Unit 3: How Can We Get Energy to Flow From One Place to Another?

45 Instructional Days

New Jersey Student Learning Standards Science

HS-PS2-5: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. [Assessment Boundary: Assessment is limited to designing and conducting investigations with provided materials and tools.]

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

HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. [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.]

HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

<u>**Science and Engineering Practices**</u> **Planning and Carrying Out Investigations** ● Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5), (HS-PS3-4) **Using Mathematics and Computational Thinking** ● Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) **Constructing Explanations and Designing Solutions** ● Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3)
<u>**Disciplinary Core Ideas**</u> **PS2.B: Types of Interactions** ● Forces at a distance are explained by fields (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. (HS-PS2-5) **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. (HS-PS3-1) ● At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-3) **PS3.B: Conversion 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. (HS-PS3-1) ● Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4)

- 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. (HS-PS3-1)
- The availability of energy limits what can occur in any system. (HS-PS3-1)
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4)

PS3.D: Energy in Chemical Processes and Everyday Life

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-5)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4)
- 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. (HS-PS3-1)

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. (HS-PS3-3)

Influences of Science, Engineering, and Technology on Society and the Natural World

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)

Scientific Knowledge Assumes an Order and Consistency in Natural Systems ● Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)
Rationale and Transfer Goals : This unit focuses on developing student understanding of how energy flows. Energy is quantitative and depends on the motion and interactions of matter and radiation within the system. Students will develop an understanding of thermodynamics, focusing on the first two laws, examining all types of energy, especially the relationship between heat and chemical energy in a reaction. Students will be able to use mathematical representations to describe energy changes both conceptually and quantitatively. This unit will also explore how an electric current can produce a magnetic field and how energy flows in and out of a system including devices like solar cells, solar ovens and generators.
Enduring Understandings: ● The first law of thermodynamics: heat is a form of energy, and in thermodynamic processes energy is conserved. ● Entropy is a thermodynamic property related to the way in which the energy of a system is distributed among the available energy levels. ● The second law of thermodynamics: the total entropy of an isolated system can never decrease over time, and is constant if all processes are reversible. ● A system is the part of the universe chosen for study. There are open systems, closed systems, and isolated systems. ● The surroundings are the part of the universe outside of the system with which the system interacts. ● Energy is the ability to do work. Kinetic energy is a moving object and thermal energy is the kinetic energy associated with random molecular motion. ● Potential energy is energy associated with forces of attraction or repulsion between objects. ● Chemical energy is associated with chemical bonds and intermolecular attractions. ● The relationship between electric currents and magnetic fields. ● Thermochemical measurements and calculations are used to assess materials as energy sources.
Essential Questions: ● How can we get energy to flow from one place to another? ● Why is energy conserved in a reaction? ● How can entropy be quantified?

● What determines a system or surroundings? ● What types of energy are involved in chemical reactions? ● What is the relationship between electric currents and magnetic fields?

Content/Objectives		Instructional Actions	
Content ***What students will know***	**Skills** ***What students will be able to do***	**Activities/Strategies** ***How we teach content and skills***	**Evidence (Assessments)** ***How we know students have learned***
● The difference between a system and the surroundings and that the total energy is conserved in an isolated system. (Law of Conservation of Energy) ● How energy is converted from one form to another (ex: potential to kinetic, kinetic to chemical) ● Create a computational model and apply it to the change in energy of a component of a system when other energies and energy flows are known. ● The second law of thermodynamics: When	● Define and give examples of systems and surroundings as well as explain the law of conservation of energy and calculate the change in thermal energy of a system. ● Design and build a device that converts energy from one form to another - identifying forms of energy being converted in the system and losses of energy by the design system to the surroundings. ● Use a computational model to calculate the changes in the energy of	● Students will complete a simulation activity titled "Energy Changes in Chemical Reactions." [Link] This activity shows how energy transforms, but is conserved. ● Students will use materials provided to build a device that will convert energy from one form to another. Students will first research and define multiple types of energy and then apply the research to their own device. ● Students will create a model using a computer program (ex: Excel) based	● Students will complete a laboratory activity to collect and record data that will be used to calculate a change in thermal energy. Students will evaluate their investigation including the accuracy and precision of the data and discuss limitations of the experiment as well as sources of error. ● Students will give a short presentation of the designed device. ● Students will take an assessment calculating change in energy of a component (when other

two components of different temperature are combined within a closed system results in a uniform energy distribution throughout the components in the system.	a component of a system and predict the maximum possible change in energy of one component when other energies and energy flows are known. ● If a hot object comes in contact with a cold object, the thermal energy lost by the hot object will equal the amount gained by the cold.	on the principle of the conservation of energy. Students will be able to manipulate the model to determine a component of the system's energy (with other energies known.) ● Students will perform a laboratory activity to understand the transfer of thermal energy collecting data including the masses of the components and the initial and final temperatures. Students will evaluate their investigation including the accuracy and precision of the data. [Link]	energies are known) as well as on entropy and the second law of thermodynamics. ● Chemistry Unit 3 Benchmark

Spiraling for Mastery

Content or Skill for this Unit	Spiral Focus from Previous Unit	Instructional Activity
● Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.	● Energy has multiple forms including motion, sound, light, and thermal energy. In	● Students will complete a self guided POGIL activity on the types of energy and identifying systems and surroundings.

• In an endothermic reaction thermal energy flows out to the surroundings. In an exothermic reaction thermal energy flows into the system. • Electric current produces a magnetic field and energy transfer can occur through fields.	an isolated system energy is conserved. • In a chemical reaction, energy can flow into the system or out to the surroundings. • Electric current is the rate of flow of electric charge.	• Students will reexamine energy level diagrams of reactions and explain the flow of energy for a particular chemical reaction. • Students will complete a laboratory activity titled "Energy Transfer Investigation." [Link] Students will be able to determine the flow of energy transfer as well as the conversion from kinetic to thermal energy.

Key resources:

Dynamic Periodic Table [Link]

POGIL: Process Oriented Guided Inquiry Learning [Link]

PhET Simulations [Link]

American Association of Chemistry Teachers [Link]

21st Century Life & Careers:

9.2.12.CAP.2: Develop college and career readiness skills by participating in opportunities such as structured learning experiences, apprenticeships, and dual enrollment programs.

9.2.12.CAP.3: Investigate how continuing education contributes to one's career and personal growth.

9.2.12.CAP.4: Evaluate different careers and develop various plans (e.g., costs of public, private, training schools) and timetables for achieving them, including educational/training requirements, costs, loans, and debt repayment.

Career Readiness, Life Literacies, & Key Skills:

9.4.12.CT.3: Enlist input from a variety of stakeholders (e.g., community members, experts in the field) to design a service learning activity that addresses a local or global issue (e.g., environmental justice).

9.4.12.CT.4: Participate in online strategy and planning sessions for course-based, school-based, or other projects and determine the strategies that contribute to effective outcomes. 9.4.12.GCA.1: Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others. 9.4.12.IML.2: Evaluate digital sources for timeliness, accuracy, perspective, credibility of the source, and relevance of information, in media, data, or other resources. 9.4.12.IML.3: Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions. 9.4.12.IML.4: Assess and critique the appropriateness and impact of existing data visualizations for an intended audience. 9.4.12.IML.5: Evaluate, synthesize, and apply information on climate change from various sources appropriately. 9.4.12.IML.6: Use various types of media to produce and store information on climate change for different purposes and audiences with sensitivity to cultural, gender, and age diversity.
<u>**InterDisciplinary Connections/Companion Standards:**</u> **NJSLS-Math** HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-5), (HS-PS3-1), (HS-PS3-3) HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-5), (HS-PS3-1), (HS-PS3-3) HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1), (HS-PS3-3) **NJSLS-ELA** WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-5), (HS-PS3-3), (HS-PS3-4)

WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5), (HS-PS3-3), (HS-PS3-4)

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-5), (HS-PS3-4)

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4)

SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1), (HS-PS3-5)

Companion Standards for ELA in Science and Technical Subjects: Reading
RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.1. Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.

Companion Standards for ELA in Science and Technical Subjects: Writing
WHST.11-12.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

WHST.11-12.5. Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.