This scope and sequence document was developed to assist teachers with the implementation of the Louisiana Student Standards for Science. This tool is not full curriculum and will need to be further built out by science educators. It has been designed to help in the initial transition to the new standards.

This document is considered a "living" document, as we believe that teachers and other educators will find ways to improve it as they use it. Please send feedback to classroomsupporttoolbox@la.gov so that we may use your input when updating this tool.

August 13, 2019

About the Sample Scope and Sequence Tools

The Louisiana Student Standards for Science represent the knowledge and skills needed for students to successfully transition to postsecondary education and the workplace. The standards call for students to:

- Apply content knowledge
- Investigate, evaluate, and reason scientifically
- Connect ideas across disciplines

This scope and sequence document is designed to assist teachers, schools, and districts with the development of instructional resources that align with the Louisiana Student Standards for Science. This scope and sequence is only a sample; it does not illustrate the only appropriate sequence to teach the standards or the only possible ways to bundle the standards. The bundles can be reorganized around different phenomenon, including phenomenon specific to Louisiana or to a region in Louisiana.

Based on the instructional shifts, this tool uses phenomena to drive 3-dimensional science instruction. The incorporated phenomena are observable events that occur in the universe and can be explained by science. They establish the purpose for learning and help students to connect their learning to real-world events.

- The standards are bundled into units.
- The units are built around an anchor phenomenon.
- One unit has been built out further to contain a series of investigative phenomena, which have been sequentially organized to reinforce one another and build toward the performance expectations.

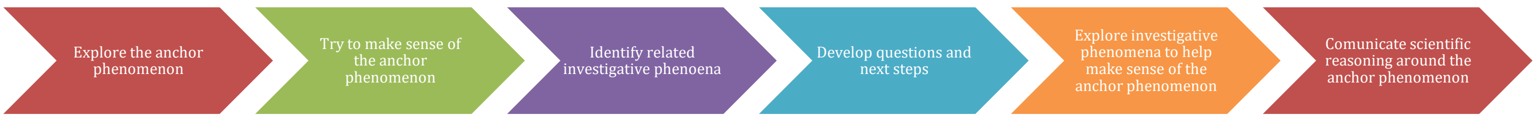
Throughout each unit, students should have multiple opportunities to apply the science and engineering practices, make sense of the crosscutting concepts, and develop a deep understanding of disciplinary core ideas.

Building out the Science Scope and Sequences for Classroom Instruction

How to Use the Anchor and Investigative Phenomena[1]

1. Explore the anchor phenomenon
2. Attempt to make sense of the phenomenon
3. Identify related phenomena
4. Develop questions and next steps
5. Explore investigative phenomena to help make sense of the anchor phenomenon
6. Communicate scientific reasoning around the anchor phenomenon

Instructional Process



Choosing an Anchor Phenomenon

Students should be able to make sense of anchoring phenomenon, but not immediately, and not without investigating it using sequences of the science and engineering practices. With instruction and guidance, students should be able to figure out, step-by-step, how and why the phenomenon works. [2]

A good anchor phenomenon[3]:

- ☐ is too complex for students to explain or design a solution for after a single lesson.
  - The explanation is just beyond the reach of what students can figure out without instruction.
  - Searching online will not yield a quick answer for students to copy.
- ☐ can be a case (pine beetle infestation, building a solution to a problem), something that is puzzling (why isn't rainwater salty?), or a wonderment (how did the solar system form?).
- ☐ has relevant data, images, and text to engage students in the range of ideas students need to understand. It should allow them to use a broad sequence of science and engineering practices to learn science through first-hand or second-hand investigations.
- ☐ will require students to develop an understanding of and apply multiple performance expectations while also engaging in related acts of mathematics, reading, writing, and

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[1] adapted from How do we bring 3-dimensional learning into our classroom?

[2] Using Phenomena

[3] Qualities of a Good Anchor Phenomenon

communication.

- ☐ is observable to students. “Observable” can be with the aid of scientific procedures (e.g., in the lab) or technological devices to see things at very large and very small scales (telescopes, microscopes), video presentations, demonstrations, or surface patterns in data.

Choosing Investigative Phenomena

Students should be able to make sense of investigative phenomenon, but not immediately, and not without investigating it using sequences of the science and engineering practices. With instruction and guidance, students should be able to figure out, step-by-step, how and why the phenomenon works.[4]

A good investigative phenomenon:

- ☐ helps students make sense of one or two parts of the anchor phenomenon.
- ☐ has relevant data, images, and text to engage students in the range of ideas students need to understand.
- ☐ can be understood or explained by students using the science and engineering practices.

Investigating the Phenomena

When a phenomenon is introduced, whether anchor or investigative, students should have the opportunity to make observations, discuss current understandings, and pose questions about the phenomenon. Once questions are compiled, it may be helpful to categorize questions as follows:

- Questions that can be investigated by our class
- Questions that can be investigated but not with our current resources and equipment
- Questions that can be researched
- Questions that cannot be answered (due to current technologies or scientific limitations)

Other Useful Questions When Designing a Sequence of Learning[5]

- How do we kick off investigations in a unit?
- How do we work with students to motivate the next step in an investigation?
- How do we help students use practices to figure out the pieces of the science ideas?
- How do we push students to go deeper and revise the science ideas we have built together so far?
- How do we help students put together pieces of the disciplinary core ideas and crosscutting concepts?

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[4] Using Phenomena

[5] Questions to Guide the Development of a Classroom Culture That Supports “Figuring Out”

Physical Science Standards Overview

The Physical Science course focuses on the study of Matter and Its Interactions, Motion and Stability: Forces and Interactions, Energy and Waves and Their Applications.

		Science and Engineering Practices								
Crosscutting Concepts		Asking Questions and Defining Problems	Developing and Using Models	Planning and Carrying Out Investigations	Analyzing and Interpreting Data	Using Mathematics and Computational Thinking	Constructing Explanations and Designing Solutions	Engaging in Argument from Evidence	Obtaining, Evaluating, and Communicating Information	All Domains
	Patterns		HS-PS1-1				HS-PS1-2			
	Cause and Effect		HS-PS3-5 HS-PS4-1	HS-PS2-5	HS-PS2-1		HS-PS2-3		HS-PS4-4	
	Scale, Proportion and Quantity									
	Systems and System Models			HS-PS3-4		HS-PS2-2				
	Energy and Matter		HS-PS1-8 HS-PS3-2			HS-PS1-7	HS-PS3-3			
	Structure and Function									
	Stability and Change									

Overview of Sample Units

	Unit 1 Atoms and The Periodic Table of Elements	Unit 2 Chemical Reactions	Unit 3 Force and Motion	Unit 4 Energy	Unit 5 Electricity and Magnetism	Unit 6 Waves
Anchor Phenomenon	The Hiroshima atomic bomb was approximately 9.84 feet in length with a diameter of 28 inches, yet it wiped out 90 percent of the city and killed 80,000 people.	Rocks spontaneously combust and cause a woman's pants to catch fire.	Reducing force on passengers during a potential crash is a primary design challenge when designing a car.	The Hubble Space Telescope was launched into orbit in 1990 and remains in service today.	A Van De Graff generator creates static electricity.	The F-117 Nighthawk was a Cold War era aircraft designed to be undetectable to enemy radar systems.
Standards	HS-PS1-1 HS-PS1-8	HS-PS1-2 HS-PS1-7 HS-PS3-2*	HS-PS2-1 HS-PS2-2 HS-PS2-3	HS-PS3-2* HS-PS3-3 HS-PS3-4	HS-PS2-5 HS-PS3-5	HS-PS4-1 HS-PS4-4

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

Unit 1: Atoms and the Periodic Table of Elements

About the Standards

Performance Expectations

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

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

Disciplinary Core Ideas

DCI	Partial Unpacking of the DCI
Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (DCI: HS.PS1A.a; PE: HS-PS1-1)	• An atom is made of subatomic particles: protons, neutrons and electrons. • The nucleus of an atom contains protons (positively charged) and neutrons, which have no net electric charge. • A positively charged nucleus is surrounded by much smaller negatively charged electrons. • Electrons are configured around the nucleus in energy levels. • Electrons in the outmost energy level are called valence electrons.
The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (DCI: HS.PS1A.b; PE: HS-PS1-1)	• The Periodic Table of Elements is an arrangement of the chemical elements ordered by atomic number or the number of protons in atoms. • The arrangement of the main groups of the periodic table reflects the patterns of electrons in the outermost energy level of atoms, and therefore, the chemical properties of the elements in each group. • The atomic mass listed for each element on the periodic table corresponds to the relative abundance of that element's different isotopes.

Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (DCI: HS.PS2B.c; PE: HS-PS1-1)	• The periodic table is used to predict the patterns of behavior of the elements. • The patterns and behaviors of elements are based on the attraction and repulsion between electrically charged particles and the patterns of the outermost electrons. • The relative reactivity and electronegativity of atoms can be determined by an element's location on the periodic table and its valence electrons attraction to the nucleus. • The number and types of bonds formed by an element and between elements, the number and charges of stable ions, and the relative sizes of atoms can be determined by an elements location on the periodic table.
Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (DCI: HS.PS1C.a; PE: HS-PS1-8)	• Fission, fusion and radioactive decay (alpha, beta and gamma) are nuclear processes. • Nuclear fission and fusion reactions release energy as the nuclear force, which binds protons and neutrons, and electrostatic forces, which cause protons to repel, are disrupted. These reactions require initial energy input in order to occur. • In fission reactions, an atom is split into two or more smaller atoms. When the nucleus splits into two or more fragments each have a smaller number of protons than were in the original nucleus. • In fusion reactions, two smaller atoms fuse together to create a heavier atom. When the two nuclei merge to form a single larger nucleus, more protons are present than were in either of the two original nuclei. • When a nuclear process takes place, radioactive particles may be produced. • Radioactive particles or decay occur when an unstable atomic nucleus loses energy by emitting radiation. • Radioactive isotopes decay, or emit radiation, at constant and characteristic rates called half-lives. • The total number of nuclear particles are the same both before and after the nuclear process, although the total number of protons and the total number of neutrons may be different before and after. • The scale of energy released or absorbed in a nuclear process is much larger (hundreds of thousands or even

millions of times larger) than the scale of energy released or absorbed in a chemical process.

- The energy that is released or absorbed during nuclear processes are harmful to human tissues.

Science and Engineering Practices

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Crosscutting Concepts

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- In nuclear processes, atoms are not conserved but the total number of protons and neutrons is conserved.
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.

Putting the Standards into Practice

Explore the anchor phenomenon

Sample Anchor Phenomenon: On August 6, 1945, during World War II, an American bomber dropped an atomic bomb over the Japanese city of Hiroshima. The Hiroshima atomic bomb was approximately 9.84 feet in length with a diameter of 28 inches, yet it wiped out 90 percent of the city of Hiroshima and killed 80,000 people.

Resources: A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

The Manhattan Project Historical Article
Science Behind the Atomic Bomb Article
Nagasaki Atomic Bombing Footage
Bombing of Hiroshima and Nagasaki: Coroner's Report
Bombing of Hiroshima and Nagasaki: Atomic Bomb Assembled
Phet: Nuclear Fission
Phet: Radioactive Dating
WWII Bomb found at Site of Fukushima Nuclear Disaster

Questions students may pose that could be used for future learning or investigations:

Try to make sense of the anchor phenomenon

- How was the atomic bomb different from conventional bombs?
- Where does the energy released in an atomic blast come from?
- What was the environmental impact of the disaster?
- Did people return to the area after the disaster?
- How long does radiation remain in the air after a nuclear disaster?
- What impact does radiation have on living organisms?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

Sample Investigative Phenomena

Identify related investigative phenomena → Develop questions and next steps → Explore investigative phenomena to help make sense of anchor phenomenon

Sample 1: Noble gases are unreactive.

- Build an Atom Simulation
- Unbearable Lightness of Helium
- Recycling of Noble Gases
- Scientists Capture Neon
- Uranium in a Cloud Chamber Video

Sample questions for students to investigate:

- Develop and use a model of an atom to support your response to the following questions:
  - What subatomic particles make up an atom, such as neon, helium etc.?
  - What subatomic particles are located in the center of an atom?
  - What unique properties do the subatomic particles of an atom possess?
- Develop and use a model of the Periodic Table of Elements to support your response to the following questions:
  - How are elements arranged on the Periodic Table of Elements?
  - What patterns are used to organize the Periodic Table of Elements? How are these patterns used to determine the reactivity and properties of elements?
  - How can trends in the periodic table be used to predict the properties of elements?
  - Where are the noble gases located on the Periodic Table of Elements? What do the location of the elements tell you about their reactivity and electronegativity and the relative sizes of their atoms?
  - How are valence electrons used to determine the reactivity and electronegativity of an element?
  - How are the properties of uranium and polonium different from other elements on the Periodic Table of Elements?
  - Based on your analysis of uranium on the Periodic Table of Elements, why is it used to power atomic bombs?

3-D learning opportunities:

SEP: Develop and use a model

DCI: HS.PS1A.a; HS.PS1A.b; HS.PS2B.c

CC: Patterns

Sample 2: Technetium-99 is used in nuclear medicine to diagnose medical conditions.

Radioisotopes in Medicine
Facts about Technetium
Technetium-99m
Medical Isotope Production without Highly Enriched Uranium

Sample questions for students to investigate:	3-D learning opportunities:

• Develop and use a model to answer the following questions:
  ◦ What is an isotope?
  ◦ How are "isotopes" of an element different from "atoms"?
  ◦ What determines if an isotope of an element is stable or radioactive?
• Why are radioactive isotopes used in nuclear medicine?
• Can nonradioactive isotopes be used to diagnose medical conditions? Why or why not? Use evidence to support your response.
• How are technetium-99 isotopes different from other technetium isotopes?
• Why was it difficult for scientists to identify technetium?
• How are uranium isotopes used in atomic bombs?
• How is the half-life of uranium-235 and technetium-99 different? How do these differences impact their use in medicine and atomic bombs?
• Make a claim supporting or refuting the use of radioactive isotopes in medicine.
• How often is the Periodic Table of Elements updated? How do scientists determine if new elements should be added to the table?
	SEP: Develop and use a model; Construct an explanation
	
	DCI: HS.PS1A.a; HS.PS1A.b; HS.PS2B.c
	
	CC: Energy and matter

Sample 3: Radioisotope thermoelectric generators are used to power satellites and planetary bodies on Mars.

Stanford University: An Overview of Radioisotope Thermoelectric Generators
Radioisotope Power: A Key Technology for Deep Space Exploration
Powering the Voyager Spacecraft with Radiation
Half-Life Graphs of Carbon-14 and Uranium-238

Sample questions for students to investigate:

- Develop and use a model of the Periodic Table of Elements to support your response to the following questions:
    - Where is neptunium located on the Periodic Table of Elements?
    - What does the location of the neptunium tell you about its reactivity and electronegativity and the relative size of its atoms? Use evidence from the Periodic Table of Elements to support your response.
- Why is neptunium used to power thermoelectric generators instead of carbon-14?
- How do radioactive materials obtain energy?
- How is radioactive energy used to power thermoelectric generators?
- Are all radioactive elements considered dangerous? Use evidence from the Periodic Table of Elements to support your response.
- What type of radioactive decay was emitted as a result of the atomic bomb dropped on the Japanese cities of Hiroshima and Nagasaki?
- How did the emitted radiation impact the Japanese community and people?
- Based on your understanding of half-life, approximately how long did radioactive particles remain in the cities of Hiroshima and Nagasaki?

3-D learning opportunities:

SEP: Develop and use a model; Mathematics and computational thinking

DCI: HS.PS1A.a; HS.PS1A.b; HS.PS2B.c; HS.PS1Ca

CC: Patterns

Sample 4: Nuclear reactors generate power.

Inside a Nuclear Reactor Video
Periodic Table (labeled by average lifespan of each element)
Will the Sun Ever Burn Out? Article
Nuclear Energy Institute: How Nuclear Reactors Work
Nuclear Energy Institute: Nuclear Fuel Processes
PBS: Nuclear Reactors and Nuclear Bombs: What Defines the Differences?

Sample questions for students to investigate:

- Develop a model to illustrate the changes in the composition of an atom and the energy released during a fission and fusion reaction.
- How are fission and fusion reactions different? Use evidence from your model to support your response.
- What role do fission and fusion reactions play in powering atomic bombs?
- How is uranium-235 different from uranium-238?
- Why is uranium-235 used to power atomic bombs instead of uranium-238?
- How is energy generated in an atomic bomb different from energy generated in a nuclear reactor?

3-D learning opportunities:

SEP: Develop and use a model

DCI: HS.PS1C.a

CC: Energy and Matter

Sample Anchor Phenomenon Reflections

Communicate scientific reasoning around the anchor phenomenon

- How is the Periodic Table of Elements used to predict the relative properties of elements based on the patterns of valence electrons and the composition of the nucleus of atoms?
- How are the components of an atom's nucleus different during the process of fission, fusion, and radioactive decay?

Unit 2: Chemical Reactions

About the Standards

Performance Expectations

- HS-PS1-2 Matter and Its Interactions: 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 Matter and Its Interactions: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- HS-PS3-2* Energy: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects.

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

Science and Engineering Practices

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, 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.
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Crosscutting Concepts

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- The total amount of energy and matter in closed systems is conserved.
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.

Putting the Standards into Practice

Explore the anchor phenomenon

Sample Anchor Phenomenon: Rocks spontaneously combust and cause a woman's pants to catch fire.

Resources: A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

- Rocks Spontaneously Combust in Woman's Pocket Article
- World's Weirdest Events Video
- Allotropes of Phosphorus
- CDC: White Phosphorus
- How dangerous is White Phosphorus?
- U.S. Department of Labor: Phosphorus Necrosis
- U.S. Department of Health and Human Services: Toxicological Profile for White Phosphorus

Questions students may pose that could be used for future learning or investigations:

Try to make sense of the anchor phenomenon

- What caused the rocks in the woman's pants to catch fire?
- How did the woman's pants ignite without a match?
- What type of rock was in the woman's pants?
- Why didn't her pants immediately combust when she put the rock in her pocket?
- Can a chemical reaction take place without a match or lighter?
- What is a chemical reaction and what do you need for a chemical reaction to take place?
- How can you tell if a chemical reaction has occurred?
- Can potential explosive reactions be predicted beforehand?
- What determines if a chemical reaction releases heat?
- What determines the products of a chemical reaction?
- What happens to the atoms involved in a chemical reaction?
- What are the reactants and products in a chemical reaction and how do they change throughout the reactions?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

Sample Anchor Phenomenon Reflections

Communicate scientific reasoning around the anchor phenomenon

- Construct 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.
- Make claim supported by evidence that atoms, and therefore mass, are conserved during a chemical reaction.
- Create a model to illustrate that energy at the microscopic scale can be accounted for as energy associated with the motions of particles and energy associated with the relative positions of particles.

Unit 3: Force and Motion

About the Standards

Performance Expectations

- HS-PS2-1 Motion and Stability: Forces and Interactions: 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 Motion and Stability: Forces and Interactions: 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 Motion and Stability: Forces and Interactions: Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

Science and Engineering Practices

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Crosscutting Concepts

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models
- Systems can be designed to cause a desired effect

Putting the Standards into Practice

Explore the anchor phenomenon

Sample Anchor Phenomenon: Reducing force on passengers during a potential crash is a primary design challenge when designing a car.

Resources: A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

Crash Test With and Without Safety Features Video
How Stuff Works: Crumple Zones
Innovations in Driving: Antilock Brakes
Adaptive Cruise Control (Subsection of Larger Article)
Typical Stopping Distances Table
Phet: Forces and Motion Basics

Questions students may pose that could be used for future learning or investigations:

Try to make sense of the anchor phenomenon

- How do car safety features reduce the amount of force acting on a passenger during a car crash?
- How do car manufacturers determine if safety features can overcome the net force acting on a passenger in a potential car crash?
- How is motion measured during crash testing?
- What causes cars to accelerate?
- How do car manufacturers determine if safety features will work when cars are traveling at high speeds?
- What factors affect the rate of acceleration of a car?
- What happens to the impacting car when it hits another car?
- How do manufactures factor in the mass and acceleration of a car when testing safety features?
- How do systems outside the car (i.e. highway safety barrels) help reduce impact during a crash?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

Sample Anchor Phenomenon Reflections

Communicate scientific reasoning around the anchor phenomenon

- Make a 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.
- 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.
- Design a device that minimizes the force on a macroscopic object during a collision.

Unit 4: Energy

About the Standards

Performance Expectations

- HS-PS3-2* Energy: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects.
- HS-PS3-3 Energy: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
- HS-PS3-4 Energy: 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).

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

Science and Engineering Practices

- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Crosscutting Concepts

- Systems can be designed to cause a desired effect.
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Putting the Standards into Practice

Sample Anchor Phenomenon: The Hubble Space Telescope (HST) is a space telescope that was launched into orbit in 1990 and remains in service today.

Explore the anchor phenomenon

Resources: A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

About the Hubble Space Telescope
Hubble's Space Armor
Ted Talk: How Do Solar Panels Work?
Temperature vs. Time Graph (from Low-Earth Orbit)
Hubble Space Telescope Image Gallery
PhET: Energy Forms and Changes
Read Works: NASA Probe to Explore the Sun's Atmosphere for the First Time

Questions students may pose that could be used for future learning or investigations:

Try to make sense of the anchor phenomenon

- How does the HST generate electricity or operate without electricity?
- How does the HST capture pictures and transmit them back to Earth?
- How has the HST managed to withstand harsh space conditions and operate for a long period of time?
- Why was it important to build the HST's mirror from 'Ultra-Low Expansion' glass?
- How does the HST use its solar panels to produce electrical energy?
- Why doesn't the HST use another type of fuel (i.e. nuclear or fossil)?
- What is the outer coating of the HST made of?
- How does the outer coating of the HST protect it from the harsh environment of space?
- How does the outer coating of the HST help it maintain its internal temperature?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

Sample Anchor Phenomenon Reflections

Communicate scientific reasoning around the anchor phenomenon

- Create a model to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects
- Design and/or build a device that works within given constraints to convert one form of energy into another form of energy. Does your device support or refute the law of conservation of energy?

- Plan and conduct an experiment to demonstrate the second law of thermodynamics

Unit 5: Electricity and Magnetism

About the Standards

Performance Expectations

- HS-PS2-5 Motion and Stability: Forces and Interactions: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- HS-PS3-5 Energy: 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.

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

Science and Engineering Practices

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Crosscutting Concepts

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system

Putting the Standards into Practice

Sample Anchor Phenomenon: A Van de Graaff generator creates static electricity.

Explore the anchor phenomenon

Resources: A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

Static Electricity- Van de Graaff Generator
History of the Van de Graaff Generator
U.S Department of Energy: Van de Graaff Generator
How Van de Graaff Generators Work
PhET: Charges and Fields
PhET: Faraday's Electromagnetic Lab
PhET: Circuit Construction Kit (DC Only)Edu

Questions students may pose that could be used for future learning or investigations:

Try to make sense of the anchor phenomenon

- How does a Van de Graaff machine work?
- What causes aluminum pans to fly off the machine?
- How do charged particles react in a magnetic field?
- Would Van de Graaff generators have any effects on a compass?
- What do electric and magnetic fields look like?
- How do charged particles react in an electric field?
- How do metals react in a magnetic field?
- How do electric and magnetic fields interact?
- How do electromagnetic cranes turn their grippers on and off?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

Sample Anchor Phenomenon Reflections

Communicate scientific reasoning around the anchor phenomenon

- Forces and Interactions: 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.
- 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

Unit 6: Waves

About the Standards

Performance Expectations

- HS-PS4-1 Waves and Their Applications: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- HS-PS4-4 Waves and Their Applications: Evaluate the validity and reliability of claims in published materials regarding the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

* The performance expectation is only partially addressed using the identified phenomenon. The performance expectation is addressed in other unit(s).

Science and Engineering Practices

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Crosscutting Concepts

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Putting the Standards into Practice

Sample Anchor Phenomenon: The F-117 Nighthawk was a Cold War era aircraft designed to be undetectable to enemy radar systems.

Explore the anchor phenomenon

Resources: A number of resources for the anchor phenomenon are included below. Teachers should screen the resources and pull photos, quotes, and data that are appropriate to share with high school students. These resources are not appropriate to be given to students as they are due to length, content, or accessibility of the content.

Lockheed Martin F-117 Nighthawk at Airshow
In-Depth Look at the Elusive F-117 Nighthawk Fighter
Weird Weather Radar Blob Tide to Chaff Used In Military Test
Explainer: What are Lidar, Radar, and Sonar?
The Electromagnetic Spectrum Infographic
How Does Stealth Technology Work?
PhET: Radio Waves and Electromagnetic Fields
PhET: Waves on a String

Questions students may pose that could be used for future learning or investigations:

Try to make sense of the anchor phenomenon

- How do radar systems detect aircrafts?
- How were F-117 Nighthawk aircrafts undetectable by enemy radar systems?
- How do chaff and other counterintelligence maneuvers affect radar systems?
- What materials are stealth aircrafts made of?
- Are stealth aircrafts constructed differently than regular aircrafts?
- Do radar systems work underwater and/or in space?
- Are electromagnetic waves (i.e. radar, cellphones, etc.) harmful to my health?

Teachers should provide Investigative Phenomenon based on student observations, questions, and the Characteristics of Quality Investigative Phenomenon.

Sample Anchor Phenomenon Reflections

Communicate scientific reasoning around the anchor phenomenon

- Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- Describe the effects different frequencies of electromagnetic radiation have when absorbed by matter.