



**CONNECTICUT TECHNICAL EDUCATION
AND CAREER SYSTEM**

Grade 11
Topics in General Science
SC310

**Connecticut Technical High School System
39 Woodland Street
Hartford, Connecticut 06105**

Table of Contents

CTECS - Vision of a Graduate	3
CTECS Instructional Model	5
Curriculum Introduction	6
Curriculum Components	7
Description of the Course	8
Advanced Topics in General Science - Course Map	11
Unit 1: Chemical Reactions	12
Priority Standard (Performance Expectation): HS-PS1-1 Matter and its Interactions	12
Priority Standard (Performance Expectation): HS-PS1-2 Matter and Its Interactions	15
Priority Standard (Performance Expectation): HS-PS1-3 Matter and Its Interactions	19
Priority Standard (Performance Expectation): HS-PS2-6 Motion and Stability: Forces and Interactions.....	24
Unit 2: The Universe, Elements, and Waves	29
Priority Standard (Performance Expectation): HS-ESS1-2 Earth’s Place in the Universe	29
Priority Standard (Performance Expectation): HS-ESS1-3 Earth’s Place in the Universe	33
Priority Standard (Performance Expectation): HS-ESS1-1 Earth’s Place in the Universe	37
Priority Standard (Performance Expectation): HS-PS4-1 Waves and their Applications in Technologies for Information Transfer.....	41
Priority Standard (Performance Expectation): HS-PS1-8 Matter and its Interactions	46
Unit 3: Forces and Interactions	51
Priority Standard (Performance Expectation): HS-PS2-1 Motion and Stability: Forces and Interactions.....	51
Priority Standards (Performance Expectations):.....	56
HS-PS2-2 Motion and Stability: Forces and Interactions.....	56
HS-PS2-3 Motion and Stability: Forces and Interactions.....	56
Priority Standards (Performance Expectations):.....	62
HS-PS3-1 Energy.....	62
HS-PS3-2 Macroscopic Energy Due to Particle Position and Motion	62
HS-PS3-3 Energy Conversion Device Design.....	62
Unit 4: Magnetic Fields	69
Priority Standard (Performance Expectation): HS-PS 2-5 Electric Current and Magnetic Fields	69
Priority Standard (Performance Expectation): HS-PS3-5 Energy	74
Priority Standard (Performance Expectation): HS-ETS1-1 Engineering Design.....	78
Appendix A: Vocabulary	81

CTECS - Vision of a Graduate

Connecticut Technical Education and Career System

Vision of a Graduate

A CTECS Graduate is...



A Problem Solver



Work Ready



Respectful



Skilled Socially



A Critical Thinker



An Effective Communicator

The Vision of a Graduate (VoG) at the Connecticut Technical Education and Career System (CTECS) embodies our commitment to preparing students for success in Connecticut's workforce.

Developed in collaboration with students, parents, staff, and employers, the VoG ensures that CTECS students are not only job-ready but also equipped to lead, innovate, and adapt in a dynamic world.

As educators, we are dedicated to developing these qualities by providing a comprehensive education that empowers our students to achieve their fullest potential and make meaningful contributions to society.

A Problem Solver

Problem solvers tackle challenges by identifying root causes of issues, brainstorming solutions, implementing effective strategies, and demonstrating adaptability.

- Engage students with open-ended, creative thinking tasks that require both conventional and innovative solutions.
- Facilitate group discussions and collaborative projects.
- Use real-world scenarios and hands-on activities.
- Highlight the importance of effort, persistence, and continuous learning.
- Provide regular feedback and encourage reflection.

Work Ready

To be work-ready includes a combination of technical expertise, soft skills, and personal qualities that ensure a graduate can effectively contribute to the workplace from day one.

- Set high standards for punctuality, responsibility, professionalism, and task completion.
- Use project-based learning and collaborative assignments.
- Emphasize clear written and verbal communication.
- Offer practical exercises like mock interviews and resume workshops.
- Integrate technology and teach digital literacy.

Respectful

Graduates who embody respectfulness emphasize the importance of treating others with dignity, valuing diversity, and fostering an inclusive and positive environment, both personally and professionally.

- Demonstrate personal, interpersonal, and professional skills.
- Show respect for diversity.
- Model respect through active listening and empathy.
- Set clear expectations for respectful interactions.
- Promote collaboration and group discussions.
- Celebrate respectful behavior.
- Address disrespect promptly and constructively.

Skilled Socially

Graduates who are skilled socially are equipped to navigate social environments, build relationships, and contribute positively to their communities and workplaces.

- Show awareness of global responsibility to others and the environment.
- Participate in community involvement.
- Design cooperative group projects and team activities
- Set expectations for respect and give regular feedback.
- Facilitate discussions on inclusivity, kindness, and respect.
- Model positive interactions and recognize strong social skills.

A Critical Thinker

Critical thinkers approach problems systematically by analyzing, evaluating, and synthesizing information to make well-informed decisions and contribute to innovative solutions.

- Encourage critical thinking individually and collaboratively.
- Design lessons that challenge assumptions and explore diverse viewpoints.
- Use open-ended questions, rigorous activities, and cross-curricular projects.
- Integrate project-based learning and real-world problem-solving.
- Offer reflective opportunities like journaling and discussions.
- Cultivate an environment that values curiosity and inquiry.

An Effective Communicator

Effective communicators convey ideas, information, and emotions accurately and persuasively, fostering understanding and collaboration.

- Communicate effectively using oral, written, visual, artistic, and technical modes.
- Include group discussions, presentations, and peer reviews.
- Promote active listening and thoughtful responses.
- Offer clear guidelines and constructive feedback.
- Stress clear, respectful, and purposeful communication.

CTECS Instructional Model

CTECS uses the Marzano Compendium to guide research-based instructional strategies that differentiate learning and promote access, engagement, and success for all students. Teachers apply these strategies to support diverse learners (including multilingual learners, students with disabilities, and students with varied academic or technical backgrounds) through scaffolds, modeling, guided practice, and multiple ways to participate and show understanding. This approach ensures every student can work toward proficiency in the Priority Standards and the competencies outlined in the CTECS Vision of a Graduate.

Curriculum Introduction

This curriculum document outlines the essential learning for this academic program and provides a clear structure for planning, instruction, and assessment. It includes the components required by NEASC Standard 2.2a, along with elements that reflect the unique nature of CTECS academic programs. The curriculum is organized to show what students learn in each course, how learning progresses across grade levels, and how instruction supports both technical skill development and the CTECS Vision of a Graduate.

Teachers should use this document to:

- Understand the overall structure and expectations of the course sequence
- Reference the Course Map to see the scope and sequence of Priority Standards
- Use the Priority Standards and Units of Study to guide daily, weekly, and cycle-based planning
- Integrate Big Ideas, Essential Questions, Skills/Learning Outcomes, vocabulary, and resources during lesson design
- Plan and implement formative assessments to monitor progress and guide instruction
- Prepare students for the District Summative Assessments, ensuring alignment with the Course Map
- Maintain consistency of instruction across campuses while adapting to student needs

Curriculum Components

Course Map

A Course Map serves as the scope and sequence for this course by outlining the progression of instructional units and the standards that guide teaching and assessment. While each campus will have individual student needs, cycle schedules, and industry-based opportunities, all instructors are expected to teach the standards outlined in the Course Map. Using the Course Map below, teachers will intentionally plan learning experiences that prepare students to meet the identified standards within the designated assessment windows.

Priority Standards (Units of Study)

Priority Standards identify the most essential learning in the trade program. They reflect the core technical competencies, safety practices, and industry-aligned skills that require the greatest instructional focus and appear on program assessments. In CTE programs, each Priority Standard also functions as a Unit of Study, because it includes the required components such as big ideas, essential questions, content topics, and skills/learning outcomes aligned to assessments.

Learning Outcomes

Learning outcomes are what students will know (Concepts) and be able to do (Skills). Concepts identify the major content topics within the Priority Standard (Unit of Study). They appear in the left column of the Learning Outcomes table and follow a similar coding structure as the Priority Standard. Skills are learning objectives that describe the measurable actions students must be able to perform to demonstrate proficiency. They appear in the right column of the Learning Outcomes table and show the progression of learning evidence in the Priority Standard.

Resources

Resources include the tools, equipment, texts, materials, and digital tools that support learning within each unit and reflect industry standards.

Assessment Practices

Teachers use ongoing formative assessments—such as questioning, checks for understanding, performance demonstrations, reflections, and teacher observation—to monitor progress, guide instruction, and support all learners in mastering the Priority Standards.

Vocabulary

Essential vocabulary includes the technical and academic terms students must understand and use accurately to engage in scientific learning and demonstrate proficiency on assessments. Vocabulary is foundational to safety, precision, and communication, and should be a primary initial focus within each unit and taught explicitly through modeling, demonstration, and repeated application.

Description of the Course

(1 credit) Advanced Topics in General Science allows students to continue to explore aspects of chemistry, physics, and earth and space sciences and to apply data collection, analysis, and interpretation skills related to those scientific concepts. Based on the Next Generation Science Standards (NGSS), the course is composed of three related disciplines: Earth and Space Science; Physical Sciences; and Engineering, Technology, and Applications of Science. This framework articulates the standards as well as the science and engineering performances, disciplinary core ideas, and crosscutting concepts. The curriculum describes the specific performances that will be assessed on the Next Generation Science Assessment. Students are expected to complete several inquiry-based projects over the course of the year.

CTECS Science Assessment & Instruction Guidelines

The grade-level **SEP (Science and Engineering Practices) Summative Assessments** for grades 9 through 12 are designed to measure mastery of the science and engineering practices identified by the NGSS (Next Generation and Science Standards). The practices describe behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems.

The SEPs are:

- **Asking Questions and Defining Problems:** A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.
- **Developing and Using Models:** A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.
- **Planning and Carrying Out Investigations:** Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
- **Analyzing and Interpreting Data:** Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.
- **Using Mathematics and Computational Thinking:** In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.
- **Constructing Explanations and Designing Solutions:** The products of science are explanations and the products of engineering are solutions.
- **Engaging in Argument from Evidence:** Argumentation is the process by which explanations and solutions are reached.

- **Obtaining, Evaluating, and Communicating Information:** Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Each grade-level SEP Summative Assessment is designed to assess mastery of specific **practices**. The expectation is that students should demonstrate mastery as outlined below in preparation for the NGSS Assessment in 11th grade. Cross-cutting concepts are incorporated across all courses.

Grade Level	Science Engineering and Practices (SEP) to be Mastered
9 General Science	Asking Questions and Defining Problems
	Planning and Carrying Out Investigations
	Analyzing and Interpreting Data
10 Biology	Developing and Using Models
	Engaging in Argument from Evidence
	Obtaining, Evaluating, and Communicating Information
11 Chemistry Advanced Topics Physics	Using Mathematics and Computational Thinking
	Constructing Explanations and Designing Solutions

Cross-Cutting Concepts (incorporated into all courses)
Cause and Effect
Structure and Function
Systems and System Models
Scale, Proportion, and Quantity
Stability and Change
Energy and Matter
Patterns

Instruction, Grading, and Assessment Considerations

The manner and pedagogy used to teach the Disciplinary Core Ideas (DCIs) is at the discretion of the instructors. They are, however, expected to support their students in demonstrating mastery of the SEPs on the common summative assessments by the end of the course, in unit order.

Instruction:

- Keeping in mind that all DCIs should be covered by the end of the school year for each course, instructors are encouraged to engage students in learning tasks that consider relevance, interest, school trades, and available materials and supplies.
- The instructional focus should be on the SEPs and the Cross-Cutting Concepts (CCCs) as identified by the NGSS.
- Instruction can be linear or spiraling and be designed around anchoring phenomena and/or storylines.
- Interim-Based Assessment:
 - 11th Grade Topics: Students will be exposed to NGSS-style questions through the NGSS Practice Assessments. Skills of focus include: Test-Taking Skills, Navigating Multi-Select Questions, Desmos Calculator, Highlighting, Online Graphing.
 - Minimum of 1 Interim-Based Assessment practice session per quarter during Junior year.

Grading:

- As mandated by the District, Mandated Grading Categories are:
 - Assessment 40%
 - Labs/Projects 30%
 - Classwork/Activities 30%

Assessment: (Summative and Formative)

- Three-dimensional district-wide unit assessments will measure mastery of Science and Engineering Practices (SEPs) in alignment with Cross Cutting Concepts (CCCs) and Disciplinary Core Ideas (DCIs).
- Claim Evidence Reasoning: CERs will measure a student's ability to use data, critical thinking, and scientific reasoning to form and support an argument.

Supporting ELs: For information on how to support English Learners in this unit, refer to the Connecticut English Language Proficiency (CELP) Standards with Correspondences to the K-12 Practices and Connecticut Core Standards. https://portal.ct.gov/-/media/SDE/English-Learners/celp_standards_content_standards_practices.pdf

Use the EL Strategies Desk Cards (Tip Sheets for ALL Classroom Teachers)

https://www.crec.org/docs/4339/RESC_Alli-ance_Desk_Cards_Revised_2.pdf for specific questioning techniques and teaching strategies to support students' learning

Advanced Topics in General Science - Course Map

Unit	Cycles	Big Idea	Standards	Interim Assessments
Unit 1: Chemical Reactions and Periodic Trends	1-3	The intrinsic structure and periodic properties of atoms serve as the fundamental blueprint that governs how substances interact, transform, and manifest in the physical world.	HS-PS1-1 Matter and its Interactions HS-PS1-2 Matter and Its Interactions HS-PS1-3 Matter and Its Interactions HS-PS2-6 Motion and Stability: Forces and Interactions	HS-PS1-1 HS-PS1-2
Unit 2: The Universe, Elements, and Waves	4-5	The universe is a self-sustaining system where nuclear processes within stars forge the building blocks of matter, releasing immense energy that powers the cosmos, while the predictable behavior of waves allows us to harness that energy to understand and communicate across it.	HS-ESS1-2 Earth's Place in the Universe HS-ESS1-3 Earth's Place in the Universe HS-ESS1-1 Earth's Place in the Universe HS-PS4-1 Waves and their Applications in Technologies for Information Transfer HS-PS1-8 Structure and Properties of Matter	HS-ESS1-2 HS-ESS1-3 HS-PS4-1
Unit 3: Forces and Interactions	6-8	The predictable laws governing force and momentum provide a mathematical framework for understanding motion, allowing us to manipulate physical interactions and engineer solutions that manage energy and impact.	HS-PS2-1 Motion and Stability: Forces and Interactions HS-PS2-2 Motion and Stability: Forces and Interactions HS-PS2-3 Motion and Stability: Forces and Interactions HS-PS3-1 Energy Change of Components in a System HS-PS3-2 Macroscopic Energy Due to Particle Position and Motion HS-PS3-3 Energy Conversion Device Design	HS-PS3-1 HS-PS2-2
Unit 4: Electro-magnetism	9-10	The reciprocal relationship between electricity and magnetism, mediated by invisible fields, provides a fundamental mechanism for energy transformation and the engineering of sustainable technological solutions.	HS-PS 2-5 Electric Current and Magnetic Fields HS-PS3-5 Energy HS-ETS1-1 Engineering Design	HS-PS2-5 HS-PS3-5

Unit 1: Chemical Reactions

Priority Standard (Performance Expectation): HS-PS1-1 Matter and its Interactions

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.

Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.

Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.

Big Idea(s):

- The arrangement of elements in the periodic table reflects their properties and guides our understanding of chemical behavior and reactivity across different groups and periods.

Essential Question(s):

- How can the patterns and trends in the periodic table be used to predict properties of elements?
- How does the number and arrangement of subatomic particles determine the properties and behavior of the element?

Examples of Engaging Phenomenon:

- [Potassium chloride \(KCl\) tastes similar to table salt \(sodium chloride, NaCl\)](#)
- [Balloons are filled with helium gas instead of hydrogen gas](#)
- [Argon gas is used when welding metals to reduce oxidation/reactivity](#)
- [Burning Steel Wool](#)
- [CSI unknown white powder](#)
- [Volatile Elements Needed for Health](#)
- Element Builder Gizmo
- [Diamond, graphene, and fullerene are different molecules/materials that are only made of Carbon](#)

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p><u>Structure and Properties of Matter</u></p> <ul style="list-style-type: none">● Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by 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.● Atoms consist of a small central region called the nucleus made of positively-charged protons (represented by atomic number) and neutral neutrons (represented as atomic mass when added to protons; isotopic average). The nucleus is surrounded by a larger region called the electron cloud that contains negatively-charged electrons.● An element is a pure substance that cannot be broken down further and still retain all of its characteristic properties.● A compound is a pure substance formed when two or more different elements are chemically bonded together. Compounds exhibit properties that are different from the properties of their constituent elements. The elements within a compound are always present in a specific, unchanging ratio. The ratio is designated through the use of subscripts. For example, H₂O.● The periodic table is designed to illustrate properties of all known elements. It orders elements in rows called periods by electron shell numbers. Elements	<p>Developing and using Models</p> <ul style="list-style-type: none">● Design or refine a solution to a complex real-world problem, based on scientific -knowledge principles, and theories.● Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.● From the given model, students identify and describe the components of the model that are relevant for their predictions, including: elements and their arrangement in the periodic table; a positively-charged nucleus composed of both protons and neutrons, surrounded by negatively-charged electrons; electrons in the outermost energy level of atoms (i.e., valence electrons); and the number of protons in each element.● Identify and describe the following relationships between components in the given model including: the arrangement of the main groups of the periodic table reflects the patterns of outermost electrons, and elements in the periodic table are arranged by the numbers of protons in atoms.● Predict, using the periodic table, the patterns of behavior of the elements based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom. Students predict the following patterns of properties: the number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements; the number and charges in stable ions that form from atoms in a group of the periodic table; the trend in reactivity and electronegativity of atoms down a group, and across a row in

are grouped in vertical columns called groups or families, that represent the number of valence electrons they possess (excluding transition metals).

- Metal reactivity decreases from left to right across periods and increases down groups.
- Nonmetal reactivity increases from left to right across periods and decreases down groups.
- Valence electrons are the electrons in the outermost shell, or energy level, of an atom. They influence how the atom will form bonds.
- The Octet Rule is that an atom will be most stable when surrounded by 8 electrons in the valence shell. An atom that does not have eight electrons will bond with other atoms to have eight electrons. (Hydrogen and Helium are exceptions since they are so small; they are stable with only two valence electrons.)
- Electrons fill the innermost shell first before moving on to the second shell, and then the third, etc. The first orbital can hold a maximum of 2 electrons, then 8 in the second orbital, 18 in the third orbital, and 32 in the fourth orbital.

the periodic table, based on attractions of outermost (valence) electrons to the nucleus; and the relative sizes of atoms both across a row and down a group in the periodic table.

Cross Cutting Concepts: Patterns

- Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Periodic Table, Element, Properties, Proton, Electron, Neutron, Periods, Groups/ Families, Valence Shell/ Energy Level, Metal, Nonmetal, Metalloid/ Semimetal, Pure Substance, Atomic Number, Atomic Symbol, Nucleus, Reactivity, Pattern, Trend, Octet Rule, Orbital, Compound, Subscript
- Additional tier 2 words to be familiar with: Atomic Radius, Molar Mass, Electronegativity, Ionization Energy

Resources: [NGSS Phenomenon Master List](#)

Priority Standard (Performance Expectation): 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.

Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.

Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.

Big Idea(s):

- Substances react to make new substances; these reactions can be predicted based on the arrangement of the atoms in the reaction.

Essential Question(s):

- How do the outermost electron states of atoms influence the outcome of a chemical reaction?
- How does the electronegativity of the elements involved determine the type of bonds they will form, and thus the outcome of the chemical reaction?

Examples of Engaging Phenomenon:

- [Alkali metals reactivity](#)
- [Sodium metal \(Na\) combines with chlorine gas \(Cl₂\) to make sodium chloride \(NaCl\), otherwise known as table salt](#)
- [Cleaning pennies](#)
- [Carbon monoxide \(CO\) formation](#)
- Periodic Trends Gizmo
- Ionic Bonds Gizmo
- Covalent Bonds Gizmo

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p><u>Chemical Reactions</u></p> <ul style="list-style-type: none">● The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.● The arrangement of the elements on the periodic table can predict the electronegativity, ionization energy, and atomic radius for all elements. These are known as periodic trends.● Electronegativity is the ability of an atom to attract shared electrons in a chemical bond and can be used to determine the type of bond formed between two elements: ionic, polar covalent, or nonpolar covalent bonds.● It is possible to predict outcomes of chemical reactions based upon the patterns of reactivity within the periodic table.<ul style="list-style-type: none">● Ionic bonding = metal bonded to nonmetal; transfer of electrons (creates ions)● Polar covalent bonding = nonmetal bonded to nonmetal; unequal sharing of pairs of electrons● Nonpolar covalent bonding = nonmetal bonded to nonmetal; equal shared pairs of electrons● Lewis dot structures are used to show valence electrons surrounding individual atoms and the bonding of elements along with lone pairs of electrons.● Covalent bonds can have single, double, or triple bonds.	<p>Analyzing and Interpreting Models</p> <ul style="list-style-type: none">● Construct an explanation of the outcome of the given reaction including: the idea that the total number of atoms of each element in the reactant and products is the same; the numbers and types of bonds (i.e., ionic, covalent) that each atom forms, as determined by the outermost (valence) electron states and the electronegativity; the outermost (valence) electron state of the atoms that make up both the reactants and the products of the reaction is based on their position in the periodic table; and a discussion of how the patterns of attraction allow the prediction of the type of reaction that occurs (e.g., formation of ionic compounds, combustion of hydrocarbons).● Identify and describe the evidence to construct the explanation including: identification of the products and reactants, including their chemical formulas and the arrangement of their outermost (valence) electrons; identification that the number and types of atoms are the same both before and after a reaction; identification of the numbers and types of bonds (i.e., ionic, covalent) in both the reactants and the products; the patterns of reactivity (e.g., the high reactivity of alkali metals) at the macroscopic level as determined by using the periodic table; and the outermost (valence) electron configuration and the relative electronegativity of the atoms that make up both the reactants and the products of the reaction based on their position in the periodic table.● Describe their reasoning that connects the evidence, along with the assumption that theories and laws that describe their natural world operate today as they did in the past and

- Noble gases do not react with other elements due to the Octet Rule.
- The chemical properties of the elements involved can be used to describe and predict chemical bonds.
- A chemical change results in a change in the elemental composition of a substance, while a physical change only changes the appearance, smell, or other superficial characteristics of a substance. Evidence of a chemical change occurring includes color change, temperature change, gas production, and precipitate formation.
- For a given compound it is possible to identify the numbers and types of bonds (i.e., ionic, covalent).
- Five basic types of chemical reactions are synthesis, decomposition, combustion, single replacement, and double replacement. These reactions are used in careers and daily life.
- Chemical reactions are notated as chemical equations that can be balanced to ensure Conservation of Matter.
- In a chemical equation, the number of moles or molecules in a substance is denoted by the coefficient (the big number before the substance). The coefficient can be changed to balance the equation, meaning changing the amount of substance being used or produced.
- When balancing equations, subscripts can NOT be changed as it would indicate a different substance. For example, H_2O and H_2O_2 are most definitely not the same, even though they are both comprised of hydrogen and oxygen.

- will continue to do so in the future, to construct an explanation for how the patterns of outermost electrons and the electronegativity of elements can be used to predict the number and types of bonds each element forms. In the explanation, students describe the causal relationship between the observable macroscopic patterns of reactivity of elements in the periodic table and the patterns of outermost electrons for each atom and its relative electronegativity.
- Construct a revised or expanded explanation about the outcome of a chemical reaction and justify the revision.

[Back to Course Map](#)

- The outcome of a simple chemical reaction can be predicted using only the reactants and their valence electrons.

Cross-Cutting Concepts:

Patterns

- Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
 - Trend, Electronegativity, Ionization Energy, Atomic Radius, Chemical Bond, Ionic Bond, Covalent Bond, Polar Bond, Nonpolar Bond, Single Bond, Double Bond, Triple Bond, Lewis Dot Structure, Ion, Energy Level, Octet Rule, Chemical Change, Physical Change, Synthesis, Decomposition, Combustion, Single Replacement, Double Replacement, Valence Electron, Reaction, Conserve, Reactant, Product, Chemical Formula, Coefficient, Subscript
- Additional tier 2 words that students should be familiar with:
 - Lone Pair, Electron Sharing, Electron Transfer, Noble Gas, Concentration, Equilibrium, Endothermic, Exothermic, Stable, Yield, Flammability, Cation, Anion

Resources: [NGSS Phenomenon Master List](#)

Priority Standard (Performance Expectation): HS-PS1-3 Matter and Its Interactions

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.

Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.

Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.

Big Idea(s):

- Intermolecular forces dictate the physical properties and behaviors of substances, including their state, conductivity, and solubility.

Essential Question(s):

- How do the bonds in a molecule affect the properties of the overall substance?
- How do electrical forces between particles determine macroscopic properties like melting point and surface tension?

Examples of Engaging Phenomenon:

- Panning for gold works because of density.
https://www.youtube.com/watch?v=dzEndIo-X8A&ab_channel=EdReeves
- [Milk and Soap Experiment](https://thewonderofscience.com/phenomenon/2018/7/11/milk-and-soap-experiment)
<https://thewonderofscience.com/phenomenon/2018/7/11/milk-and-soap-experiment>
- [Ice Cube Spikes](https://thewonderofscience.com/phenomenon/2018/6/10/ice-cube-spikes)
<https://thewonderofscience.com/phenomenon/2018/6/10/ice-cube-spikes>
- [Gecko Feet](https://thewonderofscience.com/phenomenon/2018/5/3/gecko-feet)
<https://thewonderofscience.com/phenomenon/2018/5/3/gecko-feet>
- [Floating Whiteboard Ink](https://thewonderofscience.com/phenomenon/2017/10/16/floating-whiteboard-ink)
<https://thewonderofscience.com/phenomenon/2017/10/16/floating-whiteboard-ink>

<ul style="list-style-type: none"> ● Water and Oil Don't Mix https://web.fscj.edu/Milczanowski/psc/lect/Ch10/slide10.htm#:~:text=Liquid%20water%20is%20held%20together,stay%20separate%20from%20the%20water. ● Melting Points Gizmo ● Colligative Properties Gizmo ● Density Gizmo ● Density by Comparison Gizmo ● After working with painting oils, an artist finds that she must wash her hands with soap and water to remove the oil from her hands, as rinsing with water alone does not remove the oil. ● A glass is completely filled with water. When coins are added to the full glass of water, the surface of the water rises above the rim of the glass without spilling. ● Sinking and Floating Eggs https://www.georgiascienceteacher.org/phenomena/ 	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>PS1.A Structure and Properties of Matter</p> <ul style="list-style-type: none"> ● The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. <p>PS2.B Types of Interactions</p> <ul style="list-style-type: none"> ● Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformation of matter, as well as the contact forces between material objects. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> ● Bulk properties are properties due to many atoms, ions or molecules acting together. They are determined by electrical forces within and between atoms. Examples of bulk properties of substances 	<p><u>Using Mathematics and Computational Thinking</u></p> <ul style="list-style-type: none"> ● Create a computational model or simulation of a phenomenon, designed device, process, or system. <p><u>Constructing Explanations and Designing Solutions</u></p> <ul style="list-style-type: none"> ● Design or refine a solution to a complex real-world problem, based on scientific -knowledge principles, and theories. ● Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p><u>Task Demands:</u></p> <ul style="list-style-type: none"> ● Describe the phenomenon under investigation which includes the following idea: the relationship between the measurable properties (e.g., melting point, boiling point, vapor pressure,

include [melting point](#), [boiling point](#), [solubility](#), [vapor pressure](#), [volatility](#), [surface tension](#), [density](#), [viscosity](#), and [conductivity](#).

- 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.
- Melting point and boiling point of a substance are the temperatures at which said substance will change state from a solid to a liquid and a liquid to a gas, respectively. The stronger the attractive force in a given substance, the higher the boiling point or melting point because more energy is required to cause the particles to separate.
- Vapor pressure is a measure of the tendency of a material to change into the gaseous or vapor state. It increases with temperature. The temperature at which the vapor pressure at the surface of a liquid becomes equal to the pressure exerted by the surroundings is also called the boiling point of the liquid. The stronger these forces, the lower the rate of evaporation and the lower the vapor pressure.
- Viscosity refers to a fluid's resistance to flowing. When there is a strong intermolecular force, the molecules of the liquid are strongly bonded to each other. This bonding prevents the particles from moving freely. Thus, the higher the intermolecular forces, the higher the viscosity. Liquids whose molecules are polar or capable of forming hydrogen

surface tension) of a substance and the strength of the electrical forces between the particles of the substance.

- Develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data, including bulk properties of a substance (e.g., melting point and boiling point, volatility, surface tension) that would allow inferences to be made about the strength of electrical forces between particles. Students describe why the data about bulk properties would provide information about strength of the electrical forces between the particles of the chosen substances, including the following descriptions: the spacing of the particles of the chosen substances can change as a result of the experimental procedure even if the identity of the particles does not change (e.g., when water is boiled the molecules are still present but further apart); thermal (kinetic) energy has an effect on the ability of the electrical attraction between particles to keep the particles close together. Thus, as more energy is added to the system, the forces of attraction between the particles can no longer keep the particles close together; the patterns of interactions between particles at the molecular scale are reflected in the patterns of behavior at the macroscopic scale; and together, patterns observed at multiple scales can provide evidence of the causal relationships between the strength of the electrical forces between particles and the structure of substances at the bulk scale.
- Describe the rationale for the choice of substances to compare and a description of the composition of those substances at the atomic molecular scale; a description of how the data will be collected, the number of trials, and the experimental set up and equipment required.
- Collect and record data — quantitative and/or qualitative — on the bulk properties of substances.

bonds are more viscous.

- Surface tension is the property of the surface of a liquid that allows it to resist an external force, due to the cohesive nature of its molecules. It causes the tendency of liquid surfaces at rest to shrink into the minimum surface area possible. As the intermolecular forces increase, the area of space becomes less, and the surface tension increases.
- Bulk density is defined as the mass of the many particles of the material divided by the total volume they occupy. Density can be experimentally calculated by using a triple beam balance to determine the mass of the object and a graduated cylinder in conjunction with the water displacement method (for a solid) to find the volume. Density is calculated by dividing the mass by the volume of the substance. The density of a substance is fixed and does not depend on the amount of substance present.
- [Intermolecular forces](#) are forces between two or more molecules that determine properties of a specific substance including flammability, conductivity, melting point, and boiling point. [Intramolecular forces](#) are forces that hold each individual molecule together.
- Bulk scale properties are readily applicable to real-life situations and trade scenarios, along with improvements in trade systems.
(TRADE CONCEPT)

- Evaluate their investigation, including evaluation of: assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and the ability of the data to provide the evidence required. If necessary, students refine the plan to produce more accurate, precise, and useful data.

- There is a relationship between the measurable properties (e.g., melting point, boiling point, vapor pressure, surface tension) of a substance and the strength of the electrical forces between the particles.

Cross-Cutting Concepts:

Patterns

- Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Interaction, Matter, Electrical Force, Melting Point, Boiling Point, Solubility, Vapor Pressure, Volatility, Surface Tension, Density, Sink, Float, Mass, Volume, Viscosity, Conductivity, Attraction, Repulsion, Intramolecular Force, Intermolecular Force, Flammability, Polarity, Solid, Liquid, Gas, Temperature
- Additional tier 2 words that students should be familiar with:
Electronegativity, Dissolve, Solute, Solvent, Networked Material, Cohesive, Adhesive, Triple Beam Balance, Graduated Cylinder

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

Priority Standard (Performance Expectation): HS-PS2-6 Motion and Stability: Forces and Interactions

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

Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long-chained molecules, and pharmaceuticals are designed to interact with specific receptors.

Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.

Big Idea(s):

- The unique functioning of designed materials (such as polymers or metals) is determined by the attractive and repulsive forces at the molecular level.

Essential Question(s):

- How can the molecular-level structure of a material be engineered to perform a specific function?
- How do structural properties of designed materials improve daily life?

Examples of Engaging Phenomenon:

- Water was spilled on two shirts. One shirt absorbed the water very quickly, leaving a large wet spot. On the other shirt, the water formed tiny spheres and bounced off, leaving the shirt dry. Hydrophobic and hydrophilic fabrics:
<https://www.wptnonwovens.com/blog/hydrophobic-material-vs-hydrophilic/>
<https://favouritehub.com/hydrophobic-and-hydrophilic-non-woven-materials/>
- A sample of cotton fabric was dyed with two different kinds of dye and then was washed several times to determine how well the dye stayed in the fabric. One dye faded over time; the other did not.
<https://www.texintel.com/blog/understanding-the-five-basic-fastness-standards-for-printed-textile-fabrics>
<https://www.eysan.com.tw/ultimate-guide-to-color-fastness-of-fabrics/>
- Zinc oxide was dissolved in water and the resulting solution was very difficult to stir. (ZnO is insoluble in water, forming a

paste-like mixture when combined.) Upon the addition of another liquid, the solution became much thinner and easier to stir. (ZnO is soluble in acids or bases so a dilute acid such as hydrochloric acid would be a good option. A surfactant such as sodium dodecyl sulfate would also work since it reduces surface tension, lowering the viscosity and helping the particles to disperse.)

- A glass bottle of water breaks when the water inside freezes.
<https://www.makewaterfamous.com/news/why-do-bottles-of-frozen-water-shatter#:~:text=They%20discovered%20that%20while%20the,pressure%20%E2%80%93%20enough%20to%20break%20glass.>
<https://edu.rsc.org/experiments/water-expands-when-it-freezes/407.article>

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>PS2.B Types of Interactions</p> <ul style="list-style-type: none"> ● Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformation of matter, as well as the contact forces between material objects. <p>PS1.A Structure and Properties of Matter</p> <ul style="list-style-type: none"> ● The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> ● 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. ● An attractive force is when objects exert a pull on each other, making them want to move closer together. Particles with different electromagnetic 	<p><u>Using Mathematics and Computational Thinking</u></p> <ul style="list-style-type: none"> ● Create a computational model or simulation of a phenomenon, designed device, process, or system. ● Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. <p><u>Constructing Explanations and Designing Solutions</u></p> <ul style="list-style-type: none"> ● Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories. ● Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p><u>Obtaining, Evaluating, and Communicating Information</u></p> <ul style="list-style-type: none"> ● Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible.

charges attract each other. A repulsive force is when objects push each other away. Particles with the same electromagnetic charge repel each other.

- Intermolecular forces are forces of attraction or repulsion which act between neighboring particles (atoms, molecules or ions). They are weak compared to the intramolecular forces, which keep a molecule together (e.g., covalent and ionic bonding).
- Electrostatic forces on the atomic and molecular scale result in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.
- Different materials have different properties. Some properties of materials include electrical conductivity, flexibility, durability, strength, reactivity, state of matter, chemical structure, and environmental impact.
- The properties of a material support its purpose. Materials with common properties can be used to perform similar functions, while materials with different properties are best suited for different functions.
- Molecular level structure is important in the functioning of designed materials. The structure and properties of matter and the types of interactions of matter at the atomic scale determine the function of the chosen designed material. The material's properties make it suitable for use in its designed function.

- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.
- Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Task Demands:

- Communicate scientific and technical information, using at least two different formats, including fully describing the structure, properties, and design of the chosen material(s). Cite the origin of the information as appropriate.
- Identify and communicate the evidence for why molecular level structure is important in the functioning of designed materials including: how the structure and properties of matter and the types of interactions of matter at the atomic scale determine the function of the chosen designed material(s); and how the material's properties make it suitable for use in its designed function. Students explicitly identify the molecular structure of the chosen designed material(s) (using a representation appropriate to the specific type of communication — e.g., geometric shapes for drugs and receptors, ball and stick models for long-chained molecules). Students describe the intended function of the chosen designed material(s). Students describe the relationship between the material's function and its macroscopic properties (e.g., material strength, conductivity, reactivity, state of matter, durability) and each of the following: Molecular level structure of the material; Intermolecular forces and polarity of molecules; and The

- Water has unique properties. Water molecules are polar so they form hydrogen bonds. Water has cohesive (molecules of water stick to other water molecules) and adhesive (molecules of water stick to other types of molecules) properties. It is an excellent solvent (capable of dissolving other polar molecules and ionic compounds). It has a high heat capacity (the amount of heat it must gain or lose in order to change temperature) and a high heat of vaporization (boiling point). It is less dense as a solid than as a liquid, in direct contrast to most other materials.
- The ability of electrons to move relatively freely in metals causes unique properties including ductility (ability to be drawn into a thin, long wire) and malleability (ability to be formed into a thin, flat sheet). Metals are also good conductors of heat and electricity and have a high density and high melting point.
- A polymer is any of a class of natural or synthetic substances composed of very large molecules, called macromolecules, which are multiples of simpler chemical units called monomers. Polymers make up many of the materials in living organisms and are the basis of many minerals and man-made materials including plastics. Examples of naturally occurring polymers are silk, wool, DNA, cellulose, and proteins. Examples of synthetic polymers include nylon, polyethylene, polyester, Teflon, and epoxy. The monomers in a polymer are arranged in side chains; the specific arrangements determine the properties of the substance including flexibility and

ability of electrons to move relatively freely in metals. Students describe the effects that attractive and repulsive electrical forces between molecules have on the arrangement (structure) of the chosen designed material(s) of molecules (e.g., solids, liquids, gases, network solid, polymers). Students describe that, for all materials, electrostatic forces on the atomic and molecular scale result in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.

durability.

Cross-Cutting Concepts:

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:

Electrical Conductivity, Criteria, Trade-offs, Polymer, Surface Tension, Reactivity, Charge, Conductor, Insulator, Resistance, Ductile, Malleable, Friction, Material Strength, Reactivity, Stickiness, State of Matter, Polarity, Attractive, Repulsive, Contact Force, Electron Sharing, Electron Transfer, Flexible, Durable, Normal Force, Electrostatic Forces, Environmental Impact, Structure, Function

- Additional tier 2 words that students should be familiar with:

Synthetic, Monomer, Network Solid, Iterative Improvement, Long-Chain Molecules, Network Material, Pharmaceuticals, Hydrophobic, Hydrophilic, Soluble

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

Unit 2: The Universe, Elements, and Waves

Priority Standard (Performance Expectation): HS-ESS1-2 Earth's Place in the Universe

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.

Clarification Statement: Emphasis is on the astronomical evidence of the red shift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gases (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).

Big Idea(s):

- The universe originated from a single point and has been expanding for billions of years, as evidenced by light spectra, cosmic radiation, and the current composition of matter.

Essential Question(s):

- What is the Big Bang Theory and what astronomical evidence supports it?

Examples of Engaging Phenomenon:

- Why is Space Black?
<https://thewonderofscience.com/phenomenon/2018/5/3/why-is-space-black>
- Gravitational Waves
<https://thewonderofscience.com/phenomenon/2018/7/9/gravitational-waves-and-ligo>
- Mystery of the Universe's Expansion Rate Widens with New Hubble Data
[Mystery of the Universe's Expansion Rate Widens with New Hubble Data - NASA Science](#)
- James Webb Telescope and the Cosmic Web
[NASA's Webb Identifies the Earliest Strands of the Cosmic Web - NASA](#)
- Our Universe is Expanding
[Tom Whyntie: The beginning of the universe for beginners | TED Talk](#)
[Sajan Saini: What is the universe expanding into? | TED Talk](#)
- Big Bang Theory Hubble's Law Gizmo

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>ESS1.A: The Universe and Its Stars</p> <ul style="list-style-type: none"> • The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. • The Big Bang Theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gasses, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. • Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. <p>PS4.B: Electromagnetic Radiation</p> <ul style="list-style-type: none"> • Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> • The Big Bang Theory is the most widely accepted explanation for the origin of the universe. According to this theory, the universe began as an infinitely 	<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> • Create a computational model or simulation of a phenomenon, designed device, process, or system. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> • Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories. • Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p><u>Task Demands:</u></p> <ul style="list-style-type: none"> • Construct an explanation that includes a description of how astronomical evidence from numerous sources is used collectively to support the Big Bang Theory, which states that the universe is expanding and that thus it was hotter and denser in the past, and that the entire visible universe emerged from a very tiny region and expanded. • Identify and describe the evidence to construct the explanation, including: i. The composition (hydrogen, helium and heavier elements) of stars; ii. The hydrogen-helium ratio of stars and interstellar gases; iii. The redshift of the majority of galaxies and the redshift vs. distance relationship; and iv.

small, hot, and dense point that rapidly expanded and continued to expand over 13.7 billion years. This initial period of rapid inflation set the stage for the vast and still-growing cosmos we observe today.

- One piece of evidence is the existence of cosmic microwave background radiation (CMB), a faint "echo" of the universe's early expansion that scientists can study in detail. The changes they have identified imply a hot, dense early universe that cooled as it expanded.
- Composition of matter in the universe since it matches the Big Bang Theory's prediction of approximately 74% hydrogen and 26% helium.
- Motion of galaxies. Light arriving from far-off galaxies has been "red-shifted," indicating that they are moving further away and the universe is expanding.
- Each element emits a distinct frequency of light. A spectroscope can divide light into its component wavelengths. Thus, the spectra can be used to identify the elements. When a star emits a light spectra, the spectra along with the star's brightness can be analyzed to determine the star's composition and distance from Earth. These spectra are also evidence in support of the Big Bang Theory.

The existence of cosmic background radiation. Students use a variety of valid and reliable sources for the evidence, which may include students' own investigations, theories, simulations, and peer review. Students describe the source of the evidence and the technology used to obtain that evidence.

- Connect evidence, using reasoning, along with 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, to construct the explanation for the early universe (the Big Bang theory). Students describe the following chain of reasoning for their explanation: i. Redshifts indicate that an object is moving away from the observer, thus the observed redshift for most galaxies and the redshift vs. distance relationship is evidence that the universe is expanding. ii. The observed background cosmic radiation and the ratio of hydrogen to helium have been shown to be consistent with a universe that was very dense and hot a long time ago and that evolved through different stages as it expanded and cooled (e.g., the formation of nuclei from colliding protons and neutrons predicts the hydrogen-helium ratio [numbers not expected from students], later formation of atoms from nuclei plus electrons, background radiation was a relic from that time). iii. An expanding universe must have been smaller in the past and can be extrapolated back in time to a tiny size from which it expanded.

Cross-Cutting Concepts:

Energy and Matter

- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:

Galaxy, Universe, Primordial Radiation, Cosmic Microwave Background (CMB) Radiation, Electromagnetic Energy, Emit, Absorb, Frequency, Wavelength, Light, Dense, Expand, Motion, Red-Shift, Big Bang Theory, Spectra, Matter, Nucleosynthesis, Star, Interstellar Gases, Electromagnetic Radiation, Brightness, Nuclear Fusion, Spectroscope, Composition, Distance

- Additional tier 2 words that students should be familiar with:

Dark Matter, Dark Energy, Singularity, Astronomical Evidence, Doppler Effect, Receding, Cosmos

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

Priority Standard (Performance Expectation): HS-ESS1-3 Earth's Place in the Universe

Communicate scientific ideas about the way stars, over their life cycle, produce elements.

Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.

Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of differing masses are not assessed.

Big Idea(s):

- Stars produce all atomic nuclei lighter than and including iron through nuclear fusion, while heavier elements are created during supernova explosions.

Essential Question(s):

- How do stars produce elements and why do different types of stars produce different elements?
- What are the implications of element production in stars for the formation and composition of the universe?

Examples of Engaging Phenomenon:

- The Big Bang Theory
<https://thewonderofscience.com/phenomenon/2018/7/8/the-big-bang-theory>
- Black Holes
[The Mind-Bending Math Inside Black Holes](#)
- Supernova
[What If a Supernova Exploded Close to Earth?](#)
- Life Cycle of a Star
[Lifecycle of a star | Astrophysics | Physics | FuseSchool](#)
- Hertzsprung-Russell Diagram
<https://esahubble.org/videos/heic1017b/>
https://www.youtube.com/watch?v=Vlbpj74rpY&ab_channel=LearntheSky
- H-R Diagram Gizmo
- Star Spectra Gizmo

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>ESS1.A: The Universe and Its Stars</p> <ul style="list-style-type: none"> ● The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ● Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> ● The Sun is so long-lived compared to human lifetimes that we can’t directly observe the lifespan of the Sun, and so scientists study data from many stars that are at different phases of their lifespan. ● The Hertzsprung-Russell diagram (H-R diagram) classifies star lifespans. It plots individual stars based on luminosity (amount of light emitted) versus temperature (color of star). ● The H-R diagram has sections characterized by specific types of stars (e.g. giants, white dwarfs, main sequence). ● Star mass and luminosity are related. The more massive, the brighter, and the more fusion occurring. ● Stars are a balance between the crushing force of 	<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> ● Create a computational model or simulation of a phenomenon, designed device, process, or system. ● Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> ● Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories. ● Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p>Obtaining, Evaluating, and Communicating Information</p> <ul style="list-style-type: none"> ● Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. ● Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). <p><u>Task Demands:</u></p> <ul style="list-style-type: none"> ● Communicate scientific information, using at least two different formats, and cite the origin of the information as appropriate. ● Identify and communicate the relationships between the life

gravity pressing inwards from the star's mass and the outward pressure created by fusion in the star's core.

- Fusion occurs when two lighter elements' nuclei are forced together in high temperature and pressure environments to create heavier elements. Fusion releases energy outwards that keeps the star from collapsing.
- As elements get heavier, the amount of energy released with fusion decreases. Once the outward pressure of fusion becomes less than the crushing force of gravity, the core of the star collapses. Typically this occurs when the star begins producing Iron, so for most stars, the heaviest element produced is Iron.
- When massive stars die, they explode as supernovae, creating the necessary conditions for producing elements heavier than iron.

cycle of the stars, the production of elements, and the conservation of the number of protons plus neutrons in stars. Students identify that atoms are not conserved in nuclear fusion, but the total number of protons plus neutrons is conserved. Students describe that: i. Helium and a small amount of other light nuclei (i.e., up to lithium) were formed from high-energy collisions starting from protons and neutrons in the early universe before any stars existed. ii. More massive elements, up to iron, are produced in the cores of stars by a chain of processes of nuclear fusion, which also releases energy. iii. Supernova explosions of massive stars are the mechanism by which elements more massive than iron are produced. iv. There is a correlation between a star's mass and stage of development and the types of elements it can create during its lifetime. v. Electromagnetic emission and absorption spectra are used to determine a star's composition, motion and distance to Earth.

Cross Cutting Concepts:

Energy and Matter

- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Star, Nucleosynthesis, Fusion, Supernova, Black Hole, Hertzsprung-Russell (H-R) Diagram, Big Bang Theory, Spectra, Spectroscope, Brightness, Luminosity, Composition, Element, Distance, Temperature, Mass, Pressure, Gravity, Nucleus/Nuclei, Life Cycle, Hydrogen, Helium, Heavy Elements, Mass, Electromagnetic Energy, Collapse

[Back to Course Map](#)

- Additional tier 2 words that students should be familiar with:
Element Production, Stellar Evolution, Main Sequence, Red Giant, White Dwarf, Neutron Star, Stellar Remnant, Stellar Winds,
Massive

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

Priority Standard (Performance Expectation): HS-ESS1-1 Earth's Place in the Universe

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.

Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.

Assessment Boundary: Assessment does not include details of the atomic and sub-atomic processes involved with the sun's nuclear fusion.

Big Idea(s):

- The Sun's core undergoes nuclear fusion to release immense energy that travels as radiation to sustain Earth's systems.

Essential Question(s):

- What evidence supports our understanding of the life span of the sun and the process of nuclear fusion?
- What are the implications of the sun's life span and the energy it releases for the Earth and its systems?

Examples of Engaging Phenomenon:

- Solar Flares, Sunspots, and the Solar Cycle <https://thewonderofscience.com/phenomenon/2018/7/8/solar-flares-sunspots-and-the-solar-cycle>
https://www.youtube.com/watch?v=rx9m6H6GeLs&ab_channel=NASAGoddard
https://www.youtube.com/watch?v=Z0uIcLZ5rh8&ab_channel=NASAGoddard
- Why do we sunburn?
<https://www.epa.gov/radtown/ultraviolet-uv-radiation-and-sun-exposure>
- Chemosynthesis- Exception to the Rule <https://timesofmalta.com/article/Myth-debunked-Does-all-life-on-earth-depend-on-the-sun.672339#~:text=.uvic.ca/-.Although%20it%20is%20true%20that%20nearly%20every%20organism%20on%20earth,simple%20sugars%20as%20food%20source.>
- What happens if the Sun dies?
https://www.youtube.com/watch?app=desktop&v=duCdi8eSK6Y&ab_channel=MakeItEasyEducation

<ul style="list-style-type: none"> • Aurora Borealis (Northern Lights) and Aurora Australis (Southern Lights) https://www.space.com/15139-northern-lights-auroras-earth-facts-sdcmp.html https://www.swpc.noaa.gov/products/aurora-viewline-tonight-and-tomorrow-night-experimental https://www.youtube.com/watch?v=EMw4OPjRnTo 	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>ESS1.A: The Universe and Its Stars</p> <ul style="list-style-type: none"> • The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. <p>PS3.D: Energy in Chemical Processes and Everyday Life</p> <ul style="list-style-type: none"> • Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> • Our Sun is a yellow dwarf star following a relatively stable life cycle. It begins as a main sequence star, fusing hydrogen into helium in its core for billions of years. Eventually, the hydrogen fuel will be exhausted, leading to the star expanding and becoming a red giant. After shedding its outer layers, the core will cool and become a white dwarf. It will then gradually cool further and fade into a black dwarf. This process takes place over billions of years. • All life on Earth depends on energy. Almost all of that energy comes from the Sun where nuclear fusion releases it to travel as radiation throughout the solar system. 	<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> • Create a computational model or simulation of a phenomenon, designed device, process, or system. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> • Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories. • Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p>Developing and Using Models</p> <ul style="list-style-type: none"> • Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. • Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. <p><u>Task Demands:</u></p>

- The Sun’s radiation output varies due to solar flares, the sunspot cycle, and noncyclic variations.
- Solar flares, often called “space weather,” are sudden, intense releases of energy from the Sun's atmosphere, often accompanied by coronal mass ejections, large temporary emissions of solar material. They release radiation across the electromagnetic spectrum, including X-rays and UV radiation, that can impact Earth's upper atmosphere and ionosphere.
- The Sun follows an 11-year sunspot cycle. It has variations in the number of sunspots (cooler, darker areas on the Sun's surface). During periods of high activity (solar maximum), the Sun emits slightly more electromagnetic radiation than during periods of low activity (solar minimum).
- Over centuries, the Sun's radiation can also vary in a non-cyclic way.

- Develop a model, using evidence, in which they identify and describe the relevant components, including: i. Hydrogen as the sun’s fuel; ii. Helium and energy as the products of fusion processes in the sun; and iii. That the sun, like all stars, has a life span based primarily on its initial mass, and that the sun’s lifespan is about 10 billion years.
- Describe relationships, within the model, between the components, including a description of the process of radiation, and how energy released by the sun reaches Earth’s system.
- Predict how the relative proportions of hydrogen to helium change as the sun ages, within the model. Students use the model to qualitatively describe the scale of the energy released by the fusion process as being much larger than the scale of the energy released by chemical processes. Students use the model to explicitly identify that chemical processes are unable to produce the amount of energy flowing out of the sun over long periods of time, thus requiring fusion processes as the mechanism for energy release in the sun.

Cross-Cutting Concepts:
Scale, Proportion, and Quantity

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Sun, Nuclear Fusion, Core, Energy, Radiation, Electromagnetic Spectrum, Solar Wind, Solar Flares, Life Span, Sunspot, Solar Cycle, Yellow Dwarf, Main Sequence Star, Red Giant, White Dwarf, Black Dwarf, Hydrogen, Helium

[Back to Course Map](#)

- Additional tier 2 words that students should be familiar with:
Stellar Evolution, Thermonuclear Reactions, Space Weather, X-rays, UV Radiation, Atmosphere, Ionosphere, Solar Maximum, Solar Minimum, Photosynthesis, Chemosynthesis, Coronal Mass Ejections, Photosphere

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

Priority Standard (Performance Expectation): HS-PS4-1 Waves and their Applications in Technologies for Information Transfer

Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.

Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.

Big Idea(s):

- Mathematical representations of frequency, wavelength, and wave speed reveal predictable behaviors across different media, enabling technologies to transfer information

Essential Question(s):

- How are frequency, wavelength, and speed of waves mathematically related?
- How do waves transfer energy without necessarily transferring matter?

Examples of Engaging Phenomenon:

- Tuning Fork Resonance and Ping Pong Ball
<https://thewonderofscience.com/phenomenon/2020/1/3/tuning-fork-resonance-ping-pong-ball>
- Self-Leveling Pool Table on a Cruise Ship
<https://thewonderofscience.com/phenomenon/2018/7/8/self-leveling-pool-table-on-cruise-ship>
- Rubens' Tube
<https://thewonderofscience.com/phenomenon/2018/7/8/rubens-tube>
- The Visual Microphone: Passive Recovery of Sound From Video
<https://thewonderofscience.com/phenomenon/2018/7/8/the-visual-microphone-passive-recovery-of-sound-from-video>
- Daniel Kish Uses Echolocation to Navigate
<https://thewonderofscience.com/phenomenon/2018/7/8/daniel-kish-uses-echolocation-to-navigate>
- Analog vs. Digital Television
<https://thewonderofscience.com/phenomenon/2018/7/7/analog-vs-digital-television>
- Why can we see the Sun but not hear an exploding star?

[Back to Course Map](#)

<https://www.bbc.com/reel/video/p0lh9vm3/listen-to-the-sun-like-never-before>

<https://www.youtube.com/watch?v=GlzdFukPfmC>

<https://www.youtube.com/watch?v=1Iw4leXu6ZA>

- A lit candle is placed at one end of a tube filled with carbon dioxide. A student standing at the other end of the tube can see the candle's flame. When looking through a monitor that looks at the infrared radiation emitted by the flame, the student can no longer see the candle's flame.

<https://www.youtube.com/watch?v=SeYfl45X1wo>

<https://scied.ucar.edu/learning-zone/how-climate-works/carbon-dioxide-absorbs-and-re-emits-infrared-radiation>

- Astronauts aboard the International Space Station are exposed to a different amount of ultraviolet radiation from the Sun than humans on Earth.

<https://science.howstuffworks.com/do-astronauts-need-sunscreen-in-space.htm>

https://www.lpi.usra.edu/education/explore/space_health/space_radiation/index_print.shtml

- When using light detection and ranging (LiDAR) over a forested area, the light reflects off multiple surfaces and affects the accuracy of elevation models.

<https://oceanservice.noaa.gov/facts/lidar.html#:~:text=Lidar%20%E2%80%94%20Light%20Detection%20and%20Ranging,the%20surface%20of%20the%20Earth.>

<https://www.faro.com/en/Resource-Library/Article/What-is-Lidar>

- Solar cells only capture about 20% of the energy from the sun.

<https://www.youtube.com/watch?v=8RjGHmlOu58>

<https://physicsworld.com/a/sunny-superpower-solar-cells-close-in-on-50-efficiency/>

- Sonic Boom

<https://www.youtube.com/watch?v=-1ywUmBpVGY>

https://www.youtube.com/watch?v=JO4_VHM69oI

<https://www.wonderopolis.org/wonder/what-is-a-sonic-boom>

- Breaking Glass With Your Voice

<https://www.youtube.com/watch?v=rRZT7xO5KN4>

- Why do we see lightning before we hear thunder?

<https://www.youtube.com/watch?v=LDmDg0eXrmw>

<https://www.omnicalculator.com/physics/lightning-distance>

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>PS4.A: Wave Properties</p> <ul style="list-style-type: none"> The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> Frequency, wavelength, and wave speed are related. Frequency is defined as the number of cycles per unit of time. Wavelength is the distance from one crest to another of a wave. Wave speed is the distance traveled by a given point on a wave in a given interval of time. The formula $\lambda = v/f$ where λ is the wavelength, v is the wave velocity, and f is the frequency. The speed of waves is dependent on the properties of a medium. Amplitude is an independent property of waves. It is a measure of the wave's displacement from equilibrium and models the wave's intensity. Model the anatomy of a wave to identify wavelength, frequency, and amplitude. Waves transfer energy without transferring matter. 	<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> Create a computational model or simulation of a phenomenon, designed device, process, or system. Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories. Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p><u>Task Demands:</u></p> <ul style="list-style-type: none"> Identify and describe the relevant components in the mathematical representations: i. Mathematical values for frequency, wavelength, and speed of waves traveling in various specified media; and ii. The relationships between frequency, wavelength, and speed of waves traveling in various specified media. Demonstrate that the product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and identify this relationship as the wave speed according to the mathematical relationship $v = f\lambda$. Students use the data to show that the wave speed for a particular type of wave changes as the medium through which the wave travels changes. Students predict the relative change in the wavelength of a wave when it moves from one medium to another (thus different wave speeds using the mathematical relationship $v = f\lambda$). Students express the relative

- Frequency is a measure of the energy of different types of electromagnetic waves.
- Radio Waves, Microwaves, Infrared, Visible Light, Ultraviolet, X-rays, and Gamma Rays are different wavelength bands in the spectrum of electromagnetic waves, the speed of which in a vacuum is approximately 3×10^8 m/s, and less when passing through other media.
- Some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. Some examples include: solar cells, the Photoelectric Effect, spectroscopy, infrared scanners, X-ray imaging, CT/CAT scans, and ultrasound.
(TRADE CONCEPT)

- change in terms of cause (different media) and effect (different wavelengths but same frequency).
- Assess claims, using the mathematical relationship $v = f\lambda$, about any of the three quantities when the other two quantities are known for waves travelling in various specified media. Students use the mathematical relationships to distinguish between cause and correlation with respect to the supported claims.

Cross-Cutting Concepts:

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:

[Back to Course Map](#)

Frequency, Wavelength, Speed, Wave, Medium/Media, Relationship, Equation, Electromagnetic Wave, Sound Wave, Energy, Matter, Vacuum, Amplitude, Intensity

- Additional tier 2 words that students should be familiar with:

Refraction, Diffraction, Interference, Period, Transverse Wave, Longitudinal Wave, Seismic Wave, Radio Waves, Microwaves, Infrared, Visible Light, Ultraviolet, X-rays, Gamma Rays, Electromagnetic Spectrum, Solar Cells, Photovoltaic Effect, Spectroscopy, Infrared Scanner, X-ray Imaging, CT/CAT Scan, Ultrasound

Resources: [NGSS Phenomenon Master List](#)

Priority Standard (Performance Expectation): HS-PS1-8 Matter and its Interactions

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.

Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.

Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.

Big Idea(s):

- Nuclear processes involve changes in the nucleus that release energy on a scale significantly greater than chemical reactions

Essential Question(s):

- How are specific elements produced through nuclear changes, and what evidence supports these models?
- How do humans utilize nuclear reactions for societal needs?

Examples of Engaging Phenomenon:

- Rocks from the Tuna Creek area of the Grand Canyon were tested and found to contain less lead (Pb) and more uranium (U) than rocks from the Elves Chasm area of the Grand Canyon.
<https://www.grandcanyontrust.org/grand-canyon-uranium/>
- Mousetrap Fission
https://www.youtube.com/watch?v=vjqIJW_Qr3c
- Atomic Bomb
<https://inquirygroup.org/history-lessons/atomic-bomb>
- "Nuclear Energy: Is Fission the Future?"
<https://www.youtube.com/watch?v=vp3YyFy4p8c>
- Nuclear Fission Animation
<https://www.dailymotion.com/video/x282sg>
- "Plasmas are hot, fusion is cool."
<https://www.youtube.com/watch?v=wQYKAoNSz8g>
- US Navy Nuclear Power Program- Recruiter may come in to do a presentation
- Radiocarbon Dating

- https://www.youtube.com/watch?v=phZeE7Att_s
- Half- Life Gizmo
- Nuclear Decay Gizmo
- Personal Radiation Assessment
 - <https://www.epa.gov/radiation/calculate-your-radiation-dose>
- Dominion Energy Millstone (Nuclear) Power Station produces 33% of Connecticut’s electricity as of 2023
 - <https://www.eia.gov/state/?sid=CT#tabs-3>
- Radiac beeping near a banana
 - <https://www.youtube.com/watch?v=z9LgUIKNGFg>
- The Manhattan Project
 - <https://thewonderofscience.com/phenomenon/2018/7/7/the-manhattan-project>
- Chernobyl Nuclear Meltdown
 - <https://www.georgiascienceteacher.org/phenomena/>
 - https://www.youtube.com/watch?v=phZeE7Att_s
 - <https://www.youtube.com/watch?v=uvpS2IUHZD8>
- A brand new nuclear fuel rod containing 3% U-235 was used in a nuclear reactor in New Jersey for 18 months. When it was taken out the reactor, it was found to contain 0.8% U235, 5.2% fission products, and 1.2% plutonium.

Students will know: (Disciplinary Core Ideas)

As evidenced by: (Science & Engineering Practices)

[PS1.C: Nuclear Processes](#)

- 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 OBJECTIVES:

- Nuclear processes (reactions) such as fusion, fission, and radioactive decay can be modeled by nuclear equations, which show how particles and energy are conserved in these reactions.

[Using Mathematics and Computational Thinking.](#)

- Create a computational model or simulation of a phenomenon, designed device, process, or system.
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

[Constructing Explanations and Designing Solutions](#)

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories.

- In nuclear processes, the number of atoms is not conserved, but the total number of protons plus neutrons is conserved. (Conservation of Matter/Mass/Energy).
- Nuclear fusion reactions power the Sun and other stars. In a fusion reaction, two light [nuclei](#) merge to form a single heavier nucleus. The process releases energy because the total mass of the resulting single nucleus is less than the mass of the two original nuclei. The leftover mass becomes energy. This process is being studied by scientists on Earth. Fusion is dependent on extreme conditions.
- Fission is a splitting of atoms where a tremendous amount of energy is released, along with neutrons that initiate a chain reaction.
- Isotopes of an element contain the same number of protons but differing numbers of neutrons. All isotopes of an element possess similar chemical properties, however physical properties may vary.
Some specific isotopes are more useful than others in nuclear reactions.
- Three main types of radioactive decay are alpha decay, beta decay, and gamma decay.
- Radioactive decay is the process in which a radioactive atom spontaneously gives off radiation in the form of energy or particles to reach a more stable state.

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

[Developing and Using Models](#)

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Task Demands:

- Develop models in which they identify and describe the relevant components of the models including Identification of an element by the number of protons; the number of protons and neutrons in the nucleus before and after the decay; the identity of the emitted particles (i.e., alpha, beta — both electrons and positrons, and gamma); and the scale of energy changes associated with nuclear processes, relative to the scale of energy changes associated with chemical processes.
- Develop five distinct models to illustrate the relationships between components underlying the nuclear processes of fission, fusion, and three distinct types of radioactive decay. Students include the following features, based on evidence, in all five models: the total number of neutrons plus protons is 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 and the scale of energy changes in a nuclear process is much larger (hundreds

- A half-life is the time taken for the [radioactivity](#) of a specified [isotope](#) to fall to half its original value.
- A decay curve is a graph that shows the amount or percentage of the remaining radioactive substance compared to elapsed time. Each radioactive isotope produces its own unique decay curve.
- All living creatures are exposed to natural radiation sources including the Sun, ground, and food sources. All living creatures are adapted to certain levels of radiation to reduce harm. Humans may be exposed to man-made radiation sources through medical tests such as X-rays and CT/CAT scans, air travel, and various consumer products including smoke detectors. High levels of radiation can cause health issues to all organisms.
(TRADE CONCEPT)
- Fusion/fission/decay equations can be balanced to account for number of particles and total energy (Conservation of Matter/Mass/Energy).
- Energy release and scale difference between nuclear reactions and chemical reactions are magnitudes different.

- of thousands or even millions of times larger) than the scale of energy changes in a chemical process.
- Develop a fusion model that illustrates a process in which two nuclei merge to form a single, larger nucleus with a larger number of protons than were in either of the two original nuclei.
 - Develop a fission model that illustrates a process in which a nucleus splits into two or more fragments that each have a smaller number of protons than were in the original nucleus. In both the fission and fusion models, students illustrate that these processes may release energy and may require initial energy for the reaction to take place. Students develop radioactive decay models that illustrate the differences in type of energy (e.g., kinetic energy, electromagnetic radiation) and type of particle (e.g., alpha particle, beta particle) released during alpha, beta, and gamma radioactive decay, and any change from one element to another that can occur due to the process. Students develop radioactive decay models that describe that alpha particle emission is a type of fission reaction, and that beta and gamma emission are not.

Cross Cutting Concepts:

Energy and Matter

- Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Proton, Neutron, Atomic Number, Atomic Mass, Atom, Nuclear Reaction, Nucleus, Fission, Fusion, Decay Rate, Stable, Unstable, Half-life, Radioactive, Radiation, Alpha Decay, Beta Decay, Gamma Decay, Decay Curve, Isotope, Radioactive Decay, Conserve, Mass, Energy, Chain Reaction

- Additional tier 2 words that students should be familiar with:
Transformation, Alpha Particle, Beta Particle, Gamma Radiation, Beta Emission

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

Unit 3: Forces and Interactions

Priority Standard (Performance Expectation): 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.

Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.

Big Idea(s):

- Newton’s Second Law provides a mathematical framework ($F=ma$) to predict the motion of macroscopic objects based on net force and mass

Essential Question(s):

- How can the mathematical relationships between force, mass, and acceleration be used to describe real-world phenomena?
- When is friction useful and when is it harmful in managing the motion of an object?
- How do Newton’s Laws of Motion explain the effect of all forces acting on an object in our daily lives?

Examples of Engaging Phenomenon:

- Flymo Hover Lawnmower
<https://thewonderofscience.com/phenomenon/2018/7/12/flymo-hover-lawnmower>
- Raw or Boiled Egg Experiment
<https://thewonderofscience.com/phenomenon/2018/7/11/raw-or-boiled-egg-experimentdex>
- A Bed of Nails
<https://thewonderofscience.com/phenomenon/2018/7/9/a-bed-of-nails>
- Reducing forces on passengers during a potential crash is a primary design challenge when designing a car.
<https://www.sciencebuddies.org/teacher-resources/lesson-plans/engineering-car-crash-safety-newton-third-law?from=Blog>

[Back to Course Map](#)

- Newton's Cradle
https://en.wikipedia.org/wiki/Newton%27s_cradle
NGSS Interim Assessment References Newton's Cradle (PS 3-1)
- Rocket Launch
<https://www.youtube.com/watch?v=K6rUDI0MVXI>
- Designing catapults
<https://www.youtube.com/watch?v=VwENnFw4XgI>
- The Magician's Tablecloth
<https://learning.sciencemuseumgroup.org.uk/resources/tablecloth-trick/>
- Egg Pizza
<https://www.arborsci.com/blogs/cool/introducing-newtons-laws-with-learning-cycles>
- Jelly Jar Accelerometer
<https://www.arborsci.com/blogs/cool/introducing-newtons-laws-with-learning-cycles>
- Crash a cart with a mass into a cardboard box to show how inertia keeps the mass moving even after the cart stops. You can also try taping the mass to the cart to simulate a seatbelt.
- Use roller skates and a ball to show how throwing the ball pushes you in the opposite direction.
- Tee-off Time
<https://www.arborsci.com/blogs/cool/introducing-newtons-laws-with-learning-cycles>
- Balloon Rockets
<https://sciencebob.com/make-a-balloon-rocket/>
<https://www.jpl.nasa.gov/edu/teach/activity/rocket-activity-heavy-lifting/>
- Fan Cart Gizmo
- How does a bathroom scale work? "Glencoe Science Physics" Textbook p. 110
- Spring Scale Tug of War
https://itservices.cas.unt.edu/~klittler/demo_room/mech_demos/1h10_30.html
<https://www.arborsci.com/blogs/cool/introducing-newtons-laws-with-learning-cycles>
- Drop Away
<https://www.physicsclassroom.com/mmedia/vectors/pap.cfm>
- Crater Experiment
<https://sciencing.com/second-law-motion-experiments-6952612.html>
- Wagon and String
<https://sciencing.com/second-law-motion-experiments-6952612.html>
- Dollar Bill Inertia Challenge

<ul style="list-style-type: none"> • https://stevespangler.com/experiments/dollar-bill-inertia-challenge/ • Jetpack Rockets https://www.youtube.com/watch?v=Hx9TwM4Pmhc • Sled Launch https://www.youtube.com/watch?v=D4j5bcaV2Ws • Physics of Football https://www.youtube.com/watch?v=08BFCZJDn9w https://www.youtube.com/watch?v=qu_P4lbnV_I&t=9s https://www.youtube.com/watch?v=e1lzB36aHD4&t=19s • A heavy model rocket rises a shorter distance than a lighter model rocket using the same type of engine. The position of each rocket over time is given. https://www.sciencelearn.org.nz/resources/397-calculating-rocket-acceleration 	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>PS2.A: Forces and Motion</p> <ul style="list-style-type: none"> • Newton’s second law accurately predicts changes in the motion of macroscopic objects. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> • Newton’s First Law of Motion, also known as the Law of Inertia, states that an object at rest will remain at rest and an object in motion will continue moving in a straight line at a constant speed, unless acted upon by an outside force. • Provide an example of how Newton’s First Law applies to daily life. • Newton’s Second Law of Motion states that an object’s acceleration (a) depends on both its mass 	<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> • Create a computational model or simulation of a phenomenon, designed device, process, or system. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> • Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories. • Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p>Analyzing and Interpreting Data</p> <ul style="list-style-type: none"> • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and

(m) and the force (f) applied to it. It can be written mathematically as $f=ma$. It can be used to solve motion problems that involve constant forces.

- When forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest. This state is called Equilibrium.
- Friction can affect Newton's Second Law of Motion because it often acts in the opposite direction of motion, which can reduce the net force and acceleration. For example, when a block slides on a surface, friction slows the block down and eventually stops it.
- Newton's Third Law of Motion states that for every action, there is an equal and opposite reaction.

reliable scientific claims or determine an optimal design solution.

- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Task Demands:

- Organize data that represent the net force on a macroscopic object, its mass (which is held constant), and its acceleration (e.g., via tables, graphs, charts, vector drawings).
- Analyze the data, using tools, technologies, and/or models, to identify relationships within the datasets, including:
 - i. A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration; and ii. The result of gravitation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant.
- Describe that the relationship between the observed quantities are accurately modeled across the range of data by the formula $a = F_{net}/m$ (e.g., double force yields double acceleration, etc.), using the analyzed data as evidence.
- Distinguish between causal and correlational relationships linking force, mass, and acceleration, using the data as empirical evidence.
- Express the relationship $F_{net}=ma$ in terms of causality, namely that a net force on an object causes the object to accelerate.
- Provide examples of how each of Newton's Laws apply to daily life.
- Manipulate Newton's Second Law of Motion to algebraically solve the formula for force, mass, or acceleration.

Cross-Cutting Concepts:

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Systems & Systems Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Velocity, Motion, At Rest, Force, Acceleration, Mass, Inertia, Gravity, Friction, Normal Force, Direction, Balanced Force, Unbalanced Force, Equilibrium, Equal, Opposite
- Additional tier 2 words that students should be familiar with:
Net Force, Magnitude, Gravitational Acceleration (g), Causal, Correlational

Resources: [NGSS Phenomenon Master List](#)

Priority Standards (Performance Expectations):

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

Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.

Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.

Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.

Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.

Big Idea(s):

- The total momentum of a system is conserved in the absence of net external forces; this principle allows us to predict the results of interactions and engineer safety devices that minimize impact force by increasing the time interval of a collision.

Essential Question(s):

- How does the law of conservation of momentum govern the interactions between objects or systems?
- How can knowledge of momentum and impulse be used to design and refine devices that improve safety in collisions?

Examples of Engaging Phenomenon:

- Two billiard balls collide on a frictionless pool table in an elastic collision. An elastic collision conserves energy and momentum. <https://letstalkscience.ca/educational-resources/stem-explained/billiards-and-collisions>
<https://www.youtube.com/watch?v=yFXUzf0ZC7c>

[Back to Course Map](#)

- A car crashes into a parked vehicle. In an inelastic collision, momentum is conserved, but kinetic energy is not. The two vehicles might stick together after the collision, conserving momentum while losing energy.
<https://www.physicsclassroom.com/mmedia/momentum/treci.cfm#:~:text=The%20total%20kinetic%20energy%20before,known%20as%20an%20inelastic%20collision.> <https://www.thoughtco.com/what-is-the-physics-of-a-car-collision-2698920>
<https://www.youtube.com/watch?v=QUbsZwuhPvY>
- A lump of clay is thrown at a wall and sticks to it. In a perfectly inelastic collision, the objects stick together after the collision, moving as one. Momentum is conserved, but kinetic energy is lost, typically transformed into heat, sound, or deformation energy.
- As a rocket launches, it expels gas downwards and gains upward momentum. The momentum of the expelled gas in one direction is balanced by the momentum of the rocket in the opposite direction, demonstrating the conservation of momentum.

<https://www.youtube.com/watch?v=RzNJV611O4Y>

- A firecracker explodes into fragments. The momentum of the firecracker fragments is conserved and the vector sum of the momentum of firecracker fragments after the explosion equals the initial momentum at the instant of the explosion.
<https://www.physicsclassroom.com/class/momentum/Lesson-2/Momentum-Conservation-in-Explosions>
- A gun fires a bullet and the gun recoils in the opposite direction. The momentum of the bullet and the gun are equal and opposite, demonstrating the conservation of momentum in the system. http://ffden-2.phys.uaf.edu/211_fall2013.web.dir/Rex_Hallmann/The_Physics_of_Guns/Physics_of_Guns.html
- A hockey puck hitting the wall has both momentum and kinetic energy. Momentum is always conserved while KE may or may not be conserved.

https://twu.tennis-warehouse.com/learning_center/hockeyphysics.php

<https://www.wbspenguins.com/blog/the-science-of-ice-hockey/>

https://www.nsf.gov/news/mmg/?series_name=Science%20of%20NHL%20Hockey

- When a soccer player kicks the ball, force is applied over a short time period, imparting an impulse to the ball. This impulse changes the ball's momentum, causing it to accelerate in the direction of the kick.
<https://www.youtube.com/watch?v=gyKEhYELY8> <https://tuitionphysics.com/june-2024/the-physics-behind-soccer-making-the-perfect-kick/>
- Reducing forces on passengers during a potential crash is a primary design challenge when designing a car.
<https://www.sciencebuddies.org/teacher-resources/lesson-plans/engineering-car-crash-safety-newton-third-law?from=Blog>
- Newton's Cradle

https://en.wikipedia.org/wiki/Newton%27s_cradle

NGSS Interim Assessment References Newton's Cradle (HS-PS-3-1)

- Bikers need to be both protected and have total visibility when riding. Design a helmet that protects the biker from collisions while maintaining awareness for his surroundings.

<https://www.youtube.com/watch?v=ZKbYaOiz5U4>

https://www.teachengineering.org/activities/view/bicycle_helmet_activity

- Phone screens can be easily broken if dropped on the ground. Design a phone case that protects the phone from collisions while maintaining functionality.

<https://ghostek.com/blogs/ghostek-insider/drop-protection-why-your-phone-case-needs-it?srsId=AfmBOopZSpTclZ4fm7cDQ8R-AAoRUnW7ZeeKG9VIEL9TgHQNbOAueGFO>

<https://www.youtube.com/watch?v=IMcYXG5BWCM>

Students will know: (Disciplinary Core Ideas)

As evidenced by: (Science & Engineering Practices)

PS2.A: Forces and Motion

- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

DCI OBJECTIVES:

- Momentum is conservative in a closed system.
- Energy can be conservative or non-conservative in a closed system.
- An unbalanced force applied over time on an object produces a change in its momentum.
- Collisions can cause objects' energy to change. The total kinetic energy of a system before and after a collision can be used to analyze the collision. In elastic collisions, the kinetic energy of the system is conserved. In inelastic collisions, however, the total kinetic energy is not conserved, and some of the kinetic energy is converted into other forms of

Using Mathematics and Computational Thinking

- Create a computational model or simulation of a phenomenon, designed device, process, or system.
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Constructing Explanations and Designing Solutions

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories.
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Task Demands:

- Use components of momentum to solve for unknown quantities using $p = mv$.
- Design a device that minimizes the force on a macroscopic

energy, such as sound or thermal energy.

object during a collision. In the design, students: Incorporate the concept that for a given change in momentum, force in the direction of the change in momentum is decreased by increasing the time interval of the collision ($F\Delta t = m\Delta v$); and explicitly make use of the principle above so that the device has the desired effect of reducing the net force applied to the object by extending the time the force is applied to the object during the collision. In the design plan, students describe the scientific rationale for their choice of materials and for the structure of the device.

- Describe and quantify (when appropriate) the criteria and constraints, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost, mass, the maximum force applied to the object, and requirements set by society for widely used collision-mitigation devices (e.g., seatbelts, football helmets).
- Evaluate the proposed device design or design solution, including describing the rationales for the design and comparing the design to the list of criteria and constraints. Students test and evaluate the device based on its ability to minimize the force on the test object during a collision. Students identify any unanticipated effects or design performance issues that the device exhibits.
- Improve the device performance, using the test results, by extending the impact time, reducing the device mass, and/or considering cost-benefit analysis.
- Define the system of the two interacting objects that is represented mathematically, including boundaries and initial conditions. Students identify and describe the momentum of each object in the system as the product of its mass and its velocity, $p = mv$ (p and v are restricted to one-dimensional vectors), using the mathematical representations. Students identify the claim, indicating that the total momentum of a

system of two interacting objects is constant if there is no net force on the system.

- Model and describe the physical interaction of the two objects in terms of the change in the momentum of each object as a result of the interaction. Students use the mathematical representations to model and describe the total momentum of the system by calculating the vector sum of momenta of the two objects in the system.
- Identify a system with essentially no net force on it, using the analysis of the motion of the objects before the interaction. Based on the analysis of the total momentum of the system, students support the claim that the momentum of the system is the same before and after the interaction between the objects in the system, so that momentum of the system is constant. Students identify that the analysis of the momentum of each object in the system indicates that any change in momentum of one object is balanced by a change in the momentum of the other object, so that the total momentum is constant.

Cross-Cutting Concepts:

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Systems & Systems Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Momentum, Law of Conservation of Momentum, Collision, Elastic Collision, Inelastic Collision, Potential Energy, Kinetic Energy, Mechanical Energy, Law of Conservation of Energy, System, Balanced Force, Unbalanced Force

[Back to Course Map](#)

- Additional tier 2 words that students should be familiar with:
Conservative, Non-conservative, Sound, Thermal Energy, Criteria, Constraints, Tradeoffs, Cost-Benefit Analysis

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

Priority Standards (Performance Expectations):

HS-PS3-1 Energy

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 Macroscopic Energy Due to Particle Position and Motion

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 Energy Conversion Device Design

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.

Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.

Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.

Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.

Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.

Big Idea(s):

- Energy is a conserved, quantitative property of a system that manifests at both macroscopic and microscopic scales (as motion and relative position); it can be mathematically modeled to predict system behavior and harnessed through engineered devices to perform useful work

Essential Question(s):

- How can we use mathematical models to calculate and predict energy changes within a multi-component system?
- How is energy stored and transferred at both the microscopic (particle) and macroscopic scales?
- How does energy transfer and conversion perform work to support the functions of daily life?

Examples of Engaging Phenomenon:

- Rube Goldberg Machines

<https://www.youtube.com/watch?v=UFSn8IwgQfw>

<https://www.youtube.com/watch?v=qybUFnY7Y8w>

https://www.youtube.com/watch?v=lWIGo2FOaJk&ab_channel=GreatBigStory

https://www.youtube.com/watch?v=iLruc27jrOg&ab_channel=Joseph%27sMachines

https://www.youtube.com/watch?v=7RUE2BdI3BM&t=208s&ab_channel=Joseph%27Machines

https://www.youtube.com/watch?v=0lz8_aaKNXA

<https://www.youtube.com/watch?v=mm1NfUUCJgc>

https://www.youtube.com/watch?v=iSX9fOSJ0KI&ab_channel=Joseph%27sMachines

- The Gravity Light

<https://thewonderofscience.com/phenomenon/2018/7/9/the-gravity-light>

- Magnetic Cannon

<https://thewonderofscience.com/phenomenon/2017/10/8/ps2-motion-and-stability-forces-and-interactions>

- Fire Piston

<https://thewonderofscience.com/phenomenon/2018/7/12/fire-piston>

- The Collapsing Train Car

<https://thewonderofscience.com/phenomenon/2018/6/10/the-collapsing-train-car>

- Solar Cars

<https://thewonderofscience.com/phenomenon/2018/7/8/solar-cars>

- Earthships

<https://thewonderofscience.com/phenomenon/2018/7/5/earthships>

- Apple on a String

<https://sciencing.com/science-projects-with-balloons-sound-vibration-12746567.html>

- Ball Experiment

<https://sciencing.com/science-projects-with-balloons-sound-vibration-12746567.html>

- Classroom Discussion: Pretend to be planning to drop a marble or a bowling ball. What would the difference be between the two items? Consider impact and fall rate. Lead the discussion to include the variables in the PE formula. $PE=mgh$, so more

mass and more height will lead to more potential energy, causing more force when the object is dropped.

- Ball Drop
https://www.uml.edu/docs/ball_drop_complete_tcm18-264104.pdf
- Kinetic Energy Ball Drop (Fancy Kit Not Needed) <https://www.flinnsci.com/kinetic-energy-ball-drop---demonstration-kit/ap7187/#variantDetails>
- Newton’s Cradle <https://science.howstuffworks.com/innovation/inventions/newtons-cradle.htm#:~:text=If%20Ball%20One%20had%2010,no%20energy%20along%20the%20way.https://www.quinticsports.com/newtons-cradle-conservation-of-momentum-and-energy/https://www.phys.vt.edu/outreach/projects-and-demos/demonstrations-wiki/mechanics/newtons-cradle.htmlhttps://www.scienceofgadgets.com/post/how-newton-s-cradle-demonstrates-conservation-laws>

CTE Connected Phenomena

- Culinary Connection- Why do you see the bubbles in the center of the pan first rather than the sides when you are boiling water?
- Auto Connection- Newer cars often look worse after an accident, but are actually safer for the passengers. Why?
- HVAC Connection- Why is insulation used on pipes?

Students will know: (Disciplinary Core Ideas)

As evidenced by: (Science & Engineering Practices)

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the

Using Mathematics and Computational Thinking

- Create a computational model or simulation of a phenomenon, designed device, process, or system.
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Constructing Explanations and Designing Solutions

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories.
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

[PS3.B: Conservation of Energy and Energy Transfer](#)

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

[PS3.D: Energy in Chemical Processes](#)

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

[Developing and Using Models](#)

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Task Demands:

- Identify and describe the components to be computationally modeled, including the boundaries of the system and that the reference level for potential energy = 0 (the potential energy of the initial or final state does not have to be zero); The initial energies of the system’s components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of Joules in each component), including a quantification in an algebraic description to calculate the total initial energy of the system; The energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive; and the final energies of the system components, including a quantification in an algebraic description to calculate the total final energy of the system.
- create a computational model (e.g., simple computer program, spreadsheet, simulation software package application) that is based on the principle of the conservation of energy, using the algebraic descriptions of the initial and final energy state of the system, along with the energy flows. Students use the computational model to calculate

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.

DCI OBJECTIVES:

- Gravitational Potential Energy is the energy an object has due to its position above Earth (or another body), otherwise thought of as energy due to its height. We know this energy exists because it takes effort to lift an object up to a height and also because when we release an object, it falls, gaining kinetic energy.
- Gravitational Potential Energy (GPE) can be calculated by using the formula $GPE = mgh$ where m = mass, g = gravitational constant, and h = height.
- Kinetic Energy is a form of energy that an object or a particle has by reason of its motion. If work, which transfers energy, is done on an object by applying a net force, the object speeds up and thereby gains kinetic energy.
- Kinetic Energy (KE) can be calculated by using the formula $KE = \frac{1}{2}mv^2$ where m = mass and v = velocity.
- The Law of Conservation of Energy states that energy can't be created or destroyed, but it can change forms. The total amount of energy in the universe remains

changes in the energy of one component of the system when changes in the energy of the other components and the energy flows are known.

- Predict the maximum possible change in the energy of one component of the system for a given set of energy flows, using the computational model. Students identify and describe the limitations of the computational model, based on the assumptions that were made in creating the algebraic descriptions of energy changes and flows in the system.
- Develop models in which they identify and describe the relevant components including: energy flows between the system and the surroundings, Clearly depicting both a macroscopic, such as motion, sound, light, thermal energy, potential energy or energy in fields, and a molecular/atomic-level such as motions (kinetic energy) of particles representation of the system; and depicting the forms in which energy is manifested at two different scales.
- Describe the relationships between components in their models, including changes in the relative position of objects in gravitational, magnetic or electrostatic fields that can affect the energy of the fields (e.g., charged objects moving away from each other change the field energy). As one form of energy increases, others must decrease by the same amount as energy is transferred among and between objects and fields.
- Demonstrate, using models, that in closed systems the energy is conserved on both the macroscopic and molecular/atomic scales so that as one form of energy changes, the total system energy remains constant, as evidenced by the other forms of energy changing by the same amount or changes only by the amount of energy that is transferred into or out of the system. Students use their models to illustrate that energy at the macroscopic scale can be accounted for as a combination of

constant, and the sum of all forms of energy in a closed system is always the same.

- Mechanical energy is the energy that is possessed by an object due to its motion or due to its position. Mechanical energy can be either kinetic energy (energy of motion) or potential energy (stored energy of position). Mathematically it can be expressed as $ME = KE + PE$.
- Mechanical energy “loss” is when mechanical energy is dissipated away as heat, rather than being destroyed (not possible according to the Law of Conservation of Energy.) This loss can happen through resistive forces, such as friction or drag. These forces can drain an object's kinetic energy in a way that makes it difficult to recover. The lost energy is then converted into thermal energy and remains within the universe. Thus, it is “lost” from the system but DID NOT magically disappear.
- If energy is conserved in a system, the total amount of Mechanical Energy will stay constant, but the ratio between Potential Energy and Kinetic Energy may change. Mathematically this concept can be written as $PE_1 + KE_1 = PE_2 + KE_2$.

energy associated with the motions of particles/objects and energy associated with the relative positions of particles/objects on both the macroscopic and microscopic scales.

- Design a device that converts one form of energy into another form of energy and develop a plan for the device in which they identify: scientific principles, forms of energy that will be converted from one form to another, losses of energy by the design system to the surrounding environment and describe: the scientific rationale for choices of materials and structure of the device, including how student-generated evidence influenced the design; and that this device is an example of how the application of scientific knowledge and engineering design can increase benefits for modern civilization while decreasing costs and risk.
- Describe and quantify (when appropriate) prioritized criteria and constraints for the design of the device, along with the tradeoffs implicit in these design solutions. Examples of constraints to be considered are cost and efficiency of energy conversion.
- Build and systematically and quantitatively evaluate the performance of the device against the criteria and constraints.
- Improve the device performance, using the results of the tests, by increasing the efficiency of energy conversion, keeping in mind the criteria and constraints, and noting any modifications in tradeoffs.
- Design and construct a device, given constraints within which to work, that converts one form of energy to another. Examples could include: windmill, solar cooker, Rube Goldberg Machine, rubber band car, and many more.
- Manipulate the Gravitational Potential Energy formula to algebraically solve for mass, gravitational constant, and height.

- Provide an example of how Gravitational Potential Energy applies to daily life.
- Manipulate the Kinetic Energy formula to algebraically solve for mass and velocity.
- Provide an example of how Kinetic Energy applies to daily life.
- Provide an example of how the Law of Conservation of Energy applies to daily life.

Cross-Cutting Concepts:
Systems and System Models

- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Energy and Matter

- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Energy, Convert, Law of Conservation of Energy, Energy Transfer, Energy Transformation, Constraints, Potential Energy, Gravitational Potential Energy, Kinetic Energy, Velocity, Mechanical Energy, Create, Destroy, Mass, Gravitational Constant (g), Height, Constant
- Additional tier 2 words that students should be familiar with:
Risk Mitigation, Thermal Energy, Elastic Potential Energy, Sound Energy, Electrical Energy, Light Energy, Lost Energy

Resources: [NGSS Phenomenon Master List](#), [Shock Stickers for measuring impacts](#)

Unit 4: Magnetic Fields

Priority Standard (Performance Expectation): HS-PS2-5 Electric Current and Magnetic Fields

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.

Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.

Big Idea(s):

- An electric current produces a magnetic field, and a changing magnetic field induces an electric current.

Essential Question(s):

- How are electricity and magnetism physically related?
- How can electromagnetic induction be used to generate electricity in daily life?

Examples of Engaging Phenomenon:

- Automotive: How does an electric motor work?
<https://www.youtube.com/watch?v=CWulQ1ZSE3c>
- A radio emits music from its speakers. After a magnet in the speakers is removed, no sound can be heard.
https://www.youtube.com/shorts/jzN7v_GNSJo
- A generator converts mechanical energy into electrical energy. It consists of a rectangular coil, called the armature, composed of a number of copper wires wound around an iron core. A strong permanent magnet is placed around the coil. The armature is then rotated between the magnets. Two slip rings are connected to the arms of the armature in order to provide a movable contact. The slip rings are connected to metallic brushes to pass current from the armature. When operating, the position of the armature inside the magnet keeps changing. When the magnetic field lines are perpendicular to the moving coil, the induced electromagnetic field produced increases because the number of intercepting magnetic field lines is at its maximum.

<https://www.electricgeneratorsdirect.com/stories/1485-How-Generators-Work.html#:~:text=An%20electric%20generator%20works%20by,wire%20next%20to%20a%20magnet.>

- A transformer is a device that changes (or transforms) an alternating voltage to another voltage of greater or smaller value. The transformer consists of two coils, a primary coil and a secondary coil, that are wrapped around an iron core. The alternating current is applied across the primary coil, and the new voltage output is obtained across the secondary coil. In order for a step-up transformer to convert a low voltage into a high voltage by decreasing the current, the number of turns in the primary coil is less than the number of turns in the secondary coil. A step-down transformer converts a high voltage to a low voltage by increasing the current, so the number of turns in the primary coil is greater than the number of turns in the secondary coil.

<https://www.keysight.com/used/us/en/knowledge/guides/how-does-a-transformer-work#:~:text=Transformers%20operate%20using%20electromagnetic%20induction,windings%20determines%20the%20voltage%20conversion.>

- More electrical current is produced by a windmill when the wind speed is greater.
[Wind Power! Designing a Wind Turbine](#)
[Physics of Wind Turbines](#)
- Merchandise from a store that uses electromagnetic anti-shoplifting devices will set off an alarm at the exit if the tag is not removed.
[YOUTUBE How Antitheft Tags Work](#)
- An electromagnet at a junkyard can lift old cars, while a homemade electromagnet cannot pick up much more than a few paper clips.
[Creating an Electromagnet](#)
[How Electromagnets Work](#)

Students will know: (Disciplinary Core Ideas)

As evidenced by: (Science & Engineering Practices)

PS2.B: Types of Interactions

- Newton’s Law of Universal Gravitation and Coulomb’s Law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
- Forces at a distance are explained by fields

[Using Mathematics and Computational Thinking](#)

- Create a computational model or simulation of a phenomenon, designed device, process, or system.
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

(gravitational, electric, and magnetic) permeating space that can transfer energy through space.

- Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

PS3.A: Definitions of Energy

- “Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents.

DCI OBJECTIVES:

- An electric force is the attractive or repulsive interaction between any two or more charged bodies. An electric field is a region in space where the charged object experiences a force due to its electric charge. The electric force causes the formation of the electric field around the source.
- Magnets have a magnetic field around them, a region of space where a magnetic force can be felt. Magnetic fields are created from moving charged particles. Charges can either move within the atom (stronger with the alignment of magnetic dipoles) or along a current carrying wire. Electric current through a conductive material also generates a magnetic field.
- When a magnetic field changes in either strength or direction, it creates a change in the magnetic flux through a loop of wire or a conductor. This change in magnetic flux induces an electric field. The induced electric field creates a potential difference, or voltage, across the ends of the conductor. If the conductor

Constructing Explanations and Designing Solutions

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories.
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Planning and Carrying Out Investigations

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence: 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.

Task Demands:

- Describe the phenomenon under investigation, which includes the following idea: that an electric current produces a magnetic field and that a changing magnetic field produces an electric current.
- Develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data about 1) an observable effect of a magnetic field that is uniquely related to the presence of an electric current in the circuit, and 2) an electric current in the circuit that is uniquely related to the presence of a changing magnetic field near the circuit. Students describe why these effects seen must be causal and not correlational, citing specific cause-effect relationships.
- Demonstrate within the investigation plan, the use of an

forms a closed loop (a circuit), this potential difference will drive an electric current to flow through the circuit, completing the circuit. This phenomenon is known as electromagnetic induction.

- Turning a magnet in an electromagnetic field can induce a change in energy.

electric circuit through which electric current can flow, a source of electrical energy that can be placed in the circuit, the shape and orientation of the wire, and the types and positions of detectors; a means to indicate or measure when electric current is flowing through the circuit; a means to indicate or measure the presence of a local magnetic field near the circuit; and a design of a system to change the magnetic field in a nearby circuit and a means to indicate or measure when the magnetic field is changing. In the plan, students state whether the investigation will be conducted individually or collaboratively.

- Measure and record electric currents and magnetic fields.
- Evaluate their investigation, including an evaluation of the accuracy and precision of the data collected and limitations of the investigation, and the ability of the data to provide the evidence required. If necessary, students refine the investigation plan to produce more accurate, precise, and useful data such that the measurements or indicators of the presence of an electric current in the circuit and a magnetic field near the circuit can provide the required evidence.

Cross Cutting Concepts:
Cause and Effect

- Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Electromagnetism, Induction, Magnetic Field, Magnetic Field Line, Charged Particle, Permanent Magnet, Polarity, Electric Motor, Electric Generator, Electric Current, Circuit

[Back to Course Map](#)

- Additional tier 2 words that students should be familiar with:
Right-Hand Rule, Magnetic Flux, Transformer, Ampere, Tesla, Resistance, Voltage, Volt, Potential Difference, Electrical Conductor, Electrical Insulator

Science vocabulary students are NOT expected to know:

Resources: [NGSS Phenomenon Master List](#)

<p>Priority Standard (Performance Expectation): 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.</p>	
<p style="color: red;">Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.</p> <p style="color: red;">Assessment Boundary: Assessment is limited to systems containing two objects.</p>	
<p>Big Idea(s):</p> <ul style="list-style-type: none"> When two objects interact through electric or magnetic fields, the energy stored in the field changes as the objects' positions or velocities change. 	
<p>Essential Question(s):</p> <ul style="list-style-type: none"> How does changing the distance between magnets affect the energy stored within a field? How can we model the forces and energy changes that occur when two charged objects interact? 	
<p>Examples of Engaging Phenomenon:</p> <ul style="list-style-type: none"> Magnetic free energy devices- Are the electric companies hiding the secrets to FREE energy? https://www.youtube.com/watch?v=92nsAaMvQcs Bending a stream of water with an electrically-charged balloon https://www.youtube.com/watch?v=uvG4cjc_4W4 Demonstrate: Two magnets are held close together such that they attract each other. When the magnets are further away from each other, it is easier to keep them apart. (Relation to Coulomb's Law and Universal Gravitation) https://physicsworld.com/a/sunny-superpower-solar-cells-close-in-on-50-efficiency/ https://www.electricaltechnology.org/2020/12/coulombs-laws-of-magnetic-force.html 	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>PS3.C: Relationship Between Energy and Forces</p> <ul style="list-style-type: none"> When two objects interacting through a field change relative position, the energy stored in the field is changed. 	<p><u>Using Mathematics and Computational Thinking</u></p> <ul style="list-style-type: none"> Create a computational model or simulation of a phenomenon, designed device, process, or system. Use mathematical, computational, and/or algorithmic

DCI OBJECTIVES:

- Charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges.
- Forces can be categorized as Contact Forces or Field Forces. A Contact Force is when a physical object touches another physical object and exerts a force on it. Pushes and pulls are examples of Contact Forces. Field Forces affect objects without actually touching them. Examples of Field Forces include gravity and magnetism.
- Different planets yield a different acceleration due to gravity since they possess differing masses. Different heights yield a different acceleration due to gravity since they possess a different distance between them.

representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Constructing Explanations and Designing Solutions

- Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories.
- Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Developing and Using Models

- Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
- Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Task Demands:

- Develop a model in which they identify and describe the relevant components to illustrate the forces and changes in energy involved when two objects interact, including: i. The two objects in the system, including their initial positions and velocities (limited to one dimension). ii. The nature of the interaction (electric or magnetic) between the two objects. iii. The relative magnitude and the direction of the net force on each of the objects. iv. Representation of a field as a quantity that has a magnitude and direction at all points in space and which contains energy.
- Describe the relationships between components of the model, including the change in the energy of the objects, given the

	<p>initial and final positions and velocities of the objects.</p> <ul style="list-style-type: none">● Determine whether the energy stored in the field increased, decreased, or remained the same when the objects interacted within the model. Students use the model to support the claim that the change in the energy stored in the field (which is qualitatively determined to be either positive, negative, or zero) is consistent with the change in energy of the objects. Using the model, students describe the cause and effect relationships on a qualitative level between forces produced by electric or magnetic fields and the change of energy of the objects in the system.
<p><u>Cross Cutting Concepts:</u> Cause and Effect</p> <ul style="list-style-type: none">● Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	
<p><u>Academic Vocabulary:</u></p> <ul style="list-style-type: none">- Science vocabulary students ARE expected to know: Electric Current, Magnet, Electrical Energy, Magnetic Force, Attract, Repel, Electromagnet, Electric Field, Magnetic Field, Electric Charge, Potential Energy, Contact Force, Field Force- Additional tier 2 words that students should be familiar with: Coulomb	
<p><u>Resources:</u> NGSS Phenomenon Master List</p>	

Priority Standard (Performance Expectation): HS-ETS1-1 Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.

Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.

Big Idea(s): Engineering solutions for global challenges require a balance of qualitative and quantitative criteria, such as societal needs, risk mitigation, and cost.

Essential Question(s):

- How can we balance competing priorities (cost, efficiency, safety) when designing solutions to global issues?
- How do energy transfers and transformations address the needs of modern civilization?

Examples of Engaging Phenomenon:

- Create a solar oven that will cook a pizza bagel or a s'more.
<https://www.sciencebuddies.org/stem-activities/solar-oven>
<https://climatekids.nasa.gov/smares/>
<https://www.sciencebuff.org/scienceactivity/solar-oven/>
<https://www.youtube.com/watch?v=m4tNG64IDc0>
- Refine a solar cell such that it maximizes energy output.
<https://www.greencitytimes.com/how-to-maximize-solar-panel-efficiency/>
<https://www.pveducation.org/pvcdrom/design-of-silicon-cells/solar-cell-design-principles>
<https://www.bostonsolar.us/solar-blog-resource-center/blog/how-do-temperature-and-shade-affect-solar-panel-efficiency/>
<https://www.youtube.com/watch?v=poUmBdeofpU>
- Generator Efficiency
<https://www.genpowerusa.com/blog/diesel-generator-vs-gas-generator-which-is-more-efficient/>

<p>https://www.jcdavispower.com/tips-for-maximizing-generator-efficiency-and-lifespan-on-your-worksite/ https://swiftequipment.com/how-to-calculate-the-efficiency-of-a-diesel-generator-with-formula/ https://www.youtube.com/watch?v=8hgFOWUqvJU https://www.youtube.com/watch?v=2uR_XFdZF9g</p>	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
<p>ETS1.A: Defining and Delimiting an Engineering Problem</p> <ul style="list-style-type: none"> Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. <p><u>DCI OBJECTIVES:</u></p> <ul style="list-style-type: none"> Science and engineering can be used to solve real-world problems. -Many varied solutions to a problem may be possible, but each will have strengths and weaknesses. Product testing and iterative improvements can make a product better, but likely none will be perfect. 	<p>Using Mathematics and Computational Thinking</p> <ul style="list-style-type: none"> Create a computational model or simulation of a phenomenon, designed device, process, or system. Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Design or refine a solution to a complex real-world problem, based on scientific knowledge, principles, and theories. Design or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. <p><u>Task Demands:</u></p> <ul style="list-style-type: none"> Articulate, describe, illustrate, or select the relationships, interactions, and/or processes to be explained. This may entail sorting relevant from irrelevant information or features. Express or complete a causal chain explaining how the device converts one form of energy into another form of energy. This may include indicating directions of causality in an incomplete model such as a flow chart or diagram, or completing cause and effect chains. Identify constraints that the energy converting device or solution must meet.

- Identify evidence supporting the inference of causation that is expressed in a causal chain.
- Propose, illustrate, or assemble a potential energy converting device (prototype) or solution, us.
- Test a proposed energy converting prototype and evaluate the outcomes, potentially including proposing and testing modifications to the prototype by using a simulator.

Cross-Cutting Concepts:

Energy and Matter

- 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.

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
Electric Current, Electrical Energy, Electromagnet, Magnetic Field, Electric Field, Mechanical Energy, Renewable Energy, Generator, Wind Turbine, Rube Goldberg Device, Solar Cell, Solar Oven
- Additional tier 2 words that students should be familiar with:

Resources: [NGSS Phenomenon Master List](#)

Appendix A: Vocabulary

- Absorb: The process by which atoms of an element take in characteristic frequencies of light.
- Acceleration: A change in motion that depends on both the mass of an object and the net force applied to it ($f=ma$).
- Adhesive: A property where molecules of one substance (like water) stick to other types of molecules.
- Alpha Decay: A type of radioactive decay involving the emission of an alpha particle to reach a more stable state.
- Amplitude: A measure of a wave's displacement from its equilibrium position, modeling its intensity.
- Atomic Mass: The sum of protons and neutrons in an atom's nucleus, often represented as an isotopic average.
- Atomic Number: The number of protons in an atom's nucleus, which identifies the element.
- Atomic Radius: A periodic trend representing the relative size of an atom.
- Atom: The basic unit of matter, consisting of a nucleus of protons and neutrons surrounded by an electron cloud.
- Attraction: A pull exerted by objects on each other, often due to different electromagnetic charges.
- Balanced Force: A state where all forces acting on an object are equal, resulting in no acceleration.
- Beta Decay: A type of radioactive decay involving the emission of an electron or positron.
- Big Bang Theory: The widely accepted explanation for the origin of the universe, suggesting it began as an infinitely small, hot, dense point.
- Boiling Point: The temperature at which a substance changes from a liquid to a gas.
- Brightness (Luminosity): The amount of light emitted by a star, used to determine its composition and distance from Earth.
- Bulk Properties: Characteristics of a substance (like melting point or density) that result from many atoms or molecules acting together.
- Chemical Bond: An attraction between atoms that allows the formation of chemical substances, influenced by valence electrons.
- Chemical Change: A process that results in a change in the elemental composition of a substance.
- Circuit: A closed loop of conductive material through which an electric current can flow.
- Coefficient: The large number placed before a chemical formula in an equation to denote the number of moles or molecules.
- Cohesive: A property where molecules of the same substance stick together.
- Collision: An interaction between objects that can be elastic (conserving both energy and momentum) or inelastic.
- Combustion: A chemical reaction involving a substance reacting with oxygen, often producing heat and light.
- Compound: A pure substance formed when two or more different elements are chemically bonded in a specific ratio.
- Conductivity: The ability of a material to allow the flow of heat or electricity.
- Conductor: A material, often a metal, that allows electrons to move freely.
- Conservation of Energy: The law stating that energy cannot be created or destroyed, only transferred or transformed.
- Conservation of Matter: The principle that atoms are neither created nor destroyed in chemical or nuclear processes.
- Constraints: Requirements or limitations in a design process, such as cost, mass, or efficiency.

[Back to Course Map](#)

- Contact Force: A force that results when physical objects touch each other (e.g., friction).
- Covalent Bond: A chemical bond formed when nonmetal atoms share pairs of electrons.
- Criteria: The specific requirements or desired qualities that a designed solution must meet.
- Decay Curve: A graph showing how the amount of a radioactive substance decreases over time.
- Decomposition: A type of chemical reaction where a single compound breaks down into two or more simpler substances.
- Density: The mass of a substance divided by the volume it occupies.
- Ductility: The ability of a metal to be drawn into a thin, long wire.
- Elastic Collision: A collision in which both total kinetic energy and total momentum are conserved.
- Electric Current: The flow of electric charge through a conductive material.
- Electric Field: A region of space around a charged object where other charged objects experience a force.
- Electromagnetic Induction: The process of generating an electric current by changing a magnetic field.
- Electronegativity: A measure of an atom's ability to attract shared electrons in a chemical bond.
- Electron: A negatively-charged subatomic particle located in the region surrounding the nucleus.
- Element: A pure substance consisting of only one type of atom that cannot be broken down further.
- Energy: A quantitative property of a system that depends on the motion and interactions of matter and radiation.
- Equilibrium: A state in which opposing forces are balanced, resulting in no net change in motion.
- Field Force: A force that acts at a distance without physical contact, such as gravity or magnetism.
- Fission: A nuclear process where a heavy nucleus splits into smaller fragments, releasing energy.
- Frequency: The number of wave cycles that pass a point per unit of time.
- Friction: A force that opposes motion between two surfaces in contact.
- Fusion: A nuclear process where two light nuclei merge to form a heavier nucleus, releasing immense energy.
- Gamma Decay: A radioactive process that releases high-energy electromagnetic radiation.
- Generator: A device that converts mechanical energy into electrical energy using electromagnetic induction.
- Gravity: An attractive force between masses, such as the inward pressure that prevents a star from expanding.
- Groups/Families: Vertical columns on the periodic table containing elements with similar chemical properties.
- Half-life: The time required for half of the atoms in a radioactive isotope sample to decay.
- Hertzsprung-Russell (H-R) Diagram: A tool used to classify stars by plotting their luminosity against their temperature.
- Inelastic Collision: A collision where momentum is conserved, but some kinetic energy is transformed into other forms like heat or sound.
- Inertia: The tendency of an object to resist any change in its state of rest or motion.
- Insulator: A material that resists the flow of electricity or heat.
- Intermolecular Force: Forces of attraction or repulsion that act between neighboring particles.
- Intramolecular Force: Forces that hold the atoms within a single molecule together.

[Back to Course Map](#)

- Ion: An atom or molecule with a net electric charge due to the loss or gain of electrons.
- Ionic Bond: A chemical bond formed through the transfer of electrons from a metal to a nonmetal.
- Isotopes: Forms of an element that have the same number of protons but different numbers of neutrons.
- Kinetic Energy (KE): The energy an object possesses due to its motion, calculated as $\frac{1}{2}mv^2$.
- Lewis Dot Structure: A diagram used to show the valence electrons and bonding of an atom.
- Malleability: The ability of a metal to be hammered or rolled into thin, flat sheets.
- Mass: A measure of the amount of matter in an object.
- Mechanical Energy: The sum of potential and kinetic energy in a system.
- Melting Point: The temperature at which a substance changes from a solid to a liquid.
- Metal: Elements typically characterized by being shiny, ductile, malleable, and good conductors.
- Momentum (p): A quantity of motion defined as the product of an object's mass and its velocity ($p=mv$).
- Neutron: A neutral subatomic particle found in the nucleus of an atom.
- Noble Gas: Unreactive elements in Group 18 with a full outer electron shell.
- Nucleosynthesis: The process by which stars produce elements through nuclear fusion.
- Nucleus: The small, dense, central core of an atom containing protons and neutrons.
- Octet Rule: The principle that atoms are most stable when they have eight electrons in their valence shell.
- Periodic Table: An arrangement of elements ordered by atomic number that illustrates repeating patterns of properties.
- Periods: Horizontal rows on the periodic table representing the number of electron shells.
- Physical Change: A change that alters the appearance of a substance without changing its chemical composition.
- Polarity: The distribution of electrical charge over the atoms joined by a bond.
- Polymer: A large molecule composed of many repeating subunits called monomers.
- Potential Energy (PE): Stored energy based on an object's position or configuration (e.g., gravitational or field energy).
- Product: A substance that is formed as the result of a chemical reaction.
- Proton: A positively-charged subatomic particle found in the nucleus.
- Pure Substance: A material made of only one kind of element or compound.
- Radiation: The transfer of energy through space in the form of electromagnetic waves or particles.
- Radioactive Decay: The spontaneous breakdown of an unstable nucleus, releasing radiation.
- Reactant: A substance that takes part in and undergoes change during a chemical reaction.
- Reactivity: The tendency of a substance to undergo a chemical reaction.
- Red-Shift: The displacement of light toward longer wavelengths, indicating that an object (like a galaxy) is moving away.
- Repulsion: A force that pushes objects with the same electromagnetic charge away from each other.
- Solubility: The ability of a substance (solute) to dissolve in another substance (solvent).
- Spectroscope: An instrument used to divide light into its component wavelengths (spectra).

[Back to Course Map](#)

- Subscript: A small number in a chemical formula that indicates the ratio of atoms in a compound.
- Supernova: A powerful explosion of a massive star that creates elements heavier than iron.
- Surface Tension: A property of a liquid's surface that allows it to resist external forces due to cohesive molecular behavior.
- Synthesis: A chemical reaction where two or more substances combine to form a more complex product.
- System: A set of interacting components within defined boundaries used for scientific study.
- Thermal Energy: Energy associated with the motion of particles within a substance; often released as "lost" heat.
- Trend: A predictable pattern in properties, such as those observed on the periodic table.
- Unbalanced Force: A net force acting on an object that causes it to accelerate.
- Valence Electrons: Electrons in the outermost shell of an atom that determine its chemical bonding behavior.
- Vapor Pressure: A measure of a material's tendency to change into a gaseous state.
- Velocity: The speed of an object in a specific direction.
- Viscosity: A measure of a fluid's resistance to flow.
- Wavelength: The distance between successive crests of a wave.
- Wave Speed: The speed at which a wave travels through a medium ($v = f\lambda$)