-5: Make observations and measurements to identify materials based on their properties.  
**Unit 2: Matter** | NGSS  
HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.  
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 motion of particles (objects) and energy associated with the relative positions of particles (objects).

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).

PA Stds
3.2.10.A1 Predict properties of elements using trends of the periodic table.
3.2.C.A3 Describe the three normal states of matter in terms of energy, particle motion, and phase transitions.

Eligible Content
CHEM.A.1.1.1 Classify physical or chemical changes within a system in terms of matter and/or energy
CHEM.A.2.3.1 Explain how the periodicity of chemical properties led to the arrangement of elements on the periodic table.

<table>
<thead>
<tr>
<th>Unit 3: Atomic Theory</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.</td>
<td></td>
</tr>
<tr>
<td>HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.</td>
<td></td>
</tr>
</tbody>
</table>

PA Stds
3.2.C.A5. Describe the historical development of models of the atom and how they contributed to modern atomic theory.

Eligible Content
CHEM.A.2.1.1 Describe the evolution of atomic theory leading to the current model of the atom based on the works of Dalton, Thomson, Rutherford, and Bohr.
CHEM.A.2.2.1 Predict the ground state electronic configuration and/or orbital diagram for a given atom or ion.
CHEM.A.2.2.3 Explain the relationship between the electron configuration and the atomic structure of a given atom or ion (e.g., energy levels and/or orbitals with electrons, distribution of electrons in orbitals, shapes of orbitals).
CHEM.A.2.2.4 Relate the existence of quantized energy levels to atomic emission spectra.

<table>
<thead>
<tr>
<th>Unit 4: Bonding</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.</td>
<td></td>
</tr>
<tr>
<td>HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.</td>
<td></td>
</tr>
</tbody>
</table>
| PA Stds | Explain the relationship of an element’s position on the periodic table to its atomic number, ionization energy, electronegativity, atomic size, and classification of elements. Use electronegativity to explain the difference between polar and nonpolar covalent bonds.  
3.2.C.A2  Explain how atoms combine to form compounds through both ionic and covalent bonding. Predict chemical formulas based on the number of valence electrons. Draw Lewis dot structures for simple molecules and ionic compounds.  
Eligible Content  
CHEM.A.1.1.4 Relate the physical properties of matter to its atomic or molecular structure.  
CHEM.A.2.3.2 Compare and/or predict the properties (e.g., electron affinity, ionization energy, chemical reactivity, electronegativity, atomic radius) of selected elements by using their locations on the periodic table and known trends. |
| --- | --- |
| Unit 5: Nomenclature and the Mole | NGSS:  
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.  
PA Stds:  
3.2.C.A2  Predict chemical formulas based on the number of valence electrons. Predict the chemical formulas for simple ionic and molecular compounds. Use the mole concept to determine number of particles and molar mass for elements and compounds. Determine percent compositions, empirical formulas, and molecular formulas.  
3.2.10.A5  Apply the mole concept to determine number of particles and molar mass for elements and compounds.  
3.2.C.A2  Mole, empirical/molecular formulas  
Use the mole concept to determine number of particles and molar mass for elements and compounds. Determine percent compositions, empirical formulas, and molecular formulas. |
| Unit 6: Reactions | NGSS:  
HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.  
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.  
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.  
PA Stds  
### 3.2.C.B3 Heat and Heat Transfer
- Explain the difference between an endothermic process and an exothermic process.

**Eligible Content**
- CHEM.B.2.1.3 Classify reactions as synthesis, decomposition, single replacement, double replacement, or combustion.
- CHEM.B.2.1.4 Predict products of simple chemical reactions (e.g., synthesis, decomposition, single replacement, double replacement, combustion).
- CHEM.B.2.1.5 Balance chemical equations by applying the Law of Conservation of Matter.

### Unit 7: Stoichiometry and Solutions

**NGSS:**  
HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

**PA Stds**
- 3.2.C.A4 Stoichiometry - Use stoichiometry to predict quantitative relationships in a chemical reaction.
- 3.2.C.A4 Predict how combinations of substances can result in physical and/or chemical changes. Interpret and apply the laws of conservation of mass, constant composition (definite proportions), and multiple proportions. Balance chemical equations by applying the laws of conservation of mass. Classify chemical reactions as synthesis (combination), decomposition, single displacement (replacement), double displacement, and combustion. Use stoichiometry to predict quantitative relationships in a chemical reaction.

**Eligible Content**
- CHEM.B.1.1.1 Apply the mole concept to representative particles (e.g., counting, determining mass of atoms, ions, molecules, and/or formula units).
- CHEM.B.2.1.1 Describe the roles of limiting and excess reactants in chemical reactions.
- CHEM.B.2.1.2 Use stoichiometric relationships to calculate the amounts of reactants and products involved in a chemical reaction.

### Unit 8: Gas Laws

**NGSS:**  
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 motion of particles (objects) and energy associated with the relative positions of particles (objects).

**PA Stds**
- 3.2.10.A3 Describe phases of matter according to the kinetic molecular theory.
- 3.2.C.A3 Describe the three normal states of matter in terms of energy, particle motion, and phase transitions.

**Eligible Content**
- CHEM.B.2.2.1 Utilize mathematical relationships to predict changes in the number of particles, the temperature, the pressure, and the volume in a gaseous state.
system (i.e., Boyle’s law, Charles’s law, Dalton’s law of partial pressures, the combined gas law, and the ideal gas law).

**CHEM.B.2.2.2** Predict the amounts of reactants and products involved in a chemical reaction using molar volume of a gas at STP.

| Unit 9: Rates and Equilibria, Acid/Base Theory | NGSS:  
HS-PS1-1-5 Apply scientific principles and evidence to provide an explanation about the effect of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.  
HS-PS1-1-6 Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.  
PA Standards:  
3.1.C.A2. Describe how changes in energy affect the rate of chemical reactions.  
3.2.12.A4 Describe the interactions between acids and bases.  
3.2.12.A5. Predict the shift in equilibrium when a system is subjected to a stress.  
Eligible Content  
CHEM.B.2.1.4 Predict products of simple chemical reactions (e.g., synthesis, decomposition, single replacement, double replacement, combustion).  
CHEM.A.1.1.5 Apply a systematic set of rules (IUPAC) for naming compounds and writing chemical formulas (e.g., binary covalent, binary ionic, ionic compounds containing polyatomic ions). |

### Chemistry - Advanced Chemistry 2

**Course Description:** This laboratory intensive course is designed for students who plan to pursue a career in one of the physical sciences. Students will investigate the connections among numerous chemistry topics and will apply chemical theory in problem-solving and laboratory experimentation. Students develop independent investigative skills, including the presentation of experimental results in standard laboratory report format.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Experimental Analysis and Laws of Chemical Combination | Advanced Placement Learning Objectives  
LO 1.1 The student can justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory  
LO 1.17 The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings.  
Eligible Content  
CHEM.A.1.1. Utilize significant figures to communicate the uncertainty in a quantitative observation |
| Unit 2: Organic Chemistry | NGSS:  
HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of |
atoms. 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 motion of particles (objects) and energy associated with the relative positions of particles (objects).

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).

Advanced Placement Learning Objectives

LO 1.15 The student can justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules.

LO 2.1 Students can predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views.

LO 2.7 The Student is able to explain how solutes can be separated by chromatography based on intermolecular interactions.

LO 2.10 The student can design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components.

LO 2.11 The student is able to explain the trends in properties and/or predict properties of samples consisting of particles with no permanent dipole on the basis of London dispersion forces.

LO 2.13 The student is able to describe the relationships between the structural features of polar molecules and the forces of attraction between the particles.

LO 2.16 The student is able to explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces.

LO 5.11 The student is able to identify the noncovalent interactions within and between large molecules, and/or connect the shape and function of the large molecule to the presence and magnitude of these interactions.

Eligible Content

CHEM.A.1.1.1 Classify physical or chemical changes within a system in terms of matter and/or energy

CHEM.A.2.3.1 Explain how the periodicity of chemical properties led to the arrangement of elements on the periodic table.

Unit 3: Chemical Reactions and Stoichiometry

NGSS:

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-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
Advanced Placement Learning Objectives

LO 1.2 The student is able to select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.
LO 1.3 The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance.
LO 1.4 The student is able to connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively.
LO 1.16 The student can design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution.
LO 1.17 The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings.
LO 1.18 The student is able to apply conservation of atoms to the rearrangement of atoms in various processes.
LO 3.1 Students can translate among macroscopic observations of change, chemical equations, and particle views.
LO 3.2 The student can translate an observed chemical change into a balanced chemical equation and justify the choice of equation type (molecular, ionic, or net ionic) in terms of utility for the given circumstances.
LO 3.3 The student is able to use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results.
LO 3.4 The student is able to relate quantities (measured mass of substances, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion.
LO 3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer.
LO 3.10 The student is able to evaluate the classification of a process as a physical change, chemical change, or ambiguous change based on both macroscopic observations and the distinction between rearrangement of covalent interactions and noncovalent interactions.

Unit 4: Kinetic Molecular Theory and Thermodynamics

NGSS:
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 motion of particles (objects) and energy associated with the relative positions of particles (objects).
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in energy and is function of the enthalpy.

Advanced Placement Learning Objectives

LO 2.4 The student is able to use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors.
LO 2.5 The student is able to refine multiple representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample.
LO 2.6 The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases.
LO 2.12 The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions.
LO 3.11 The student is able to interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes.
LO 5.2 The student is able to relate temperature to the motions of particles, either via particulate representations, such as drawings of particles with arrows indicating velocities, and/or via representations of average kinetic energy and distribution of kinetic energies of the particles, such as plots of the Maxwell-Boltzmann distribution.
LO 5.3 The student can generate explanations or make predictions about the transfer of thermal energy between systems based on this transfer being due to a kinetic energy transfer between systems arising from molecular collisions.
LO 5.4 The student is able to use conservation of energy to relate the magnitudes of the energy changes occurring in two or more interacting systems, including identification of the systems, the type (heat versus work), or the direction of energy flow.
LO 5.5 The student is able to use conservation of energy to relate the magnitudes of the energy changes when two non-reacting substances are mixed or brought into contact with one another.
LO 5.6 The student is able to use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/vaporization, relate energy changes associated with a chemical reaction to the enthalpy of the reaction, and relate energy changes to $\Delta V$ work.
LO 5.7 The student is able to design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure.

Eligible Content
CHEM.B.2.2.1 Utilize mathematical relationships to predict changes in the number of particles, the temperature, the pressure, and the volume in a gaseous system (i.e., Boyle’s law, Charles’ law, Dalton’s law of partial pressures, the combined gas law, and the ideal gas law).
CHEM.B.2.2.2 Predict the amounts of reactants and products involved in a chemical reaction using molar volume of a gas at STP.

Unit 5: Atomic Theory and Electron Configurations

NGSS
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-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
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 motion of particles (objects) and energy associated with the relative positions of
Advanced Placement Learning Objectives
LO 1.5 The student is able to explain the distribution of electrons in an atom or ion based upon data.
LO 1.6 The student is able to analyze data relating to electron energies for patterns and relationships.
LO 1.9 The student is able to predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model.
LO 1.10 Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity.
LO 1.12 The student is able to explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model.
LO 1.13 Given information about a particular model of the atom, the student is able to determine if the model is consistent with specified evidence.

Eligible Content
CHEM.A.2.1.1 Describe the evolution of atomic theory leading to the current model of the atom based on the works of Dalton, Thomson, Rutherford, and Bohr.
CHEM.A.2.2.1 Predict the ground state electronic configuration and/or orbital diagram for a given atom or ion.
CHEM.A.2.2.3 Explain the relationship between the electron configuration and the atomic structure of a given atom or ion (e.g., energy levels and/or orbitals with electrons, distribution of electrons in orbitals, shapes of orbitals).
CHEM.A.2.2.4 Relate the existence of quantized energy levels to atomic emission spectra.

Unit 6: Chemical Bonding

NGSS:
HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

Advanced Placement Learning Objectives
LO 2.1 Students can predict properties of substances based on their chemical
formulas, and provide explanations of their properties based on particle views.

| LO 2.17 | The student can predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements. |
| LO 2.18 | The student is able to rank and justify the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table. |
| LO 2.21 | The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity. |
| LO 2.23 | The student can create a representation of an ionic solid that shows essential characteristics of the structure and interactions present in the substance. |
| LO 2.24 | The student is able to explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level. |
| LO 2.31 | The student can create a representation of a molecular solid that shows essential characteristics of the structure and interactions present in the substance. |
| LO 2.32 | The student is able to explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level. |
| LO 5.1 | The student is able to create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order (for covalent interactions) and polarity (for intermolecular interactions), which influence the interaction strength. |
| LO 5.8 | The student is able to draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bond. |

Eligible Content

CHEM.A.1.1.4 Relate the physical properties of matter to its atomic or molecular structure.

---

### Unit 7: States of Matter and Colligative Properties

<table>
<thead>
<tr>
<th>Advanced Placement Learning Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO 2.3</td>
</tr>
<tr>
<td>LO 2.8</td>
</tr>
<tr>
<td>LO 2.9</td>
</tr>
<tr>
<td>LO 2.14</td>
</tr>
<tr>
<td>LO 2.15</td>
</tr>
</tbody>
</table>
ionic solids and molecules in water and other solvents on the basis of particle views that include intermolecular interactions and entropic effects.

LO 2.11 The student is able to explain the trends in properties and/or predict properties of samples consisting of particles with no permanent dipole on the basis of London dispersion forces.

LO 2.13 The student is able to describe the relationships between the structural features of polar molecules and the forces of attraction between the particles.

LO 2.16 The student is able to explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces.

LO 2.29 The student can create a representation of a covalent solid that shows essential characteristics of the structure and interactions present in the substance.

LO 2.30 The student is able to explain a representation that connects properties of a covalent solid to its structural attributes and to the interactions present at the atomic level.

LO 5.9 The student is able to make claims and/or predictions regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and the types of intermolecular forces through which the molecules interact.

Unit 8: Chemical Kinetics and Equilibrium

Advanced Placement Learning Objectives

LO 4.1 The student is able to design and/or interpret the results of an experiment regarding the factors (i.e., temperature, concentration, surface area) that may influence the rate of a reaction.

LO 4.2 The student is able to analyze concentration vs. time data to determine the rate law for a zeroth-, first-, or second-order reaction.

LO 4.3 The student is able to connect the half-life of a reaction to the rate constant of a first-order reaction and justify the use of this relation in terms of the reaction being a first-order reaction.

LO 4.4 The student is able to connect the rate law for an elementary reaction to the frequency and success of molecular collisions, including connecting the frequency and success to the order and rate constant, respectively.

LO 4.5 The student is able to explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation.

LO 4.6 The student is able to use representations of the energy profile for an elementary reaction (from the reactants, through the transition state, to the products) to make qualitative predictions regarding the relative temperature dependence of the reaction rate.

LO 4.7 The student is able to evaluate alternative explanations, as expressed by reaction mechanisms, to determine which are consistent with data regarding the overall rate of a reaction, and data that can be used to infer the presence of a reaction intermediate.

LO 4.8 The student can translate among reaction energy profile representations, particulate representations, and symbolic representations (chemical equations) of a chemical reaction occurring in the presence and absence of a catalyst.
<table>
<thead>
<tr>
<th><strong>Unit 9: Acid Base Chemistry and Slightly Soluble Salt Equilibrium</strong></th>
<th><strong>Advanced Placement Learning Objectives</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>LO 4.9 The student is able to explain changes in reaction rates arising from the use of acid-base catalysts, surface catalysts, or enzyme catalysts, including selecting appropriate mechanisms with or without the catalyst present.</td>
<td>LO 6.11 The student can generate or use a particulate representation of an acid (strong or weak or polyprotic) and a strong base to explain the species that will have large versus small concentrations at equilibrium.</td>
</tr>
<tr>
<td>LO 5.16 The student can use LeChatelier’s principle to make qualitative predictions for systems in which coupled reactions that share a common intermediate drive formation of a product.</td>
<td></td>
</tr>
<tr>
<td>LO 5.17 The student can make quantitative predictions for systems involving coupled reactions that share a common intermediate, based on the equilibrium constant for the combined reaction.</td>
<td></td>
</tr>
<tr>
<td>LO 5.18 The student can explain why a thermodynamically favored chemical reaction may not produce large amounts of product (based on consideration of both initial conditions and kinetic effects), or why a thermodynamically unfavored chemical reaction can produce large amounts of product for certain sets of initial conditions.</td>
<td></td>
</tr>
<tr>
<td>LO 6.1 The student is able to, given a set of experimental observations regarding physical, chemical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes.</td>
<td></td>
</tr>
<tr>
<td>LO 6.2 The student can, given a manipulation of a chemical reaction or set of reactions (e.g., reversal of reaction or addition of two reactions), determine the effects of that manipulation on Q or K.</td>
<td></td>
</tr>
<tr>
<td>LO 6.3 The student can connect kinetics to equilibrium by using reasoning about equilibrium, such as LeChatelier’s principle, to infer the relative rates of the forward and reverse reactions.</td>
<td></td>
</tr>
<tr>
<td>LO 6.4 The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use the tendency of Q to approach K to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached.</td>
<td></td>
</tr>
<tr>
<td>LO 6.5 The student can, given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K.</td>
<td></td>
</tr>
<tr>
<td>LO 6.6 The student can, given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use stoichiometric relationships and the law of mass action (Q equals K at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction.</td>
<td></td>
</tr>
<tr>
<td>LO 6.7 The student is able, for a reversible reaction that has a large or small K, to determine which chemical species will have very large versus very small concentrations at equilibrium.</td>
<td></td>
</tr>
<tr>
<td>LO 6.8 The student is able to use LeChatelier’s principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium.</td>
<td></td>
</tr>
<tr>
<td>LO 6.9 The student is able to use LeChatelier’s principle to design a set of conditions that will optimize a desired outcome, such as product yield.</td>
<td></td>
</tr>
<tr>
<td>LO 6.10 The student is able to connect LeChatelier’s principle to the comparison of Q to K by explaining the effects of the stress on Q and K.</td>
<td></td>
</tr>
</tbody>
</table>
LO 6.12 The student can reason about the distinction between strong and weak acid solutions with similar values of pH, including the percent ionization of the acids, the concentrations needed to achieve the same pH, and the amount of base needed to reach the equivalence point in a titration.
LO 6.13 The student can interpret titration data for monoprotic or polyprotic acids involving titration of a weak or strong acid by a strong base (or a weak or strong base by a strong acid) to determine the concentration of the titrant and the pKa for a weak acid, or the pKb for a weak base.
LO 6.14 The student can, based on the dependence of Kw on temperature, reason that neutrality requires [H+] = [OH–] as opposed to requiring pH = 7, including especially the applications to biological systems.
LO 6.15 The student can identify a given solution as containing a mixture of strong acids and/or bases and calculate or estimate the pH (and concentrations of all chemical species) in the resulting solution.
LO 6.16 The student can identify a given solution as being the solution of a monoprotic weak acid or base (including salts in which one ion is a weak acid or base), calculate the pH and concentration of all species in the solution, and/or infer the relative strengths of the weak acids or bases from given equilibrium concentrations.
LO 6.17 The student can, given an arbitrary mixture of weak and strong acids and bases (including polyprotic systems), determine which species will react strongly with one another (i.e., with K >1) and what species will be present in large concentrations at equilibrium.
LO 6.18 The student can design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid-base pair and estimating the concentrations needed to achieve the desired capacity.
LO 6.19 The student can relate the predominant form of a chemical species involving a labile proton (i.e., protonated/deprotonated form of a weak acid) to the pH of a solution and the pKa associated with the labile proton.
LO 6.20 The student can identify a solution as being a buffer solution and explain the buffer mechanism in terms of the reactions that would occur on addition of acid or base.
LO 6.21 The student can predict the solubility of a salt, or rank the solubility of salts, given the relevant Ksp value.
LO 6.22 The student can interpret data regarding solubility of salts to determine, or rank, the relevant Ksp values.
LO 6.23 The student can interpret data regarding the relative solubility of salts in terms of factors (common ions, pH) that influence the solubility.

Unit 10: Entropy, Free Energy, and Electrochemistry

Advanced Placement Learning Objectives
LO 3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday’s laws.
LO 3.13 The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions.
LO 5.12 The student is able to use representations and models to predict the sign and relative magnitude of the entropy change associated with chemical or physical processes.
LO 5.13 The student is able to predict whether or not a physical or chemical process is thermodynamically favored by determination of (either quantitatively or
qualitatively) the signs of both $\Delta H^\circ$ and $\Delta S^\circ$, and calculation or estimation of $\Delta G^\circ$ when needed.

LO 5.14 The student is able to determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy.

LO 5.15 The student is able to explain how the application of external energy sources or the coupling of favorable with unfavorable reactions can be used to cause processes that are not thermodynamically favorable to become favorable.

LO 6.24 The student can analyze the enthalpic and entropic changes associated with the dissolution of a salt, using particulate level interactions and representations.

LO 6.25 The student is able to express the equilibrium constant in terms of $\Delta G^\circ$ and RT and use this relationship to estimate the magnitude of K and, consequently, the thermodynamic favorability of the process.

<table>
<thead>
<tr>
<th>Unit 11: Lab Final</th>
<th>AP Learning Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO 2.10 The student can design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components.</td>
<td></td>
</tr>
</tbody>
</table>

**Physics - Physics: Sights, Sounds, and Circuits**

**Course Description**: This lab-based semester course will explore concepts of physics with limited emphasis on mathematics. Students will investigate topics related to types of energy, properties of light, mirrors, lenses, sound, musical instruments, current, voltage and simple circuits. This broad-based class is open to all students in 11th and 12th grades who have not taken a full year physics course.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Sights</td>
<td>NGSS: HS-PS4-1 - Support a claim concerning the relationship of frequency,</td>
</tr>
</tbody>
</table>
wavelength, and wave speed in different mediums.

**PA Stds**

3.2.10.B5 - Understand that waves transfer energy without transferring matter. Compare and contrast the wave nature of light and sound. Describe the components of the electromagnetic spectrum. Describe the difference between sound and light waves.

3.2.10.B6 - Explain how the behavior of matter and energy follow predictable patterns followed by laws.

3.2.10.B7 - Know that both direct and indirect observations are used by scientists to study the natural world and universe

3.4.12C The speed of a wave in any medium is the produce to the wave’s frequency and wavelength.

3.4.12C Wave transmission, reflection, refraction, and/or absorption occurs when waves travel between two different mediums.

3.4.12C As waves pass through each other, they create new waves with characteristics that are derived from the characteristics of the original waves.

### Unit 2: Sounds

**NGSS:**

HS-PS4-1 - Support a claim concerning the relationship of frequency, wavelength, and wave speed in different mediums.

**PA Stds**

3.2.10.B5 - Understand that waves transfer energy without transferring matter. Compare and contrast the wave nature of light and sound. Describe the components of the electromagnetic spectrum. Describe the difference between sound and light waves.

3.2.10.B6 - Explain how the behavior of matter and energy follow predictable patterns followed by laws.

3.2.10.B7 - Know that both direct and indirect observations are used by scientists to study the natural world and universe

3.4.12C The speed of a wave in any medium is the produce to the wave’s frequency and wavelength.

3.4.12C Wave transmission, reflection, refraction, and/or absorption occurs when waves travel between two different mediums.

3.4.12C As waves pass through each other, they create new waves with characteristics that are derived from the characteristics of the original waves.

### Unit 3: Circuits

**NGSS:**

HS-PS3-3 - Build a device which converts one form of energy into another form of energy.

**PA Stds**

3.2.10.B4 - Describe quantitatively the relationships between voltage, current, and resistance to electrical energy and power. Describe the relationship between electricity and magnetism as two aspects of a single electromagnetic force.

3.2.P.B4 - Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. Explain how electrical induction is used in technology.

### Unit 4: Putting It All

Culmination of previous standards.
# Physics - Physics 1

**Course Description:** This course is designed for the student who desires a basic understanding of the fundamentals that govern our universe. Physics 1 is an algebra-based introduction to a broad range of topics: linear kinematics, dynamics, momentum, energy, wave theory, and electricity. Student involvement in discussions and laboratory activities is emphasized. Critical thinking and problem solving skills are stressed.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Motion in One Dimension    | PA Stds  
3.2.P.B1  
Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration.  
3.4.12.C: Analyze the principles of translational motion, velocity and acceleration as they relate to freefall and projectile motion. |
| Unit 2: Vectors and Projectile Motion | PA Stds  
3.2.P.B1  
Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration.  
3.4.12.C: Analyze the principles of translational motion, velocity and acceleration as they relate to freefall and projectile motion. |
| Unit 3: Dynamics                   | NGSS:  
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.  
PA Stds  
3.2.P.B1  
Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, *velocity*, and acceleration. Use force and *mass* to explain translational motion or simple harmonic motion of objects.  
3.2.P.B6: Unifying Themes: Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.  
3.4.10.B: Know Newton's Law of Motion (including inertia, action and reaction) & gravity and apply them to solve problems related to force & mass.  
3.4.12.B: Describe inertia, motion, equilibrium, and action/reaction concepts through words, models, and mathematical symbols. |
| Unit 4: Uniform Circular Motion    | NGSS  
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.  
PA Stds  
3.2.P.B1  
Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and *mass* to explain translational motion or simple harmonic motion of objects. |
<table>
<thead>
<tr>
<th>Unit 5: Work and Energy</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-PS3-1. Create a computational model to calculate the change in energy of one component in a system when the change in energy of the other component(s) and energy flow in and out of the system are known.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PA Stds</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit 6: Momentum and Collisions</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PA Stds</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects.</td>
</tr>
<tr>
<td>3.2.P.B6 PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton’s laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.</td>
</tr>
<tr>
<td>3.4.10.B: Use knowledge of conservation of energy and momentum to explain common phenomena</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit 7: Oscillations</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-PS3-1. Create a computational model to calculate the change in energy of one component in a system when the change in energy of the other component(s) and energy flow in and out of the system are known.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PA Stds</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.P.B6 PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton’s laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.</td>
</tr>
<tr>
<td>3.4.12.C: Analyze the principles of rotational motion to solve problems relating to angular momentum and torque.</td>
</tr>
<tr>
<td>3.4.12.C: Interpret a model that illustrates circular motion and acceleration.</td>
</tr>
<tr>
<td><strong>Unit 8: Waves and Sound</strong></td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td><strong>HS-PS4-1.</strong> Use mathematical representations to support a claim regarding relationships among frequency, wavelength, and speed of waves traveling in various media.</td>
</tr>
<tr>
<td><strong>3.2.P.B1</strong> Use force and mass to explain translational motion or simple harmonic motion of objects.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Unit 9: Light (if time permits)</strong></th>
<th><strong>NGSS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HS-PS4-1.</strong> Use mathematical representations to support a claim regarding relationships among frequency, wavelength, and speed of waves traveling in various media.</td>
<td><strong>PA Stds</strong></td>
</tr>
<tr>
<td><strong>HS-PS4-3.</strong> 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.</td>
<td><strong>3.2.P.A6</strong> Compare and contrast scientific theories. Know that both direct and indirect observations are used by scientists to study the natural world and universe. Identify questions and concepts that guide scientific investigations. Formulate and revise explanations and models using logic and evidence.</td>
</tr>
<tr>
<td><strong>HS-PS4-4.</strong> Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.</td>
<td><strong>Recognize and analyze alternative explanations and models. Explain the importance of accuracy and precision in making valid measurements.</strong></td>
</tr>
<tr>
<td><strong>HS-PS4-5.</strong> 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.</td>
<td><strong>Examine the status of existing theories. Evaluate experimental information for</strong></td>
</tr>
</tbody>
</table>
relevance and adherence to science processes. Judge that conclusions are consistent and logical with experimental conditions. Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. Communicate and defend a scientific argument.

3.2.12.B5 Research how principles of wave transmissions are used in a wide range of technologies. Research technologies that incorporate principles of wave transmission.

3.2.12.B7 Examine the status of existing theories. Evaluate experimental information for relevance and adherence to science processes. Judge that conclusions are consistent and logical with experimental conditions. Interpret results of experimental research to predict new information, propose additional investigable questions, or advance a solution. Communicate and defend a scientific argument.

3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism.

3.2.P.B5 Explain how waves transfer energy without transferring matter.

Physics - Adv. Physics 1

Course Description: This nested set of courses is designed for the student seriously considering a career in engineering or a related technical field. Advanced Physics 1 and Advanced Engineering Technology are scheduled back-to-back (in consecutive blocks) allowing for project work and integration of physics into engineering applications. The student will receive 1 credit and a separate weighted grade for each section of the course. Physics concepts will be algebra-based and include linear and rotational kinematics, dynamics, momentum, energy, wave theory, sound, electricity, magnetism, and other special topics time permitting. Critical thinking and problem solving skills are stressed with evaluation being based upon tests, quizzes, laboratory exercises, projects, homework and participation. Advanced Engineering gives students the opportunity to learn about and experience engineering topics through direct instruction, class work, activities, tests, labs and projects. Students will also experience engineering through guest speakers, field trips and face-to-face interactions with practicing engineers. STEM (Science, Technology, Engineering and Math) concepts are emphasized throughout.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Motion in One and Two Dimensions</td>
<td>PA Stds</td>
</tr>
<tr>
<td></td>
<td>3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration.</td>
</tr>
<tr>
<td>Unit 2: Vectors and Dynamics</td>
<td>NGSS</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>PA Stds</td>
</tr>
<tr>
<td></td>
<td>3.2.P.B1 Use force and mass to explain translational motion or simple harmonic motion of objects.</td>
</tr>
<tr>
<td></td>
<td>3.2.12.B6 Constancy/Change. Compare and contrast motion of objects using</td>
</tr>
</tbody>
</table>
### Unit 3: Circular Motion

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

**PA Stds**
- 3.2.P.B1 Use force and mass to explain translational motion or simple harmonic motion of objects.
- 3.2.P.B6 Patterns Scale Models Constancy/Change

Use Newton’s laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.


### Unit 4: Work and Energy

**NGSS**
- HS-PS3-1. Create a computational model to calculate the change in energy of one component in a system when the change in energy of the other component(s) and energy flow 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 motion of particles (objects) and energy associated with the relative positions of particles (objects).
- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

**PA Stds**
- 3.2.P.B2 Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum.
- 3.2.12.B2 Explain how energy flowing through an open system can be lost. Demonstrate how the law of conservation of momentum and the conservation of energy provide alternative approaches to predict and describe the motion of objects.

### Unit 5: Applications of Energy and Its Conservation

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

**PA Stds**
<table>
<thead>
<tr>
<th>Unit 6: Momentum and Collisions</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>PA Stds</td>
<td></td>
</tr>
<tr>
<td>3.2.P.B2 Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum.</td>
<td></td>
</tr>
<tr>
<td>3.2.12.B2 Explain how energy flowing through an open system can be lost. Demonstrate how the law of conservation of momentum and the conservation of energy provide alternative approaches to predict and describe the motion of objects.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit 7: Electrostatics</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>PA Stds</td>
<td></td>
</tr>
<tr>
<td>3.2.12.B4 Describe conceptually the attractive and repulsive forces between objects relative to their charges and the distance between them.</td>
<td></td>
</tr>
<tr>
<td>3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit 8: D.C. Circuits</th>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-PS3-1. Create a computational model to calculate the change in energy of one component in a system when the change in energy of the other component(s) and energy flow in and out of the system are known.</td>
<td></td>
</tr>
<tr>
<td>HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.</td>
<td></td>
</tr>
</tbody>
</table>
| Unit 9: Magnetism and Electromagnetic Induction | PA Stds  
3.2.P.B4  
Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, and resistance, and the connections between them.  
NGSS  
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.  
PA Stds  
3.2.P.B4  
Explain how stationary and moving particles result in electricity and magnetism. Explain how electrical induction is applied in technology.  
| --- | --- |
| Unit 10: Oscillations | NGSS  
HS-PS3-1. Create a computational model to calculate the change in energy of one component in a system when the change in energy of the other component(s) and energy flow 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 motion of particles (objects) and energy associated with the relative positions of particles (objects).  
PA Stds  
3.2.P.B1, Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration.  
3.2.P.B1 Use force and mass to explain translational motion or simple harmonic motion of objects.  
3.2.P.B2, Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum.  
| Unit 11: Waves and Sound | NGSS  
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 motion of particles (objects) and energy associated with the relative positions of particles (objects).  
HS-PS4-1. Use mathematical representations to support a claim regarding relationships among frequency, wavelength, and speed of waves traveling in various media.  
HS-PS4-5. 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. |
### PA Stds

3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration.
3.2.P.B1 Use force and mass to explain translational motion or simple harmonic motion of objects.
3.2.P.B2 Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum.
3.2.P.B5 Explain how waves transfer energy without transferring matter.
Explain how waves carry information from remote sources that can be detected and interpreted.
Describe the causes of wave frequency, speed, and wavelength.

### Physics - Advanced Placement Physics 1+

**Course Description:** This course provides a systematic introduction to foundational physics; including translational and rotational mechanics, electrostatics, and elementary circuitry. Further topics will be introduced as time allows and may include: fluids, heat and thermodynamics, light and optics, sound, electromagnetism, quantum theory, nuclear physics, etc. Emphasis is on the development of conceptual understanding and problem-solving ability using algebra and trigonometry. Frequent laboratory experiences are coordinated with classroom work.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: One Dimension Kinematics</td>
<td>Advanced Placement Standards</td>
</tr>
<tr>
<td></td>
<td>3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations.</td>
</tr>
<tr>
<td></td>
<td>3.A.1.2: The student is able to design an experimental investigation of the motion of an object.</td>
</tr>
<tr>
<td></td>
<td>3.A.1.3: The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.</td>
</tr>
<tr>
<td>Unit 2: Two Dimensional Kinematics and Vectors</td>
<td>Advanced Placement Standards</td>
</tr>
<tr>
<td></td>
<td>3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations.</td>
</tr>
<tr>
<td></td>
<td>3.A.1.2: The student is able to design an experimental investigation of the motion of an object.</td>
</tr>
<tr>
<td></td>
<td>3.A.1.3: The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.</td>
</tr>
<tr>
<td>Unit 3: Dynamics</td>
<td>Advanced Placement Standards</td>
</tr>
<tr>
<td></td>
<td>1.C.1.1: The student is able to design an experiment for collecting data to determine the relationship between the net force exerted on an object its inertial mass and its acceleration.</td>
</tr>
<tr>
<td></td>
<td>1.C.3.1: The student is able to design a plan for collecting data to measure</td>
</tr>
</tbody>
</table>
gravitational mass and to measure inertial mass and to distinguish between the two experiments.

2.B.1.1: The student is able to apply $F_g = mg$ to calculate the gravitational force on an object with mass $m$ in a gravitational field of strength $g$ in the context of the effects of a net force on objects and systems.

3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

3.A.3.1: The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.

3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself.

3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force.

3.A.4.1: The student is able to construct explanations of physical situations involving the interaction of bodies using Newton’s third law and the representation of action-reaction pairs of forces.

3.A.4.2: The student is able to use Newton’s third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free body diagrams that include the application of Newton’s third law to identify forces.

3.B.1.1: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton’s second law in a variety of physical situations with acceleration in one dimension.

3.B.1.2: The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces.

3.B.1.3: The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.

3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

3.C.4.1: The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces.

3.C.4.2: The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.

<table>
<thead>
<tr>
<th>Unit 4: Uniform Circular Motion and Gravitation</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.C.3.1: The student is able to design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments.</td>
<td></td>
</tr>
</tbody>
</table>
2.B.1.1: The student is able to apply \( F_g = mg \) to calculate the gravitational force on an object with mass \( m \) in a gravitational field of strength \( g \) in the context of the effects of a net force on objects and systems.

2.B.2.1: The student is able to apply \( g = GM/r^2 \) to calculate the gravitational field due to an object with mass \( M \), where the field is a vector directed toward the center of the object of mass \( M \).

2.B.2.2: The student is able to approximate a numerical value of the gravitational field \( (g) \) near the surface of an object from its radius and mass relative to those of the Earth or other reference objects.

3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

3.A.3.1: The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.

3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force.

3.A.4.1: The student is able to construct explanations of physical situations involving the interaction of bodies using Newton’s third law and the representation of action-reaction pairs of forces.

3.A.4.2: The student is able to use Newton’s third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton’s third law to identify forces.

3.B.1.2: The student is able to design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces.

3.B.1.3: The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.

3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

3.C.1.1: The student is able to use Newton’s law of gravitation to calculate the gravitational force the two objects exert on each other and use that force in contexts other than orbital motion.

3.C.1.2: The student is able to use Newton’s law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion.

3.C.2.2: The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.

3.G.1.1: The student is able to articulate situations when the gravitational force is
the dominant force and when the electromagnetic, weak, and strong forces can be ignored.

4.A.2.2: The student is able to evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified.

<table>
<thead>
<tr>
<th>Unit 5: Work and Energy</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.E.1.1: The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves.</td>
<td></td>
</tr>
<tr>
<td>3.E.1.2: The student is able to use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged.</td>
<td></td>
</tr>
<tr>
<td>3.E.1.3: The student is able to use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether kinetic energy of that object would increase, decrease, or remain unchanged.</td>
<td></td>
</tr>
<tr>
<td>3.E.1.4: The student is able to apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object and the displacement of the object.</td>
<td></td>
</tr>
<tr>
<td>4.C.1.1: The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.</td>
<td></td>
</tr>
<tr>
<td>4.C.1.2: The student is able to predict changes in the total energy of a system due to changes in position and speed of objects or frictional interactions within the system.</td>
<td></td>
</tr>
<tr>
<td>4.C.2.1: The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass.</td>
<td></td>
</tr>
<tr>
<td>4.C.2.2: The student is able to apply the concepts of Conservation of Energy and the Work-Energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system.</td>
<td></td>
</tr>
<tr>
<td>5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.</td>
<td></td>
</tr>
<tr>
<td>5.B.1.1: The student is able to set up a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy.</td>
<td></td>
</tr>
<tr>
<td>5.B.1.2: The student is able to translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies.</td>
<td></td>
</tr>
<tr>
<td>5.B.2.1: The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of</td>
<td></td>
</tr>
</tbody>
</table>
conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.

5.B.3.1: The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.

5.B.3.2: The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.

5.B.3.3: The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.

5.B.4.1: The student is able to describe and make predictions about the internal energy of systems.

5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.

5.B.5.1: The student is able to design an experiment and analyze data to examine how a force exerted on an object or system does work on the object or system as it moves through a distance.

5.B.5.2: The student is able to design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system.

5.B.5.3: The student is able to predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance.

5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).

5.B.5.5: The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.

Unit 6: Momentum

Advanced Placement Standards

3.D.1.1: The student is able to justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force.

3.D.2.1: The student is able to justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.

3.D.2.2: The student is able to 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.

3.D.2.3: The student is able to analyze data to characterize 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.

3.D.2.4: The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an
object over time.

4.B.1.1: The student is able to calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.).

4.B.1.2: The student is able to analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.

4.B.2.1: The student is able to apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system.

4.B.2.2: The student is able to perform analysis on data presented as a force-time graph and predict the change in momentum of a system.

5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.

5.D.1.1: The student is able to make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions.

5.D.1.2: The student is able to apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations.

5.D.1.3: The student is able to apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy.

5.D.1.4: The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.

5.D.1.5: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.

5.D.2.1: The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic.

5.D.2.2: The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.
5.D.2.3: The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.  
5.D.2.4: The student is able to analyze data that verify conservation of momentum in collisions with and without an external friction force. 
5.D.2.5: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. 
5.D.3.1: The student is able to predict the velocity of the center of mass of a system when there is no interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center of mass motion of the system and is able to determine that there is no external force).

<table>
<thead>
<tr>
<th>Unit 7: Rotational Mechanics</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.F.1.1: The student is able to use representations of the relationship between force and torque.</td>
<td>3.F.1.1: The student is able to use representations of the relationship between force and torque.</td>
</tr>
<tr>
<td>3.F.1.2: The student is able to compare the torques on an object caused by various forces.</td>
<td>3.F.1.2: The student is able to compare the torques on an object caused by various forces.</td>
</tr>
<tr>
<td>3.F.1.3: The student is able to estimate the torque on an object caused by various forces in comparison to other situations.</td>
<td>3.F.1.3: The student is able to estimate the torque on an object caused by various forces in comparison to other situations.</td>
</tr>
<tr>
<td>3.F.1.4: The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.</td>
<td>3.F.1.4: The student is able to design an experiment and analyze data testing a question about torques in a balanced rigid system.</td>
</tr>
<tr>
<td>3.F.1.5: The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction).</td>
<td>3.F.1.5: The student is able to calculate torques on a two-dimensional system in static equilibrium, by examining a representation or model (such as a diagram or physical construction).</td>
</tr>
<tr>
<td>3.F.2.1: The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis.</td>
<td>3.F.2.1: The student is able to make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis.</td>
</tr>
<tr>
<td>3.F.2.2: The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.</td>
<td>3.F.2.2: The student is able to plan data collection and analysis strategies designed to test the relationship between a torque exerted on an object and the change in angular velocity of that object about an axis.</td>
</tr>
<tr>
<td>3.F.3.1: The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.</td>
<td>3.F.3.1: The student is able to predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.</td>
</tr>
<tr>
<td>3.F.3.2: In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.</td>
<td>3.F.3.2: In an unfamiliar context or using representations beyond equations, the student is able to justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.</td>
</tr>
<tr>
<td>3.F.3.3: The student is able to plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.</td>
<td>3.F.3.3: The student is able to plan data collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.</td>
</tr>
<tr>
<td>4.A.1.1 The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.</td>
<td>4.A.1.1 The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.</td>
</tr>
<tr>
<td>4.D.1.1: The student is able to describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected</td>
<td>4.D.1.1: The student is able to describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected</td>
</tr>
</tbody>
</table>
objects change the angular velocity and angular momentum of the system.
4.D.1.2: The student is able to plan data collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data.
4.D.2.1: The student is able to describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems.
4.D.2.2: The student is able to plan a data collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems.
4.D.3.1: The student is able to use appropriate mathematical routines to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum.
4.D.3.2: The student is able to plan a data collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted.
5.E.1.1: The student is able to make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque.
5.E.1.2: The student is able to make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero.
5.E.2.1: The student is able to describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system. Students are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses.

<table>
<thead>
<tr>
<th>Unit 8: Simple Harmonic Motion and Oscillations</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.B.3.1: The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.</td>
<td></td>
</tr>
<tr>
<td>3.B.3.2: The student is able to design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.</td>
<td></td>
</tr>
<tr>
<td>3.B.3.3: The student can analyze data to identify qualitative or quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion to use that data to determine the value of an unknown.</td>
<td></td>
</tr>
<tr>
<td>3.B.3.4: The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force.</td>
<td></td>
</tr>
<tr>
<td>5.B.2.1: The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.</td>
<td></td>
</tr>
</tbody>
</table>
| 5.B.3.1: The student is able to describe and make qualitative and/or quantitative
predictions about everyday examples of systems with internal potential energy.
5.B.3.2: The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.
5.B.3.3: The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.
5.B.4.1: The student is able to describe and make predictions about the internal energy of systems.
5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.

<table>
<thead>
<tr>
<th>Unit 9: Mechanical Waves and Interference</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.A.1.1: The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave.</td>
<td></td>
</tr>
<tr>
<td>6.A.1.2: The student is able to describe representations of transverse and longitudinal waves.</td>
<td></td>
</tr>
<tr>
<td>6.A.2.1: The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.</td>
<td></td>
</tr>
<tr>
<td>6.A.3.1: The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.</td>
<td></td>
</tr>
<tr>
<td>6.A.4.1: The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.</td>
<td></td>
</tr>
<tr>
<td>6.B.1.1: The student is able to use a graphical representation of a periodic mechanical wave (position versus time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.</td>
<td></td>
</tr>
<tr>
<td>6.B.2.1: The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.</td>
<td></td>
</tr>
<tr>
<td>6.B.4.1: The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.</td>
<td></td>
</tr>
<tr>
<td>6.B.5.1: The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.</td>
<td></td>
</tr>
<tr>
<td>6.D.1.1: The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.</td>
<td></td>
</tr>
<tr>
<td>6.D.1.2: The student is able to design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves).</td>
<td></td>
</tr>
<tr>
<td>6.D.1.3: The student is able to design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium.</td>
<td></td>
</tr>
<tr>
<td>6.D.2.1: The student is able to analyze data or observations or evaluate evidence</td>
<td></td>
</tr>
</tbody>
</table>
of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes.

6.D.3.1: The student is able to refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively.

6.D.3.2: The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.

6.D.3.3: The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air.

6.D.3.4: The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.

6.D.4.1: The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.

6.D.4.2: The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.

6.D.5.1: The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.

**Unit 10: Electric Forces and Fields**

**Advanced Placement Standards**

1.B.1.1: The student is able to make claims about natural phenomena based on conservation of electric charge.

1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.

1.B.2.1 The student is able to construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices.

1.B.3.1: The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated.

3.C.2.1: The student is able to use Coulomb’s law qualitatively and quantitatively to make predictions about the interaction between two electric point charges.

3.C.2.2: The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.

5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge and linear momentum to those situations.
<table>
<thead>
<tr>
<th>Unit 11: Electric Potential and Capacitance</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.B.1.1: The student is able to make claims about natural phenomena based on conservation of electric charge.</td>
<td></td>
</tr>
<tr>
<td>1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.</td>
<td></td>
</tr>
<tr>
<td>1.B.2.2: The student is able to make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes.</td>
<td></td>
</tr>
<tr>
<td>1.B.2.3: The student is able to challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object.</td>
<td></td>
</tr>
<tr>
<td>1.B.3.1: The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated.</td>
<td></td>
</tr>
<tr>
<td>2.C.1.1: The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge ( q ) placed in an electric field ( E ) using the mathematical model of the relation between an electric force and an electric field: ( F = qE ); a vector relation.</td>
<td></td>
</tr>
<tr>
<td>2.C.1.2: The student is able to calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities.</td>
<td></td>
</tr>
<tr>
<td>2.C.2.1: The student is able to qualitatively and semi-quantitatively apply the vector relationship between the electric field and the net electric charge creating that field.</td>
<td></td>
</tr>
<tr>
<td>2.C.3.1: The student is able to explain the inverse square dependence of the electric field surrounding a spherically symmetric electrically charged object.</td>
<td></td>
</tr>
<tr>
<td>2.C.4.1: The student is able to distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field) and make claims about the spatial behavior of the fields using qualitative or semi-quantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field.</td>
<td></td>
</tr>
<tr>
<td>2.C.4.2: The student is able to apply mathematical routines to determine the magnitude and direction of the electric field at specified points in the vicinity of a small set (2–4) of point charges, and express the results in terms of magnitude and direction of the field in a visual representation by drawing field vectors of appropriate length and direction at the specified points.</td>
<td></td>
</tr>
<tr>
<td>2.C.5.1: The student is able to create representations of the magnitude and direction of the electric field at various distances (small compared to plate size) from two electrically charged plates of equal magnitude and opposite signs, and is able to recognize that the assumption of uniform field is not appropriate near edges of plates.</td>
<td></td>
</tr>
<tr>
<td>2.C.5.2: The student is able to calculate the magnitude and determine the direction of the electric field between two electrically charged parallel plates,</td>
<td></td>
</tr>
</tbody>
</table>
given the charge of each plate, or the electric potential difference and plate separation.

2.C.5.3: The student is able to represent the motion of an electrically charged particle in the uniform field between two oppositely charged plates and express the connection of this motion to projectile motion of an object with mass in the Earth’s gravitational field.

2.E.1.1: The student is able to construct or interpret visual representations of the isolines of equal gravitational potential energy per unit mass and refer to each line as a gravitational equipotential.

2.E.2.1: The student is able to determine the structure of isolines of electric potential by constructing them in a given electric field.

2.E.2.2: The student is able to predict the structure of isolines of electric potential by constructing them in a given electric field and make connections between these isolines and those found in a gravitational field.

2.E.2.3: The student is able to qualitatively use the concept of isolines to construct isolines of electric potential in an electric field and determine the effect of that field on electrically charged objects.

2.E.3.1: The student is able to apply mathematical routines to calculate the average value of the magnitude of the electric field in a region from a description of the electric potential in that region using the displacement along the line on which the difference in potential is evaluated.

2.E.3.2: The student is able to apply the concept of the isoline representation of electric potential for a given electric charge distribution to predict the average value of the electric field in the region.

3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself.

3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force.

3.A.3.4: The student is able to make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge.

3.A.4.1: The student is able to construct explanations of physical situations involving the interaction of bodies using Newton’s third law and the representation of action-reaction pairs of forces.

3.A.4.2: The student is able to use Newton’s third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.

3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton’s third law to identify forces.

3.B.1.3: The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.
3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton’s second law in a variety of physical situations.
3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.
3.C.2.1: The student is able to use Coulomb’s law qualitatively and quantitatively to make predictions about the interaction between two electric point charges.
3.C.2.2: The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.
3.C.2.3: The student is able to use mathematics to describe the electric force that results from the interaction of several separated point charges (generally 2 to 4 point charges, though more are permitted in situations of high symmetry).
3.G.1.2: The student is able to connect the strength of the gravitational force between two objects to the spatial scale of the situation and the masses of the objects involved and compare that strength to other types of forces.
3.G.2.1: The student is able to connect the strength of electromagnetic forces with the spatial scale of the situation, the magnitude of the electric charges, and the motion of the electrically charged objects involved.
4.E.3.1: The student is able to make predictions about the redistribution of charge during charging by friction, conduction, and induction.
4.E.3.2: The student is able to make predictions about the redistribution of charge caused by the electric field due to other systems, resulting in charged or polarized objects.
4.E.3.3: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors.
4.E.3.4: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors that predicts charge distribution in processes involving induction or conduction.
4.E.3.5: The student is able to plan and/or analyze the results of experiments in which electric charge rearrangement occurs by electrostatic induction, or is able to refine a scientific question relating to such an experiment by identifying anomalies in a data set or procedure.
5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.
5.B.2.1: The student is able to calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.
5.C.2.1: The student is able to predict electric charges on objects within a system by application of the principle of charge conservation within a system.
5.C.2.2: The student is able to design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and
qualitatively analyze that data.

5.C.2.3: The student is able to justify the selection of data relevant to an investigation of the electrical charging of objects and electric charge induction on neutral objects.

<table>
<thead>
<tr>
<th>Unit 12: Electric Current and Circuits</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.B.1.1: The student is able to make claims about natural phenomena based on conservation of electric charge.</td>
<td></td>
</tr>
<tr>
<td>1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.</td>
<td></td>
</tr>
<tr>
<td>1.E.2.1: The student is able to choose and justify the selection of data needed to determine resistivity for a given material.</td>
<td></td>
</tr>
<tr>
<td>4.E.4.1: The student is able to make predictions about the properties of resistors and/or capacitors when placed in a simple circuit, based on the geometry of the circuit element and supported by scientific theories and mathematical relationships.</td>
<td></td>
</tr>
<tr>
<td>4.E.4.2: The student is able to design a plan for the collection of data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.</td>
<td></td>
</tr>
<tr>
<td>4.E.4.3: The student is able to analyze data to determine the effect of changing the geometry and/or materials on the resistance or capacitance of a circuit element and relate results to the basic properties of resistors and capacitors.</td>
<td></td>
</tr>
<tr>
<td>4.E.5.1: The student is able to make and justify a quantitative prediction of the effect of a change in values or arrangements of one or two circuit elements on the currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.</td>
<td></td>
</tr>
<tr>
<td>4.E.5.2: The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel.</td>
<td></td>
</tr>
<tr>
<td>4.E.5.3: The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors.</td>
<td></td>
</tr>
<tr>
<td>5.B.9.1: The student is able to construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff’s loop rule).</td>
<td></td>
</tr>
<tr>
<td>5.B.9.2: The student is able to apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff’s loop rule ((\Sigma \Delta V=0)) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches.</td>
<td></td>
</tr>
</tbody>
</table>
5.B.9.3: The student is able to apply conservation of energy (Kirchhoff’s loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch.

5.B.9.4: The student is able to analyze experimental data including an analysis of experimental uncertainty that will demonstrate the validity of Kirchhoff’s loop rule.

5.B.9.5: The student is able to use conservation of energy principles (Kirchhoff’s loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors.

5.B.9.6: The student is able to mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy.

5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff’s Loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor.

5.B.9.8: The student is able to translate between graphical and symbolic representations of experimental data describing relationships among power, current, and potential difference across a resistor.

5.C.3.1: The student is able to apply conservation of electric charge (Kirchhoff’s junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed.

5.C.3.2: The student is able to design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed.

5.C.3.3: The student is able to use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit.

5.C.3.4: The student is able to predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff’s junction rule and relate the rule to the law of charge conservation.

5.C.3.5: The student is able to determine missing values and direction of electric current in branches of a circuit with resistors and NO capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule.

5.C.3.6: The student is able to determine missing values and direction of electric current in branches of a circuit with both resistors and capacitors from values and directions of current in other branches of the circuit through appropriate selection of nodes and application of the junction rule.

5.C.3.7: The student is able to determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other
Unit 13: Magnetism and Induction

<table>
<thead>
<tr>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.C.4.1: The student is able to distinguish the characteristics that differ between monopole fields (gravitational field of spherical mass and electrical field due to single point charge) and dipole fields (electric dipole field and magnetic field) and make claims about the spatial behavior of the fields using qualitative or semiquantitative arguments based on vector addition of fields due to each point source, including identifying the locations and signs of sources from a vector diagram of the field.</td>
</tr>
<tr>
<td>2.D.1.1: The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field.</td>
</tr>
<tr>
<td>2.D.2.1: The student is able to create a verbal or visual representation of a magnetic field around a long straight wire or a pair of parallel wires.</td>
</tr>
<tr>
<td>2.D.3.1: The student is able to describe the orientation of a magnetic dipole placed in a magnetic field in general and the particular cases of a compass in the magnetic field of the Earth and iron filings surrounding a bar magnet.</td>
</tr>
<tr>
<td>2.D.4.1: The student is able to use the representation of magnetic domains to qualitatively analyze the magnetic behavior of a bar magnet composed of ferromagnetic material.</td>
</tr>
<tr>
<td>3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.</td>
</tr>
<tr>
<td>3.A.3.2: The student is able to challenge a claim that an object can exert a force on itself.</td>
</tr>
<tr>
<td>3.A.3.3: The student is able to describe a force as an interaction between two objects and identify both objects for any force.</td>
</tr>
<tr>
<td>3.A.4.1: The student is able to construct explanations of physical situations involving the interaction of bodies using Newton’s third law and the representation of action-reaction pairs of forces.</td>
</tr>
<tr>
<td>3.A.4.2: The student is able to use Newton’s third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.</td>
</tr>
<tr>
<td>3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton’s third law to identify forces.</td>
</tr>
<tr>
<td>3.C.3.1: The student is able to use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor.</td>
</tr>
<tr>
<td>3.C.3.2: The student is able to plan a data collection strategy appropriate to an investigation of the direction of the force on a moving electrically charged object caused by a current in a wire in the context of a specific set of equipment and instruments and analyze the resulting data to arrive at a conclusion.</td>
</tr>
<tr>
<td>4.E.1.1: The student is able to use representations and models to qualitatively describe the magnetic properties of some materials that can be affected by...</td>
</tr>
</tbody>
</table>
magnetic properties of other objects in the system.

4.E.2.1: The student is able to construct an explanation of the function of a simple electromagnetic device in which an induced emf is produced by a changing magnetic flux through an area defined by a current loop (i.e., a simple microphone or generator) or of the effect on behavior of a device in which an induced emf is produced by a constant magnetic field through a changing area.

<table>
<thead>
<tr>
<th>Unit 14: Extra Topics (Fluids, Relativity, Atomic/Quantum, Nuclear, Light/Optics, Heat and Thermodynamics).</th>
<th>Advanced Placement Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>THERMODYNAMICS -</td>
<td></td>
</tr>
<tr>
<td>1.E.3.1: The student is able to design an experiment and analyze data from it to examine thermal conductivity.</td>
<td></td>
</tr>
<tr>
<td>4.C.3.1: The student is able to make predictions about the direction of energy transfer due to temperature differences based on interactions at the microscopic level.</td>
<td></td>
</tr>
<tr>
<td>5.A.2.1: The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.</td>
<td></td>
</tr>
<tr>
<td>5.B.4.1: The student is able to describe and make predictions about the internal energy of systems.</td>
<td></td>
</tr>
<tr>
<td>5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system.</td>
<td></td>
</tr>
<tr>
<td>5.B.5.4: The student is able to make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential energy).</td>
<td></td>
</tr>
<tr>
<td>5.B.5.5: The student is able to predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object or system through a distance.</td>
<td></td>
</tr>
<tr>
<td>5.B.5.6: The student is able to design an experiment and analyze graphical data in which interpretations of the area under a pressure-volume curve are needed to determine the work done on or by the object or system.</td>
<td></td>
</tr>
<tr>
<td>5.B.6.1: The student is able to describe the models that represent processes by which energy can be transferred between a system and its environment because of differences in temperature: conduction, convection, and radiation.</td>
<td></td>
</tr>
<tr>
<td>5.B.7.1: The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles.</td>
<td></td>
</tr>
<tr>
<td>5.B.7.2: The student is able to create a plot of pressure versus volume for a thermodynamic process from given data.</td>
<td></td>
</tr>
<tr>
<td>5.B.7.3: The student is able to use a plot of pressure versus volume for a thermodynamic process to make calculations of internal energy changes, heat, or work, based upon conservation of energy principles (i.e., the first law of thermodynamics).</td>
<td></td>
</tr>
<tr>
<td>7.A.1.1: The student is able to make claims about how the pressure of an ideal</td>
<td></td>
</tr>
</tbody>
</table>
gas is connected to the force exerted by molecules on the walls of the container, and how changes in pressure affect the thermal equilibrium of the system.

7.A.1.2: Treating a gas molecule as an object (i.e., ignoring its internal structure), the student is able to analyze qualitatively the collisions with a container wall and determine the cause of pressure, and at thermal equilibrium, to quantitatively calculate the pressure, force, or area for a thermodynamic problem given two of the variables.

7.A.2.1: The student is able to qualitatively connect the average of all kinetic energies of molecules in a system to the temperature of the system.

7.A.2.2: The student is able to connect the statistical distribution of microscopic kinetic energies of molecules to the macroscopic temperature of the system and to relate this to thermodynamic processes.

7.A.3.1: The student is able to extrapolate from pressure and temperature or volume and temperature data to make the prediction that there is a temperature at which the pressure or volume extrapolates to zero.

7.A.3.2: The student is able to design a plan for collecting data to determine the relationships between pressure, volume, and temperature, and amount of an ideal gas, and to refine a scientific question concerning a proposed incorrect relationship between the variables.

7.A.3.3: The student is able to analyze graphical representations of macroscopic variables for an ideal gas to determine the relationships between these variables and to ultimately determine the ideal gas law $PV = nRT$.

7.B.1.1: The student is able to construct an explanation, based on atomic-scale interactions and probability, of how a system approaches.

7.B.2.1: The student is able to connect qualitatively the second law of thermodynamics in terms of the state function called entropy and how it (entropy) behaves in reversible and irreversible processes.

**FLUID MECHANICS -**

1.E.1.1: The student is able to predict the densities, differences in densities, or changes in densities under different conditions for natural phenomena and design an investigation to verify the prediction.

1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects.

3.C.4.1: The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces.

3.C.4.2: The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.

5.B.10.1: The student is able to use Bernoulli’s equation to make calculations related to a moving fluid.

5.B.10.2: 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.
| 5.B.10.3: | The student is able to use Bernoulli’s equation and the continuity equation to make calculations related to a moving fluid. |
| 5.B.10.4: | The student is able to construct an explanation of Bernoulli’s equation in terms of the conservation of energy. |
| 5.F.1.1: | The student is able to make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation). |

**LIGHT AND OPTICS -**

| 6.A.1.2: | The student is able to describe representations of transverse and longitudinal waves. |
| 6.A.1.3: | The student is able to analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation. |
| 6.A.2.2: | The student is able to contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation. |
| 6.B.3.1: | The student is able to construct an equation relating the wavelength and amplitude of a wave from a graphical representation of the electric or magnetic field value as a function of position at a given time instant and vice versa, or construct an equation relating the frequency or period and amplitude of a wave from a graphical representation of the electric or magnetic field value at a given position as a function of time and vice versa. |
| 6.C.1.1: | The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves. |
| 6.C.1.2: | The student is able to construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition. |
| 6.C.2.1: | The student is able to make claims about the diffraction pattern produced when a wave passes through a small opening, and to qualitatively apply the wave model to quantities that describe the generation of a diffraction pattern when a wave passes through an opening whose dimensions are comparable to the wavelength of the wave. |
| 6.C.3.1: | The student is able to qualitatively apply the wave model to quantities that describe the generation of interference patterns to make predictions about interference patterns that form when waves pass through a set of openings whose spacing and widths are small compared to the wavelength of the waves. |
| 6.C.4.1: | The student is able to predict and explain, using representations and models, the ability or inability of waves to transfer energy around corners and behind obstacles in terms of the diffraction property of waves in situations involving various kinds of wave phenomena, including sound and light. |
| 6.E.1.1: | The student is able to make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed. |
6.E.2.1: The student is able to make predictions about the locations of object and image relative to the location of a reflecting surface. The prediction should be based on the model of specular reflection with all angles measured relative to the normal to the surface.

6.E.3.1: The student is able to describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media.

6.E.3.2: The student is able to plan data collection strategies as well as perform data analysis and evaluation of the evidence for finding the relationship between the angle of incidence and the angle of refraction for light crossing boundaries from one transparent material to another (Snell’s law).

6.E.3.3: The student is able to make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation.

6.E.4.1: The student is able to plan data collection strategies, and perform data analysis and evaluation of evidence about the formation of images due to reflection of light from curved spherical mirrors.

6.E.4.2: The student is able to use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the reflection of light from surfaces.

6.E.5.1: The student is able to use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the refraction of light through thin lenses.

6.E.5.2: The student is able to plan data collection strategies, perform data analysis and evaluation of evidence, and refine scientific questions about the formation of images due to refraction for thin lenses.

6.F.1.1: The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation.

6.F.2.1: The student is able to describe representations and models of electromagnetic waves that explain the transmission of energy when no medium is present.

QUANTUM, ATOMIC AND NUCLEAR -

1.A.2.1: The student is able to construct representations of the differences between a fundamental particle and a system composed of fundamental particles and to relate this to the properties and scales of the systems being investigated.

1.A.4.1: The student is able to construct representations of the energy-level structure of an electron in an atom and to relate this to the properties and scales of the systems being investigated.

1.C.4.1: The student is able to articulate the reasons that the theory of conservation of mass was replaced by the theory of conservation of mass-energy.

1.D.1.1: The student is able to explain why classical mechanics cannot describe
all properties of objects by articulating the reasons that classical mechanics must be refined and an alternative explanation developed when classical particles display wave properties.

1.D.3.1: The student is able to articulate the reasons that classical mechanics must be replaced by special relativity to describe the experimental results and theoretical predictions that show that the properties of space and time are not absolute. [Students will be expected to recognize situations in which non-relativistic classical physics breaks down and to explain how relativity addresses that breakdown, but students will not be expected to know in which of two reference frames a given series of events corresponds to a greater or lesser time interval, or a greater or lesser spatial distance; they will just need to know that observers in the two reference frames can “disagree” about some time and distance intervals.

3.G.3.1: The student is able to identify the strong force as the force that is responsible for holding the nucleus together.

4.C.4.1: The student is able to apply mathematical routines to describe the relationship between mass and energy and apply this concept across domains of scale.

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

5.B.11.1: The student is able to apply conservation of mass and conservation of energy concepts to a natural phenomenon and use the equation \( E = mc^2 \) to make a related calculation.

5.C.1.1: The student is able to analyze electric charge conservation for nuclear and elementary particle reactions and make predictions related to such reactions based upon conservation of charge.

5.D.1.6: The student is able to make predictions of the dynamical properties of a system undergoing a collision by application of the principle of linear momentum conservation and the principle of the conservation of energy in situations in which an elastic collision may also be assumed.

5.D.1.7: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.

5.D.2.5: The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.

5.D.2.6: The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.
5.D.3.2: The student is able to make predictions about the velocity of the center of mass for interactions within a defined one-dimensional system.
5.D.3.3: The student is able to make predictions about the velocity of the center of mass for interactions within a defined two-dimensional system.
5.G.1.1: The student is able to apply conservation of nucleon number and conservation of electric charge to make predictions about nuclear reactions and decays such as fission, fusion, alpha decay, beta decay, or gamma decay.
6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect.
6.F.4.1: The student is able to select a model of radiant energy that is appropriate to the spatial or temporal scale of an interaction with matter.
6.G.1.1: The student is able to make predictions about using the scale of the problem to determine at what regimes a particle or wave model is more appropriate.
6.G.2.1: The student is able to articulate the evidence supporting the claim that a wave model of matter is appropriate to explain the diffraction of matter interacting with a crystal, given conditions where a particle of matter has momentum corresponding to a de Broglie wavelength smaller than the separation between adjacent atoms in the crystal.
6.G.2.2: The student is able to predict the dependence of major features of a diffraction pattern (e.g., spacing between interference maxima), based upon the particle speed and de Broglie wavelength of electrons in an electron beam interacting with a crystal. (de Broglie wavelength need not be given, so students may need to obtain it.)
7.C.1.1: The student is able to use a graphical wave function representation of a particle to predict qualitatively the probability of finding a particle in a specific spatial region.
7.C.2.1: The student is able to use a standing wave model in which an electron orbit circumference is an integer multiple of the de Broglie wavelength to give a qualitative explanation that accounts for the existence of specific allowed energy states of an electron in an atom.
7.C.3.1: The student is able to predict the number of radioactive nuclei remaining in a sample after a certain period of time, and also predict the missing species (alpha, beta, gamma) in a radioactive decay.
7.C.4.1: The student is able to construct or interpret representations of transitions between atomic energy states involving the emission and absorption of photons. [For questions addressing stimulated emission, students will not be expected to recall the details of the process, such as the fact that the emitted photons have the same frequency and phase as the incident photon; but given a representation of the process, students are expected to make inferences such as figuring out from energy conservation that since the atom loses energy in the process, the emitted photons taken together must carry more energy than the incident photon.]
**Course Description:** This is intended as a second year course in physics designed for college-bound students who plan to major in engineering, medicine or one of the physical sciences. Completion of Physics 1, Adv Physics 1: AET, or AP Physics 1+ is highly recommended as well as completion or concurrent enrollment in Calculus. It emphasizes guided inquiry and student centered learning to foster the development of critical thinking skills, with the application of introductory differential and integral calculus.

The curriculum consists of one semester of mechanics and one of electromagnetism. Topics in Mechanics include: Kinematics, Newtonian Dynamics, Work and Energy, Momentum Conservation and Collisions, Rotational Kinematics and Dynamics, Equilibrium, Oscillations and Gravitation. Topics in Electromagnetism include: Electrostatics, Electric Potential and Capacitance, D.C. Circuits, Magnetic Fields and Forces, Electromagnetic Induction and Maxwell’s Equations. This course includes a hands-on laboratory component comparable to a semester-long introductory college-level physics laboratory course.

<table>
<thead>
<tr>
<th><strong>Unit Titles</strong></th>
<th><strong>Standards</strong></th>
</tr>
</thead>
</table>
| Unit 1: Motion in One Dimension | NGSS
| | 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. 
| | Advanced Placement Learning Objectives
| | I.A.1. a) Students should understand the general relationships among position, velocity, and acceleration for the motion of a particle along a straight line, so that: (1) Given a graph of one of the kinematic quantities, position, velocity, or acceleration, as a function of time, they can recognize in what time intervals the other two are positive, negative, or zero, and can identify or sketch a graph of each as a function of time. (2) Given an expression for one of the kinematic quantities, position, velocity, or acceleration, as a function of time, they can determine the other two as a function of time, and find when these quantities are zero or achieve their maximum and minimum values.
| | b) Students should understand the special case of motion with constant acceleration, so they can: (1) Write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities. (2) Use the kinematic equations, and to solve problems involving one-dimensional motion with constant acceleration.
| | c) Students should know how to deal with situations in which acceleration is a specified function of velocity and time so they can write an appropriate differential equation and solve it for $u$ by separation of variables, incorporating correctly a given initial value of $u$.
| | PA Stds
| | 3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration.
| Unit 2: Vectors and Motion in Two and Three Dimensions | NGSS: 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.  
Advanced Placement Learning Objectives  
2. Motion in two dimensions, including projectile motion a) Students should be able to add, subtract, and resolve displacement and velocity vectors, so they can:  
(1) Determine components of a vector along two specified, mutually perpendicular axes.  
(2) Determine the net displacement of a particle or the location of a particle relative to another.  
(3) Determine the change in velocity of a particle or the velocity of one particle relative to another.  
b) Students should understand the general motion of a particle in two dimensions so that, given functions x(t) and y(t) which describe this motion, they can determine the components, magnitude, and direction of the particle’s velocity and acceleration as functions of time.  
c) Students should understand the motion of projectiles in a uniform gravitational field, so they can:  
(1) Write down expressions for the horizontal and vertical components of velocity and position as functions of time, and sketch or identify graphs of these components.  
(2) Use these expressions in analyzing the motion of a projectile that is projected with an arbitrary initial velocity.  
PA Stds  
3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. |
| --- | --- |
| Unit 3: Dynamics | NGSS 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.  
Advanced Placement Learning Objectives  
2. Motion in two dimensions, including projectile motion a) Students should be able to add, subtract, and resolve displacement and velocity vectors, so they can:  
(1) Determine components of a vector along two specified, mutually perpendicular axes.  
(2) Determine the net displacement of a particle or the location of a particle relative to another.  
(3) Determine the change in velocity of a particle or the velocity of one particle relative to another.  
b) Students should understand the general motion of a particle in two dimensions so that, given functions x(t) and y(t) which describe this motion, they can determine the components, magnitude, and direction of the particle’s velocity and acceleration as functions of time.  
c) Students should understand the motion of projectiles in a uniform gravitational field, so they can:  
(1) Write down expressions for the horizontal and vertical components of velocity and position as functions of time, and sketch or identify graphs of these components.  
(2) Use these expressions in analyzing the motion of a projectile that is projected with an arbitrary initial velocity. |
and position as functions of time, and sketch or identify graphs of these components.

(2) Use these expressions in analyzing the motion of a projectile that is projected with an arbitrary initial velocity.

B. Newton's laws of motion
1. Static equilibrium (first law) Students should be able to analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.

2. Dynamics of a single particle (second law) a) Students should understand the relation between the force that acts on an object and the resulting change in the object’s velocity, so they can:
   (1) Calculate, for an object moving in one dimension, the velocity change that results when a constant force \( F \) acts over a specified time interval.
   (2) Calculate, for an object moving in one dimension, the velocity change that results when a force \( F(t) \) acts over a specified time interval.
   (3) Determine, for an object moving in a plane whose velocity vector undergoes a specified change over a specified time interval, the average force that acted on the object.

b) Students should understand how Newton’s Second Law, \( \sum F = ma \), applies to an object subject to forces such as gravity, the pull of strings, or contact forces, so they can:
   (1) Draw a well-labeled, free-body diagram showing all real forces that act on the object.
   (2) Write down the vector equation that results from applying Newton’s Second Law to the object, and take components of this equation along appropriate axes.
   (3) Students should be able to analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, such as motion up or down with constant acceleration. Objectives for the AP AP Course ® Physics Courses B C
   (4) Students should understand the significance of the coefficient of friction, so they can:
      (1) Write down the relationship between the normal and frictional forces on a surface.
      (2) Analyze situations in which an object moves along a rough inclined plane or horizontal surface.
      (3) Analyze under what circumstances an object will start to slip, or to calculate the magnitude of the force of static friction. e) Students should understand the effect of drag forces on the motion of an object, so they can:
         (1) Find the terminal velocity of an object moving vertically under the influence of a retarding force dependent on velocity.
         (2) Describe qualitatively, with the aid of graphs, the acceleration, velocity, and displacement of such a particle when it is released from rest or is projected vertically with specified initial velocity.
         (3) Use Newton’s Second Law to write a differential equation for the velocity of the object as a function of time.
         (4) Use the method of separation of variables to derive the equation for the velocity as a function of time from the differential equation that follows from Newton’s Second Law.
         (5) Derive an expression for the acceleration as a function of time for an object falling under the influence of drag forces.

PA Stds
| 3.2.P.B1 | Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects.  |
| 3.2.P.B6 | Use Newton’s laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies. |

**Unit 4: Work and Energy**

**NGSS**

- 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 motion of particles (objects) and energy associated with the relative positions of particles.

**Advanced Placement Learning Objectives**

**C. Work, energy, power**

1. **Work and the work-energy theorem**
   a) Students should understand the definition of work, including when it is positive, negative, or zero, so they can:
      1. Calculate the work done by a specified constant force on an object that undergoes a specified displacement.
      2. Relate the work done by a force to the area under a graph of force as a function of position, and calculate this work in the case where the force is a linear function of position.
      3. Use integration to calculate the work performed by a force \( F(x) \) on an object that undergoes a specified displacement in one dimension.
      4. Use the scalar product operation to calculate the work performed by a specified constant force \( F \) on an object that undergoes a displacement in a plane.
   b) Students should understand and be able to apply the work-energy theorem, so they can:
      1. Calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object.
      2. Calculate the work performed by the net force, or by each of the forces that make up the net force, on an object that undergoes a specified change in speed or kinetic energy.
      3. Apply the theorem to determine the change in an object’s kinetic energy and speed that results from the application of specified forces, or to determine the force that is required in order to bring an object to rest in a specified distance.

2. **Forces and potential energy**
   a) Students should understand the concept of a conservative force, so they can:
      1. State alternative definitions of “conservative force” and explain why these definitions are equivalent.
      2. Describe examples of conservative forces and non-conservative forces.
   b) Students should understand the concept of potential energy, so they can:
      1. State the general relation between force and potential energy, and explain why potential energy can be associated only with conservative forces.
      2. Calculate a potential energy function associated with a specified one-dimensional force \( F(x) \).
      3. Calculate the magnitude and direction of a one-dimensional force when given...
the potential energy function $U(x)$ for the force.

4. Write an expression for the force exerted by an ideal spring and for the
   potential energy of a stretched or compressed spring.

5. Calculate the potential energy of one or more objects in a uniform
   gravitational field.

3. Conservation of energy
   a) Students should understand the concepts of
      mechanical energy and of total energy, so they can:
      (1) State and apply the relation between the work performed on an object by
          nonconservative forces and the change in an object’s mechanical energy.
      (2) Describe and identify situations in which mechanical energy is converted to other
          forms of energy.
      (3) Analyze situations in which an object’s mechanical energy is changed by
          friction or by a specified externally applied force.
   b) Students should understand conservation of energy, so they can:
      (1) Identify situations in which mechanical energy is or is not conserved.
      (2) Apply conservation of energy in analyzing the motion of systems of
          connected objects, such as an Atwood’s machine.
      (3) Apply conservation of energy in analyzing the motion of objects that move
          under the influence of springs.
      (4) Apply conservation of energy in analyzing the motion of objects that move
          under the influence of other non-constant one-dimensional forces.
   c) Students should be able to recognize and solve problems that call for
      application both of conservation of energy and Newton’s Laws.

4. Power
   Students should understand the definition of power, so they can:
   a) Calculate the power required to maintain the motion of an object with constant
      acceleration (e.g., to move an object along a level surface, to raise an object at a
      constant rate, or to overcome friction for an object that is moving at a constant
      speed).
   b) Calculate the work performed by a force that supplies constant power, or the
      average power supplied by a force that performs a specified amount of work.

PA Stds
3.2.12.B2 Explain how energy flowing through an open system can be lost.
Demonstrate how the law of conservation of momentum and conservation of
energy provide alternate approaches to predict and describe the motion of
objects.
3.2.12.B6 Compare and contrast motions of objects using forces and
conservation laws.

Unit 5: Systems of
Particles and Momentum

NGSS:
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 science and engineering ideas to design, evaluate, and refine a
device that minimizes the force on a macroscopic object during a collision.*

Advanced Placement Learning Objectives:
D. Systems of particles, linear momentum
1. Center of mass
   a) Students should understand the technique for finding center
      of mass, so they can:
      (1) Identify by inspection the center of mass of a symmetrical object.
      (2) Locate the center of mass of a system consisting of two such objects.
(3) Use integration to find the center of mass of a thin rod of non-uniform density
b) Students should be able to understand and apply the relation between center-of-mass velocity and linear momentum, and between center-of-mass acceleration and net external force for a system of particles.
c) Students should be able to define center of gravity and to use this concept to express the gravitational potential energy of a rigid object in terms of the position of its center of mass.

2. Impulse and momentum Students should understand impulse and linear momentum, so they can:
a) Relate mass, velocity, and linear momentum for a moving object, and calculate the total linear momentum of a system of objects.
b) Relate impulse to the change in linear momentum and the average force acting on an object.
c) State and apply the relations between linear momentum and center-of-mass motion for a system of particles.
d) Calculate the area under a force versus time graph and relate it to the change in momentum of an object.
e) Calculate the change in momentum of an object given a function $F(t)$ for the net force acting on the object.

3. Conservation of linear momentum, collisions
a) Students should understand linear momentum conservation, so they can:
(1) Explain how linear momentum conservation follows as a consequence of Newton’s Third Law for an isolated system.
(2) Identify situations in which linear momentum, or a component of the linear momentum vector, is conserved.
(3) Apply linear momentum conservation to one-dimensional elastic and inelastic collisions and two-dimensional completely inelastic collisions.
(4) Apply linear momentum conservation to two-dimensional elastic and inelastic collisions.
(5) Analyze situations in which two or more objects are pushed apart by a spring or other agency, and calculate how much energy is released in such a process.

b) Students should understand frames of reference, so they can:
(1) Analyze the uniform motion of an object relative to a moving medium such as a flowing stream.
(2) Analyze the motion of particles relative to a frame of reference that is accelerating horizontally or vertically at a uniform rate.

PA Stds
3.2.12.B2 Explain how energy flowing through an open system can be lost. Demonstrate how the law of conservation of momentum and conservation of energy provide alternate approaches to predict and describe the motion of objects.
3.2.12.B6 Compare and contrast motions of objects using forces and conservation laws.

Unit 6: Rotational Motion

NGSS
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.

Advanced Placement Learning Objectives:
E. Circular motion and rotation 1. Uniform circular motion Students should understand the uniform circular motion of a particle, so they can:
a) Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.
b) Describe the direction of the particle’s velocity and acceleration at any instant during the motion.
c) Determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities.
d) Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, in situations such as the following:
(1) Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve).
(2) Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel).
2. Torque and rotational statics a) Students should understand the concept of torque, so they can:
(1) Calculate the magnitude and direction of the torque associated with a given force. (2) Calculate the torque on a rigid object due to gravity.
b) Students should be able to analyze problems in statics, so they can:
(1) State the conditions for translational and rotational equilibrium of a rigid object.
(2) Apply these conditions in analyzing the equilibrium of a rigid object under the combined influence of a number of coplanar forces applied at different locations.
c) Students should develop a qualitative understanding of rotational inertia, so they can:
(1) Determine by inspection which of a set of symmetrical objects of equal mass has the greatest rotational inertia.
(2) Determine by what factor an object’s rotational inertia changes if all its dimensions are increased by the same factor.
d) Students should develop skill in computing rotational inertia so they can find the rotational inertia of:
(1) A collection of point masses lying in a plane about an axis perpendicular to the plane.
(2) A thin rod of uniform density, about an arbitrary axis perpendicular to the rod.
(3) A thin cylindrical shell about its axis, or an object that may be viewed as being made up of coaxial shells.
e) Students should be able to state and apply the parallel-axis theorem.
3. Rotational kinematics and dynamics a) Students should understand the analogy between translational and rotational kinematics so they can write and apply relations among the angular acceleration, angular velocity, and angular displacement of an object that rotates about a fixed axis with constant angular acceleration.
b) Students should be able to use the right-hand rule to associate an angular velocity vector with a rotating object.
c) Students should understand the dynamics of fixed-axis rotation, so they can:
(1) Describe in detail the analogy between fixed-axis rotation and straight-line translation.
(2) Determine the angular acceleration with which a rigid object is accelerated about a fixed axis when subjected to a specified external torque or force. (3) Determine the radial and tangential acceleration of a point on a rigid object. (4) Apply conservation of energy to problems of fixed-axis rotation. (5) Analyze problems involving strings and massive pulleys.

d) Students should understand the motion of a rigid object along a surface, so they can:
(1) Write down, justify, and apply the relation between linear and angular velocity, or between linear and angular acceleration, for an object of circular cross section that rolls without slipping along a fixed plane, and determine the velocity and acceleration of an arbitrary point on such an object.
(2) Apply the equations of translational and rotational motion simultaneously in analyzing rolling with slipping.
(3) Calculate the total kinetic energy of an object that is undergoing both translational and rotational motion, and apply energy conservation in analyzing such motion.

4. Angular momentum and its conservation
a) Students should be able to use the vector product and the right-hand rule, so they can:
(1) Calculate the torque of a specified force about an arbitrary origin.
(2) Calculate the angular momentum vector for a moving particle.
(3) Calculate the angular momentum vector for a rotating rigid object in simple cases where this vector lies parallel to the angular velocity vector.
b) Students should understand angular momentum conservation, so they can:
(1) Recognize the conditions under which the law of conservation is applicable and relate this law to one- and two-particle systems such as satellite orbits.
(2) State the relation between net external torque and angular momentum, and identify situations in which angular momentum is conserved.
(3) Analyze problems in which the moment of inertia of an object is changed as it rotates freely about a fixed axis.
(4) Analyze a collision between a moving particle and a rigid object that can rotate about a fixed axis or about its center of mass.

PA Stds
3.2.12.B1 Analyze the principles of rotational motion to solve problems relating to angular momentum and torque.
3.2.12.B2 Explain how energy flowing through an open system can be lost. Demonstrate how the law of conservation of momentum and conservation of energy provide alternate approaches to predict and describe the motion of objects
3.2.12.B6 Compare and contrast motions of objects using forces and conservation laws
3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Relate torque and rotational inertia to explain rotational motion.
3.2.P.B2 Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum.
to angular momentum and torque.
3.2.12.B6 Compare and contrast motions of objects using forces and conservation laws.

Unit 8: Oscillations

NGSS
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-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 motion of particles (objects) and energy associated with the relative positions of particles

Advanced Placement Learning Objectives
1. Simple harmonic motion (dynamics and energy relationships) Students should understand simple harmonic motion, so they can:
   a) Sketch or identify a graph of displacement as a function of time, and determine from such a graph the amplitude, period, and frequency of the motion.
   b) Write down an appropriate expression for displacement of the form \( A \sin \omega t \) or \( A \cos \omega t \) to describe the motion.
   c) Find an expression for velocity as a function of time.
   d) State the relations between acceleration, velocity, and displacement, and identify points in the motion where these quantities are zero or achieve their greatest positive and negative values.
   e) State and apply the relation between frequency and period.
   f) Recognize that a system that obeys a differential equation of the form \( \ddot{x} = -\omega^2 x \) must execute simple harmonic motion, and determine the frequency and period of such motion.
   g) State how the total energy of an oscillating system depends on the amplitude of the motion, sketch or identify a graph of kinetic or potential energy as a function of time, and identify points in the motion where this energy is all potential or all kinetic.
   h) Calculate the kinetic and potential energies of an oscillating system as functions of time, sketch or identify graphs of these functions, and prove that the sum of kinetic and potential energy is constant.
   i) Calculate the maximum displacement or velocity of a particle that moves in simple harmonic motion with specified initial position and velocity.
   j) Develop a qualitative understanding of resonance so they can identify situations in which a system will resonate in response to a sinusoidal external force.
2. Mass on a spring Students should be able to apply their knowledge of simple harmonic motion to the case of a mass on a spring, so they can:
   a) Derive the expression for the period of oscillation of a mass on a spring.
   b) Apply the expression for the period of oscillation of a mass on a spring.
   c) Analyze problems in which a mass hangs from a spring and oscillates vertically.
   d) Analyze problems in which a mass attached to a spring oscillates horizontally.
   e) Determine the period of oscillation for systems involving series or parallel combinations of identical springs, or springs of differing lengths.
3. Pendulum and other oscillations Students should be able to apply their knowledge of simple harmonic motion to the case of a pendulum, so they can:
a) Derive the expression for the period of a simple pendulum.
b) Apply the expression for the period of a simple pendulum.
c) State what approximation must be made in deriving the period.
d) Analyze the motion of a torsional pendulum or physical pendulum in order to determine the period of small oscillations.

PA Stds
3.2.12.B2 Demonstrate how the law of conservation of momentum and conservation of energy provide alternate approaches to predict and describe the motion of objects
3.2.12.B6 Compare and contrast motions of objects using forces and conservation laws.
3.2.P.B1 Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration.
Use force and mass to explain translational motion or simple harmonic motion of objects.
3.2.P.B2 Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum.

Unit 9: Gravitation

NGSS
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-PS2-4. 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-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

Advanced Placement Learning Objectives
4. Newton’s law of gravity Students should know Newton’s Law of Universal Gravitation, so they can:
a) Determine the force that one spherically symmetrical mass exerts on another.
b) Determine the strength of the gravitational field at a specified point outside a spherically symmetrical mass.
c) Describe the gravitational force inside and outside a uniform sphere, and calculate how the field at the surface depends on the radius and density of the sphere.
5. Orbits of planets and satellites Students should understand the motion of an object in orbit under the influence of gravitational forces, so they can:
a) For a circular orbit:
(1) Recognize that the motion does not depend on the object’s mass; describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radius of the orbit; and derive expressions for the velocity and period of revolution in such an orbit.
(2) Derive Kepler’s Third Law for the case of circular orbits.
(3) Derive and apply the relations among kinetic energy, potential energy, and total energy for such an orbit.
b) For a general orbit:
(1) State Kepler’s three laws of planetary motion and use them to describe in
qualitative terms the motion of an object in an elliptical orbit.
(2) Apply conservation of angular momentum to determine the velocity and
radial distance at any point in the orbit.
(3) Apply angular momentum conservation and energy conservation to relate the
speeds of an object at the two extremes of an elliptical orbit.
(4) Apply energy conservation in analyzing the motion of an object that is
projected straight up from a planet’s surface or that is projected directly toward
the planet from far above the surface.

PA Stds
3.2.12.B6 Compare and contrast motions of objects using forces and
conservation laws
3.2.P.B2 Describe the rotational motion of objects using the conservation of
energy and conservation of angular momentum. Explain how gravitational,
electrical, and magnetic forces and torques give rise to rotational motion

Unit 10: Electric Force and Field

NGSS
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
macrowscopic object, its mass, and its acceleration.
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-PS3-5. Develop and use a model of two objects interacting through electrical
or magnetic fields to illustrate the forces between objects and the changes in
energy of the objects due to the interaction.

Advanced Placement Learning Objectives:
III. ELECTRICITY AND MAGNETISM A. Electrostatics
1. Charge and Coulomb’s Law
a) Students should understand the concept of electric charge, so they can:
(1) Describe the types of charge and the attraction and repulsion of charges.
(2) Describe polarization and induced charges.
   b) Students should understand Coulomb’s Law and the principle of superposition, so they can:
   (1) Calculate the magnitude and direction of the force on a positive or negative
   charge due to other specified point charges.
   (2) Analyze the motion of a particle of specified charge and mass under the
   influence of an electrostatic force.
2. Electric field and electric potential (including point charges)
a) Students should understand the concept of electric field, so they can:
(1) Define it in terms of the force on a test charge.
(2) Describe and calculate the electric field of a single point charge.
(3) Calculate the magnitude and direction of the electric field produced by two or
   more point charges.
   (4) Calculate the magnitude and direction of the force on a positive or negative
   charge placed in a specified field.
   (5) Interpret an electric field diagram.
   (6) Analyze the motion of a particle of specified charge and mass in a uniform
   electric field.
### Unit 11: Gauss’ Law

**NGSS**

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

**Advanced Placement Learning Objectives**

3. Gauss’s law
   a) Students should understand the relationship between electric field and electric flux, so they can:
      (1) Calculate the flux of an electric field through an arbitrary surface or of a field uniform in magnitude over a Gaussian surface and perpendicular to it. (2) Calculate the flux of the electric field through a rectangle when the field is perpendicular to the rectangle and a function of one coordinate only.
      (3) State and apply the relationship between flux and lines of force.
   b) Students should understand Gauss’s Law, so they can:
      (1) State the law in integral form, and apply it qualitatively to relate flux and electric charge for a specified surface. (2) Apply the law, along with symmetry arguments, to determine the electric field for a planar, spherical, or cylindrically symmetric charge distribution. (3) Apply the law to determine the charge density or total charge on a surface in terms of the electric field near the surface.

### Unit 12: Electric Potential

**NGSS**

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.

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

**Advanced Placement Learning Objectives**

2. Electric field and electric potential (including point charges)
   (a) Students should understand the concept of electric field, so they can:
      (1) Define it in terms of the force on a test charge.
      (2) Describe and calculate the electric field of a single point charge.
      (3) Calculate the magnitude and direction of the electric field produced by two or more point charges.
      (4) Calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field.
      (5) Interpret an electric field diagram.
(6) Analyze the motion of a particle of specified charge and mass in a uniform electric field.  
(b) Students should understand the concept of electric potential, so they can:  
(1) Determine the electric potential in the vicinity of one or more point charges.  
(2) Calculate the electrical work done on a charge or use conservation of energy to determine the speed of a charge that moves through a specified potential difference.  
(3) Determine the direction and approximate magnitude of the electric field at various positions given a sketch of equipotentials.  
(4) Calculate the potential difference between two points in a uniform electric field, and state which point is at the higher potential.  
(5) Calculate how much work is required to move a test charge from one location to another in the field of fixed point charges.  
(6) Calculate the electrostatic potential energy of a system of two or more point charges, and calculate how much work is required to establish the charge system.  
(7) Use integration to determine electric potential difference between two points on a line, given electric field strength as a function of position along that line.  
(8) State the general relationship between field and potential, and define and apply the concept of a conservative electric field.

4. Fields and potentials of other charge distributions  
(a) Students should be able to use the principle of superposition to calculate by integration:  
(1) The electric field of a straight, uniformly charged wire.  
(2) The electric field and potential on the axis of a thin ring of charge, or at the center of a circular arc of charge.  
(3) The electric potential on the axis of a uniformly charged disk.  
(b) Students should know the fields of highly symmetric charge distributions, so they can:  
(1) Identify situations in which the direction of the electric field produced by a charge distribution can be deduced from symmetry considerations.  
(2) Describe qualitatively the patterns and variation with distance of the electric field of:  
(a) Oppositely-charged parallel plates.  
(b) A long, uniformly-charged wire, or thin cylindrical or spherical shell.  
(3) Use superposition to determine the fields of parallel charged planes, coaxial cylinders, or concentric spheres.  
(4) Derive expressions for electric potential as a function of position in the above cases.

PA Stds  
3.2.12.B4 Describe conceptually the attractive and repulsive forces between objects relative to their charges and the distance between them.  
3.2.12.B6 CONSTANCY/CHANGE Compare and contrast motions of objects using forces and conservation laws.  
3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them.

Unit 13: Capacitance  
NGSS  
HS-PS3-5. Develop and use a model of two objects interacting through electrical
or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Advanced Placement Learning Objectives

B. Conductors, capacitors, dielectrics

1. Electrostatics with conductors
   a) Students should understand the nature of electric fields in and around conductors, so they can:
      (1) Explain the mechanics responsible for the absence of electric field inside a conductor, and know that all excess charge must reside on the surface of the conductor.
      (2) Explain why a conductor must be an equipotential, and apply this principle in analyzing what happens when conductors are connected by wires. (3) Show that all excess charge on a conductor must reside on its surface and that the field outside the conductor must be perpendicular to the surface. b) Students should be able to describe and sketch a graph of the electric field and potential inside and outside a charged conducting sphere.
   c) Students should understand induced charge and electrostatic shielding, so they can:
      (1) Describe the process of charging by induction.
      (2) Explain why a neutral conductor is attracted to a charged object.
      (3) Explain why there can be no electric field in a charge-free region completely surrounded by a single conductor, and recognize consequences of this result.
      (4) Explain why the electric field outside a closed conducting surface cannot depend on the precise location of charge in the space enclosed by the conductor, and identify consequences of this result.

2. Capacitors
   a) Students should understand the definition and function of capacitance, so they can:
      (1) Relate stored charge and voltage for a capacitor.
      (2) Relate voltage, charge, and stored energy for a capacitor.
      (3) Recognize situations in which energy stored in a capacitor is converted to other forms.
   b) Students should understand the physics of the parallel-plate capacitor, so they can:
      (1) Describe the electric field inside the capacitor, and relate the strength of this field to the potential difference between the plates and the plate separation.
      (2) Relate the electric field to the density of the charge on the plates.
      (3) Derive an expression for the capacitance of a parallel-plate capacitor.
      (4) Determine how changes in dimension will affect the value of the capacitance.
      (5) Derive and apply expressions for the energy stored in a parallel-plate capacitor and for the energy density in the field between the plates.
      (6) Analyze situations in which capacitor plates are moved apart or moved closer together, or in which a conducting slab is inserted between capacitor plates, either with a battery connected between the plates or with the charge on the plates held fixed.
   c) Students should understand cylindrical and spherical capacitors, so they can:
      (1) Describe the electric field inside each.
      (2) Derive an expression for the capacitance of each.

3. Dielectrics
   Students should understand the behavior of dielectrics, so they can:
a) Describe how the insertion of a dielectric between the plates of a charged parallel plate capacitor affects its capacitance and the field strength and voltage between the plates.

b) Analyze situations in which a dielectric slab is inserted between the plates of a capacitor.

PA Stds
3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them.

Unit 14: D.C. Circuits

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

Advanced Placement Learning Objectives
C. Electric circuits
1. Current, resistance, power
   a) Students should understand the definition of electric current, so they can relate the magnitude and direction of the current to the rate of flow of positive and negative charge.
   b) Students should understand conductivity, resistivity, and resistance, so they can:
      (1) Relate current and voltage for a resistor.
      (2) Write the relationship between electric field strength and current density in a conductor, and describe, in terms of the drift velocity of electrons, why such a relationship is plausible.
      (3) Describe how the resistance of a resistor depends upon its length and cross-sectional area, and apply this result in comparing current flow in resistors of different material or different geometry.
      (4) Derive an expression for the resistance of a resistor of uniform cross-section in terms of its dimensions and the resistivity of the material from which it is constructed.
      (5) Derive expressions that relate the current, voltage, and resistance to the rate at which heat is produced when current passes through a resistor.
      (6) Apply the relationships for the rate of heat production in a resistor.

2. Steady-state direct current circuits with batteries and resistors only
   a) Students should understand the behavior of series and parallel combinations of resistors, so they can:
      (1) Identify on a circuit diagram whether resistors are in series or in parallel.
      (2) Determine the ratio of the voltages across resistors connected in series or the ratio of the currents through resistors connected in parallel.
      (3) Calculate the equivalent resistance of a network of resistors that can be broken down into series and parallel combinations.
      (4) Calculate the voltage, current, and power dissipation for any resistor in such a network of resistors connected to a single power supply.
      (5) Design a simple series-parallel circuit that produces a given current through and potential difference across one specified component, and draw a diagram for the circuit using conventional symbols.
   b) Students should understand the properties of ideal and real batteries, so they can:
Calculate the terminal voltage of a battery of specified emf and internal resistance from which a known current is flowing.

(2) Calculate the rate at which a battery is supplying energy to a circuit or is being charged up by a circuit.

c) Students should be able to apply Ohm's law and Kirchhoff's rules to direct-current circuits, in order to:

(1) Determine a single unknown current, voltage, or resistance.

(2) Set up and solve simultaneous equations to determine two unknown currents.

d) Students should understand the properties of voltmeters and ammeters, so they can:

(1) State whether the resistance of each is high or low.

(2) Identify or show correct methods of connecting meters into circuits in order to measure voltage or current.

(3) Assess qualitatively the effect of finite meter resistance on a circuit into which these meters are connected.

3. Capacitors in circuits

a) Students should understand the and steady-state behavior of capacitors connected in series or in parallel, so they can:

(1) Calculate the equivalent capacitance of a series or parallel combination.

(2) Describe how stored charge is divided between capacitors connected in parallel.

(3) Determine the ratio of voltages for capacitors connected in series.

(4) Calculate the voltage or stored charge, under steady-state conditions, for a capacitor connected to a circuit consisting of a battery and resistors.

b) Students should understand the discharging or charging of a capacitor through a resistor, so they can:

(1) Calculate and interpret the time constant of the circuit.

(2) Sketch or identify graphs of stored charge or voltage for the capacitor, or of current or voltage for the resistor, and indicate on the graph the significance of the time constant.

(3) Write expressions to describe the time dependence of the stored charge or voltage for the capacitor, or of the current or voltage for the resistor.

(4) Analyze the behavior of circuits containing several capacitors and resistors, including analyzing or sketching graphs that correctly indicate how voltages and currents vary with time.

3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them.

Unit 15: Magnetic Force and Field

NGSS:

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

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

Advanced Placement Learning Objectives

D. Magnetic Fields

1. Forces on moving charges in magnetic fields Students should understand the force experienced by a charged particle in a magnetic field, so they can:
a) Calculate the magnitude and direction of the force in terms of $q$, $v$, and $B$, and explain why the magnetic force can perform no work.
b) Deduce the direction of a magnetic field from information about the forces experienced by charged particles moving through that field.
c) Describe the paths of charged particles moving in uniform magnetic fields.
d) Derive and apply the formula for the radius of the circular path of a charge that moves perpendicular to a uniform magnetic field.
e) Describe under what conditions particles will move with constant velocity through crossed electric and magnetic fields.

2. Forces on current-carrying wires in magnetic fields Students should understand the force exerted on a current-carrying wire in a magnetic field, so they can:
   a) Calculate the magnitude and direction of the force on a straight segment of current carrying wire in a uniform magnetic field.
   b) Indicate the direction of magnetic forces on a current-carrying loop of wire in a magnetic field, and determine how the loop will tend to rotate as a consequence of these forces.
   c) Calculate the magnitude and direction of the torque experienced by a rectangular loop of wire carrying a current in a magnetic field.

3. Fields of long current-carrying wires Students should understand the magnetic field produced by a long straight current carrying wire, so they can:
   a) Calculate the magnitude and direction of the field at a point in the vicinity of such a wire.
   b) Use superposition to determine the magnetic field produced by two long wires.
   c) Calculate the force of attraction or repulsion between two long current-carrying wires.

4. Biot-Savart law and Ampere’s law
   a) Students should understand the Biot-Savart Law, so they can:
      (1) Deduce the magnitude and direction of the contribution to the magnetic field made by a short straight segment of current-carrying wire. (2) Derive and apply the expression for the magnitude of $B$ on the axis of a circular loop of current.
   b) Students should understand the statement and application of Ampere’s Law in integral form, so they can:
      (1) State the law precisely.
      (2) Use Ampere’s law, plus symmetry arguments and the right-hand rule, to relate magnetic field strength to current for planar or cylindrical symmetries.
   c) Students should be able to apply the superposition principle so they can determine the magnetic field produced by combinations of the configurations listed above.

PA Stds
3.2.P.B4  Explain how stationary and moving particles result in electricity and magnetism.
3.2.P.B2  Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.
3.2.12.B4 Describe conceptually the attractive and repulsive forces between objects relative to their charges and the distance between them.

Unit 16: Electromagnetic Induction

NGSS:
HS-PS2-5. Plan and conduct an investigation to provide evidence that an electrical current can produce a magnetic field and that a changing magnetic field can produce an electrical current.
HS-PS3-5. Develop and use a model of two objects interacting through electrical or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Advanced Placement Learning Objectives
E. Electromagnetism
1. Electromagnetic induction (including Faraday’s law and Lenz’s law)
   a) Students should understand the concept of magnetic flux, so they can:
      (1) Calculate the flux of a uniform magnetic field through a loop of arbitrary orientation.
      (2) Use integration to calculate the flux of a non-uniform magnetic field, whose magnitude is a function of one coordinate, through a rectangular loop perpendicular to the field.
   b) Students should understand Faraday’s law and Lenz’s law, so they can:
      (1) Recognize situations in which changing flux through a loop will cause an induced emf or current in the loop.
      (2) Calculate the magnitude and direction of the induced emf and current in a loop of wire or a conducting bar under the following conditions:
         (a) The magnitude of a related quantity such as magnetic field or area of the loop is changing at a constant rate.
         (b) The magnitude of a related quantity such as magnetic field or area of the loop is a specified non-linear function of time.
   c) Students should be able to analyze the forces that act on induced currents so they can determine the mechanical consequences of those forces.
2. Inductance (including LR and LC circuits)
   a) Students should understand the concept of inductance, so they can:
      (1) Calculate the magnitude and sense of the emf in an inductor through which a specified changing current is flowing.
      (2) Derive and apply the expression for the self-inductance of a long solenoid.
   b) Students should understand the transient and steady state behavior of DC circuits containing resistors and inductors, so they can:
      (1) Apply Kirchhoff’s rules to a simple LR series circuit to obtain a differential equation for the current as a function of time.
      (2) Solve the differential equation obtained in (1) for the current as a function of time through the battery, using separation of variables.
      (3) Calculate the initial transient currents and final steady state currents through any part of a simple series and parallel circuit containing an inductor and one or more resistors.
      (4) Sketch graphs of the current through or voltage across the resistors or inductor in a simple series and parallel circuit.
      (5) Calculate the rate of change of current in the inductor as a function of time.
      (6) Calculate the energy stored in an inductor that has a steady current flowing through it.
3. Maxwell’s equations Students should be familiar with Maxwell’s equations so they can associate each equation with its implications.

PA Stds
3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism. Explain how electrical induction is applied in technology.
**Physics - Advanced Topics in Physics**

**Course Description:** This course addresses select topics in physics, utilizing calculus to analyze rigorous problems. Content would be drawn from among the following areas: Thermodynamics, The Special Theory of Relativity, Atomic and Nuclear Physics, Quantum Mechanics, Cosmology, and assorted mathematical methods in physics.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Thermodynamics</td>
<td>NGSS</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>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 motion of particles (objects) and energy associated with the relative positions of particles</td>
</tr>
<tr>
<td></td>
<td>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).</td>
</tr>
<tr>
<td></td>
<td>PA Stds</td>
</tr>
<tr>
<td></td>
<td>3.2.12.B2 Explain how energy flowing through an open system can be lost. Demonstrate how the law of conservation of momentum and conservation of energy provide alternate approaches to predict and describe the motion of objects.</td>
</tr>
<tr>
<td></td>
<td>3.2.12.B3 Describe the relationship between the average kinetic molecular energy, temperature, and phase changes.</td>
</tr>
<tr>
<td></td>
<td>3.2.P.B3 Analyze the factors that influence convection, conduction, and radiation between objects or regions that are at different temperatures.</td>
</tr>
</tbody>
</table>
| Unit 2: Mechanical Waves | NGSS:  
HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.  
HS-PS4-5. 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.*  

PA Standards  
3.2.12.B5 Research how principles of wave transmissions are used in a wide range of technologies. Research technologies that incorporate principles of wave transmission.  
3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism. |
| --- | --- |
| Unit 3: Electromagnetic Waves | NGSS:  
HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.  
HS-PS4-3. 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.  
HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.  
HS-PS4-5. 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.*  

PA Standards  
3.2.12.B5 Research how principles of wave transmissions are used in a wide range of technologies. Research technologies that incorporate principles of wave transmission.  
3.2.P.B4 Explain how stationary and moving particles result in electricity and magnetism. |
| Unit 4: Photons and Matter Waves | NGSS:  
HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.  
HS-PS4-3. 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.  

PA Stds  
3.2.P.B5 Explain how waves transfer energy without transferring matter. |
Explain how waves carry information from remote sources that can be detected and interpreted. Describe the causes of wave frequency, speed, and wavelength.

3.2.12.B5 Research how principles of wave transmissions are used in a wide range of technologies. Research technologies that incorporate principles of wave transmission.

Environmental Science - Environmental Science 1 and Environmental Science

Environmental Science 1 Course Description: This course is designed for students interested in a challenging and rigorous course in Environmental Science. Students will investigate interactions among physical, chemical, biological and Earth systems. Inquiry activities related to the areas of study are emphasized. Students participate in laboratory activities, field trips, independent studies, small group activities and discussions.

Environmental Science Course Description: In this course, students investigate the interactions between people and their environment. Emphasis is placed on interrelationships among chemical, physical, biological and earth sciences. Students participate in laboratory exercises, field trips, independent studies, small group activities and discussions. Topics covered include forestry, wildlife, local geology, ornithology, aquatic ecology and principles of ecology.

<table>
<thead>
<tr>
<th>Unit Titles</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Unit 1: Forest Resources and Management | NGSS  
HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environmental and biodiversity  
HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity  
PA Stds                                                                                           |
4.1.12.D - Analyze the effects of new and emerging technologies on biodiversity in specific ecosystems.  

Unit 2: Biomes & Ecology

<table>
<thead>
<tr>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.</td>
</tr>
<tr>
<td>HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.</td>
</tr>
<tr>
<td>HS-LS2-4: Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem</td>
</tr>
<tr>
<td>PA Stds</td>
</tr>
<tr>
<td>4.1.12.A - Analyze the significance of biological diversity in an ecosystem.</td>
</tr>
<tr>
<td>4.1.10.A - Examine the effects of limiting factors on population dynamics.</td>
</tr>
<tr>
<td>4.1.10.C - Evaluate the efficiency of energy flow within a food web.</td>
</tr>
<tr>
<td>4.1.10.D - Research practices that impact biodiversity in specific ecosystems.</td>
</tr>
<tr>
<td>4.1.10.E - Analyze how humans influence the pattern of natural changes (e.g. primary / secondary succession and desertification) in ecosystems over time.</td>
</tr>
<tr>
<td>4.1.12.A - Analyze the significance of biological diversity in an ecosystem.</td>
</tr>
</tbody>
</table>

Unit 3: Wildlife Studies

<table>
<thead>
<tr>
<th>NGSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environmental and biodiversity</td>
</tr>
<tr>
<td>HS-LS4-6: Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity</td>
</tr>
<tr>
<td>PA Stds</td>
</tr>
<tr>
<td>4.1.10.A - Examine the effects of limiting factors on population dynamics.</td>
</tr>
<tr>
<td>4.1.10.B - Explain the consequences of interrupting natural cycles.</td>
</tr>
<tr>
<td>4.1.10.D - Research practices that impact biodiversity in specific ecosystems. Analyze the relationship between habitat changes to plant and animal population fluctuations.</td>
</tr>
<tr>
<td>4.1.10.E - Analyze how humans influence the pattern of natural changes (e.g. primary / secondary succession and desertification)</td>
</tr>
</tbody>
</table>
| Unit 4: Geology & Soils | NGSS  
HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.  
HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.  
HS-ESS3-3 Create a computational simulation to illustrate the relationships among the management of natural resources, the sustainability of human populations, and biodiversity.  
HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. |
|-----------------------|-------------------------------------------------|
| Unit 5: Aquatics      | NGSS  
HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environmental and biodiversity  |
|                       | PA Stds  
4.2.12.A Examine environmental laws related to land use management and its impact on the water quality and flow within a watershed.  
4.2.12.C Analyze the effects of policies and regulations at various governmental levels on water quality. |
| Unit 6: Human Populations & Current Issues in Environmental Science | NGSS  
HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.  |
|                       | PA Stds  
4.5.12.A Research how technology influences the sustainable use of natural resources.  
4.1.12.C Research how humans affect energy flow within an ecosystem. (Describe the impact of industrial, agricultural, and commercial enterprises on an ecosystem) |