PLANNED INSTRUCTION

A PLANNED COURSE FOR

Applications of Physical Science

STEELS: Science, Technology and Engineering,
Environmental Literacy and Sustainability

Curriculum writing committee:
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Grade Level: 11,12

Date of Board Approval:

Course Weighting: Applications of Physical Science

Major Assessments	**45%**
Skill Application	**30%**
Skills Practice	**20%**
Participation	**5%**
Total	**100%**

Curriculum Map

Overview: This course is a science elective designed to provide insights into the applications of physical science concepts. The course will include a mix of discovery learning, laboratory inquiry, and direct instruction. Main topics in this course include periodic table, matter, inference, chemical composition, atomic structure, chemistry of batteries, pH, gasses and pressure, introductory stoichiometry, Newton's Laws, pressure, work measurement, electricity, force and friction, energy conversion, fluid dynamic, and thermodynamics. Students will complete labs to develop their understanding of these concepts. They will complete lab reports to express their methods and findings.

Goals:

Marking Period 1:

Unit 1: Collisions & Momentum (35 days)

- Momentum as a product of mass and velocity
- Newton's Second Law of Motion
- Force, acceleration, and time relationships
- IPhysical principles apply to real-world scenarios

Unit 2: Survey of Biology Systems, Ecology, and Evolution (10 Days)

- Module A: Cells and Processes
    - Biological Principles
    - Chemistry of Life
    - Bioenergetics
    - Homeostasis and Transport

Marking Period 2

Unit 2: Survey of Biology Systems, Ecology, and Evolution (10 Days)

- Module B: Continuity and Unity of Life
    - Genetics
    - Theory of Evolution
    - Ecology

    - Cellular Reproduction

Unit 3: Energy Flow from Earth's Systems (32 Days)
- Complex energy transfer mechanisms across electrical systems (power generation, transmission, and consumption)
- Thermodynamic principles underlying electrical energy generation and grid-scale distribution
- Reliability, efficiency, and sustainability of various energy sources

Unit 4: Thermodynamics in Earth's Systems (3 Days)
- Climate Systems and Ocean Dynamics
- Geophysical Mechanisms
- Environmental Impact Analysis

Marking Period 3

Unit 4: Thermodynamics in Earth's Systems - Continued (27 Days)
- Scientific Research and Data Interpretation
- Interdisciplinary Connections

Unit 5: Molecular Processes in Earth Systems (18 Days)
- Properties of different liquids and their interactions with surface materials.
- Liquids or events responsible for specific land formations on Earth, the Moon, or Mars based on observed properties.
- Atomic structure and how elements interact to form the periodic table.
- Properties of substances to atomic-scale interactions, such as electronegativity.
- The law of conservation of matter to balance chemical equations accurately.

Marking Period 4

Unit 5: Molecular Processes in Earth Systems - Continued (12 Days)
- Structure of a substance affects its ability to be recycled into different substances.
- Substances needed for successful living and working beyond Earth, considering their sourcing, manufacturing, and recycling.

Unit 6: Energy from Chemical & Nuclear Processes (33 Days)
- Address climate change, building upon concepts introduced in the first unit of the course.
- Fuels used for transportation, including gasoline, diesel, and biofuels.
- Explain the combustion reactions occurring in various engine types (gasoline, diesel, and biofuel) and identify the source of energy in these reactions.
- Quantify the amount of energy released during combustion reactions.
- Non-carbon-based fuel options such as electric vehicles, hydrogen, and uranium, considering engineering aspects.
- Transportation options to address environmental, safety, and other concerns.

- Fuels and transportation solutions for specific transportation goals, considering their impact on the Earth and communities.

Big Ideas: 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. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

Textbook and Supplemental Resources:

- Glencoe Physical Science 2017
- Open SciEd
- University of Colorado PhET Simulations
- Carolina Science Products

Curriculum Plan

Unit 1: Collisions & Momentum

What can we do to make driving safer for everyone?

Standards (by number):	**Essential Questions:**
Science: 3.2.9-12.I 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. 3.2.9-12.J 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. 3.2.9-12.K Apply scientific and engineering ideas to design, evaluate and refine a device that minimizes the force on a macroscopic object during a collision. 3.2.9-12.O 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. 3.2.9-12.S 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.	➔ Why is driving safer today than it was ten years ago, even though the number of vehicle collisions has gone up? ➔ How does being distracted affect whether you will avoid a collision? ➔ How does speed affect whether you will avoid a collision? ➔ What affects the amount of time it takes a vehicle to stop after the driver presses the breaks? ➔ Can we use mathematical models to explain differences in stopping in wet conditions? ➔ Do our motion relationships help predict any of the interactions or outcomes in a collision? ➔ Can our models be used to predict the motion of real-world vehicles in a collision? ➔ What interactions happen during a vehicle collision, and when do they happen?
Technology and Engineering: 3.5.9-12.E Evaluate how technology and engineering advancements alter human health and capabilities.	➔ How do safety features affect the forces over time on a person during a collision? ➔ How are the bodies of cards designed to make collisions safer?

3.5.9-12.F Evaluate a technological innovation that arose from a specific society's unique need or want. 3.5.9-12.G Evaluate a technological innovation that was met with societal resistance impacting its development. 3.5.9-12.P Apply a broad range of design skills to a design thinking process. 3.5.9-12.H Evaluate ways that technology and engineering can impact individuals, society, and the environment. 3.5.9-12.Q Implement and critique principles, elements, and factors of design. 3.5.9-12.V Apply principles of human-centered design.	➔ How do the rigidity and length of the crumple zone influence the safety of the occupants during a collision? ➔ How can we use our models from across the unit to explain how vehicle systems can be designed to increase safety? ➔ What can we do to make driving safer for everyone in our community?
Environmental Literacy and Sustainability: 3.4.9-12.H Design and evaluate solutions in which individuals and societies can promote stewardship in environmental quality and community well-being.	➔ How can we use our science ideas and societal wants and needs to evaluate arguments around design solutions? ➔ What can we do to make driving safer for everyone in our community?

Students will be able to… (SEP)	Students will know…. (DCI)	Students will apply…(CCC)
Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Theories and laws provide explanations in science. Laws are statements or descriptions of the relationships among observable phenomena. Use mathematical	Newton's second law accurately predicts changes in the motion of macroscopic objects. 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. Criteria may need to be broken down into simpler ones that can be approached systematically,	*Patterns* Mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system *Cause and Effect* Cause and effect relationships to explain and predict behaviors in complex natural and designed systems. *Systems and System Models* Models (e.g., physical,

representations of phenomena to describe explanations. Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. Create a computational model or simulation of a phenomenon, designed device, process, or system. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. Design, evaluate, and/or refine a	and decisions about the priority of certain criteria over others (trade-offs) may be needed. 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. 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. When two objects interacting through a field change relative position, the energy stored in the field is changed.	mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. Models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. Total amount of energy and matter in closed systems is conserved. *Structure and Function* Investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem.

solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.	Disparities in the technologies available to different groups of people have consequences for public health and prosperity, but deciding whether to introduce a new technology should consider local resources and the role of culture in acceptance of the new technology. 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. Advances in science have been applied by engineers to design new products, processes, and systems, while improvements in technology have enabled breakthroughs in scientific knowledge. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. Analyze cultural, social, economic, or political changes (separately or together) that may be triggered by the transfer of a specific technology from one society to another. Include both anticipated and unanticipated effects. Students know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts or solving authentic problems.	

	When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	

Core Activities/Corresponding Instructional Methods/DOK Levels **35 Days**
The students will: ➢ Ask questions about patterns in vehicle safety over time that we have identified using empirical data and about factors that might have affected them (such as driver distraction, safety features, vehicle mass, and vehicle velocity). (DOK 2) ➢ Develop a model of a vehicle-driver system that includes safety components designed to alter the physics of a collision in order to predict the impact of these components on traffic safety statistics. (DOK 3)
The students will: ➢ Analyze videos of two drivers encountering a sudden obstacle by graphing change in distance over time in order to describe and predict how being distracted can affect the risk of a potential vehicle collision. (DOK 2)
The students will: ➢ Use a mathematical model (distance = speed * time) to generate data about how speed affects reaction distance based on average reaction times for distracted versus undistracted drivers. (DOK 3) ➢ Use student-generated evidence from video data and mathematical modeling to make a claim about the problem of distracted driving. Identify design solutions that could have the effect of decreasing reaction distances to prevent a collision in the event of a sudden obstacle, and identify a range of constraints associated with each solution. (DOK 2)
The students will:

➢ Use mathematical representations of the relationship between mass, initial speed, force, and stopping time and algebraic thinking to make a quantitative claim that predicts how much changing the braking force will affect the time it takes a vehicle to stop. (DOK 3) ➢ Use simple limit cases and algebraic thinking to determine whether curve fits of data on the relationship between force, mass, initial speed, and stopping time make sense compared to what is known about the real world. (DOK 3)
The students will: ➢ Use a graph of speed as a function of time to explain differences in braking force due to road conditions, and consider how we can design systems to prevent drivers from running yellow or red lights. (DOK 2) ➢ Use graphs and an algebraic function representing Newton's second law to predict, describe, and solve for the motion of a cart and the magnitude of the friction forces acting on the cart as variables are changed along a track. (DOK 2)
The students will: ➢ Analyze data collected from speed and force sensors and use multiple mathematical representations to describe and make claims about the patterns that show the relationship between different variables in a collision (force applied to a vehicle, mass, and change in velocity of a vehicle). (DOK 2) ➢ Apply techniques of algebra to solve for an unknown initial condition or outcome of a collision in a two-object system using a version of Newton's second law, arranged to describe conservation of momentum. (DOK 3)
The students will: ➢ Evaluate a series of explanations for what might be causing driving to get more dangerous over time, including the impact of new technology, by looking for correlations in new data, recognizing that this does not prove causality. (DOK 2) ➢ Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. (DOK 2)
The students will: ➢ Develop timeline models of vehicle collisions using animations and simulation data to illustrate and compare changes in motion for the systems of a vehicle and crash test dummies that are too fast to observe directly. (DOK 3)
The students will: ➢ Develop an explanation for why designs of vehicle safety features improve survivability and why survivability changes in collisions at different speeds with the same safety features, using the relationships of Newton's second law and evidence derived from graphs produced by a collision simulation. (DOK 3)

The students will: ➢ Design and evaluate a solution to reduce the peak force (function/effect) in a collision through the choice and modification of type of material and the structure (causes) used in building, testing, and comparing physical models of alternate front-end crumple-zones. (DOK 4) ➢ Analyze force and motion graphs of cart collisions with differing front-end crumple zone designs as well as driver survivability data in order to identify patterns in peak forces, time of impact, and design characteristics of the crumple zone (amount of deformation, thickness of material, and structure/length). (DOK 2)
The students will: ➢ Analyze patterns in graphical data from simulated collisions to make and support scientific claims about how the rigidity and the length characteristics of the crumple zone of a vehicle can be designed to optimize safety during a collision. (DOK 3)
The students will: ➢ Evaluate and compare competing arguments related to policy decisions to change speed limits within driving systems based on scientific knowledge and principles, prioritized criteria, unequal effects, limitations (e.g., trade-offs), constraints, and societal and ethical impacts. (DOK 4) ➢ Identify multiple simple criteria in the complex vehicle-driver system that combine to determine the vehicle safety in collisions and organize the scientific ideas that explain how these criteria can be used to design safer vehicle-driver systems. Then apply ideas about forces and changes in motion to explain how prioritizing certain criteria could create a safer design. (DOK 2)
The students will: ➢ Evaluate and compare competing arguments for a design solution based on scientific knowledge and principles, prioritized criteria, limitations (e.g., trade-offs), constraints, and societal and ethical impacts. (DOK 4)
The students will: ➢ Define a design problem within a vehicle-related system by analyzing how transportation technologies impact society to a level that requires attention or mitigation, considering the scale, proportion, and quantity at which the problem is significant. (DOK 2) ➢ Design and/or refine a solution to a problem related to vehicle safety, considering cause-effect relationships suggested or predicted by smaller-scale mechanisms within the system and prioritizing certain criteria over others to optimize the focus. (DOK 4) ➢ Use reasonable assumptions or approximations to develop a mathematical model to generate data to predict behavior of a design solution, analyze a system or support an explanation, and meet prioritized criteria. (DOK 3)
The students will:

➢ Apply scientific ideas, principles, and evidence that we developed over the course of the unit related to changes in the motion of macroscopic objects to answer questions on our DQB about how the safety features we had questions about may have been designed to mitigate risk. (DOK 4)

Correctives:

- This can also be done by projecting onto a whiteboard and using dry erase markers. If you use a whiteboard or something else temporary, be sure all students have a chance to copy the trends onto *Total Crashes Over Time (since 1996)*.

- If you use a monitor to share the slides instead of a projector, you can sketch the trends freehand on a sheet of chart paper affixed near the front of the room. Prepare the chart paper beforehand with graph axes to help students see how the two representations are related.

- If some students need additional time analyzing the data, use this as an opportunity to differentiate. *Data Jigsaw B: US Traffic Fatalities* and *Data Jigsaw D: Non-occupants Killed in Traffic Crashes* are very similar to the example done as a class and thus will be easier to scaffold by pointing to *Total Crashes Over Time (since 1996)*. *Data Jigsaw A: Vehicle Miles Traveled* and *Data Jigsaw F: Percent of Fatalities that Were Alcohol-Related* have new patterns, but they are fairly straightforward trends to identify. *Data Jigsaw C: Percent of Traffic Crashes with Fatalities and Injuries* and *Data Jigsaw E: Registered Vehicles* will be the most novel data sets for students.

- If you have an additional day, consider giving students the opportunity to do the distracted driver analysis on their own. Each student (or student pair) will need a computer, a fine tip dry erase marker, and a transparency sheet. They should use tape to attach the transparency sheet to the monitor, and mark and label each car position with the marker. They can then measure the distance between the marks and go through the calculations on their own to determine the scale on their screens so they can convert into meters. Average the class's results to create a consensus position-time graph at the front of the room.
    - Ask, *How could we test to see whether being distracted impacts our reaction time?* Have students use https://www.justpark.com/creative/reaction-time-test/ to test their reaction times normally and when another student is distracting them; they will notice that being distracted does make a difference. You can also give them something to unwrap, like a book wrapped in paper, to simulate someone who is trying to eat and drive.

- Another way to measure reaction time is the ruler drop test. One person holds a ruler by the end and another person watches it and gets ready to catch it, trying to catch it as quickly as possible after it is dropped. Where on the ruler the second person catches it is an accurate measure of time because the acceleration due to gravity is constant on Earth's surface.

- Come together as a class and graph the distracted driver on the same axes as for the undistracted driver. You can move the position-line that the class created for the distracted driver to the left of the vertical position-line for the undistracted driver. Use another color and/or pattern, and create a key to distinguish between the two lines.

- Give the class a moment to pre-think about these solutions if there is time. To do this, say, *We don't know if speed limits affect reaction time, but they definitely affect reaction distance. Can you think of any design solutions that could increase the amount of reaction time we have?*

- Solicit 2-3 ideas. Accept all ideas. You may see ideas about cell phones that sense when you are driving and turn off notifications, heads-up displays that help keep your eyes on the road, hands-free cell phone solutions, or automatic braking.

- If students feel comfortable reading and interpreting speed versus time graphs after Lesson 3, they may not require this much scaffolding. Feel free to move more quickly through **slide D** and the *Braking Variables Predictions*, or skip them, based on your students' needs.

- If students need extra support with data collection strategies, consider making time to read the *Data Analysis Reading* together or providing it as a resource.

- To extend students' sensemaking about braking and avoiding collisions, you can have students work with the collision avoidance restricted view version of the vehicle collision simulator (https://s3.amazonaws.com/p.3simulation/collisions/collision-avoidance.html). Consider having students try to recreate the scenarios they read about and adjust the parameters to test their design solutions.

- Some students may need more support in making the jump to thinking more abstractly about the motion and forces when using the smart cart. *Optional Collision Introduction* provides an additional activity that scaffolds students through semsaking about the data when the smart cart collides with a wall and stops as opposed to bouncing, which is more similar to the stopping they investigated in Lesson 4. The slides for this extra transitional activity are provided at the end of the slide deck on **slides C1-C4** and are used in place of **slide D**. This activity is meant to provide an alternative framing that is more concrete, more hands on, and clarifies the individual steps of the work in a coherent way.

- Depending on the comfort of your class's ability to read and compare graphs, another option is to first organize students into five "expert groups" to analyze the same data set together. Distribute the same data set to each member of an expert group, with each group receiving a different data set. Give students time to discuss what they see and come to some basic conclusions as an expert group before moving into the mixed data set groups to compare each handout's data. If expert groups are used, consider going from group to group using the questions on *Data Set Descriptions and Differentiation* to help students process their data set. You may use the same questions with the mixed data set groups.

- For students who need additional support, consider providing a timeline template with a list of the key events as a graphic organizer scaffold.

- This activity can be adjusted to differentiate. *Safety Optimization Investigation* asks students to optimize both variables independently. If students are struggling with navigating the simulation and optimization, you can have them optimize only one variable. Be sure that both variables are covered by the class as a whole. If students are very comfortable with the simulation and optimize the variables quickly, have them then combine the two and optimize while changing both seat belt stiffness and airbag rigidity. This can be added to the handout by copying the tables onto a blank piece of paper and attaching them to the rest of the handout.

- Some students may have found a scenario that had a very high or 100% likelihood of survival. If so, test those designs at the higher speed as a class. This will provide an opportunity to talk about how optimization for one condition might not be optimal for all conditions.

Extensions:

- If you wish to spend more time making sense of braking and reaction time and motion graphs, the collision avoidance restricted view of the vehicle collisions simulation (https://www.nhtsa.gov/sites/nhtsa.gov/files/nhtsa-ppt-schoolbus.pdf) can be used to let students investigate relationships by adjusting the distance, speed, reaction time, braking force, and road conditions. This view of the simulation only shows data for the vehicle in order to be appropriate for use at this point in the unit. The simulation creates graphs of distance from the barrier and vehicle velocity that can be connected to the graphs students have made and analyzed. Note that the term velocity is not introduced formally until Lesson 6.

- To extend the sensemaking about the changes in velocity over time, consider providing students with the velocity vs. time graphs for the vehicle and crash test dummies for each collision.

- These graphs can be made using the simulation https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html.
    - The settings for the collision with safety features are:
        - Distance From Barrier 10 m
        - Vehicle Speed 40 mph
        - Vehicle Mass 1500 kg
        - Driver Mass 77.5 kg
        - Crumple Zone Length 1 m
        - Crumple Zone Rigidity 450 kN
        - Seat Belt Stiffness 60 kN/m
        - Airbag Rigidity 15 kN
        - No braking
    - The settings for the collision without safety features are:

        - Distance From Barrier 10 m
        - Vehicle Speed 40 mph
        - Vehicle Mass 1500 kg
        - Driver Mass 77.5 kg
        - Crumple Zone Length 1 m
        - Crumple Zone Rigidity 450 kN
        - No Seat Belt
        - No Airbag

- In the second and third lesson sets of the unit, there are several extension opportunities for students who are interested in the content to explore further. You may want to have students hold on to their extra questions and ideas for exploration during the design project in Lesson 14 (see *Design Challenge Organizer Key* in Lesson 14 for more details). Be sure to encourage students to record their questions on the DQB. You may also want to provide individual or small group extension readings to students with specific interests before the project. *Extension Opportunities* provides some examples of extension questions students may have and resources from the project resource database that you could provide.

- Consider engaging students in a force diagram extension activity. See the *Two-Car Collision Forces* handout for the activity and the *Two-Car Collision Forces Key* for possible responses.

- If your students are comfortable with analyzing across multiple graphs at this point, consider having them create the graphs and test other rigidity conditions using the crumple zones restricted view of the Vehicle Collision Simulator (https://s3.amazonaws.com/p.3simulation/collisions/crumple-zones.html).

- Have students create the graphs and test out other length conditions using the crumple zones restricted view of the Vehicle Collision Simulator (https://s3.amazonaws.com/p.3simulation/collisions/crumple-zones.html) in order to form their claims on *Investigating Rigidity*. Note that the graph scales will not match, so students might need extra guidance interpreting the graphs or using CODAP (https://codap.concord.org/app/static/dg/en/cert/index.html) to match the scales.

Assessments:

Diagnostic	Formative	Summative
• Initial Models • Driving Question Board	• Exit Ticket • Branding Variables Prediction • Comparing Tree Speeds • Design Solution Comparison • Argumentation Tool	• Buss Collision Assessment • Survivability versus Length • Community Design Solution Project

Unit 2: Survey of Biological Systems, Ecology, and Evolution

How do organisms, cells, the environment, genetics, and heredity interact with each other on Earth? (Biology Keystone Review)

<u>Standards (by number):</u>	**<u>Essential Questions:</u>**
Science: 3.1.9-12.B Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. 3.1.9-12 E Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. 3.1.9-12.G Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy 3.1.9-12.J Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. 3.1.9-12.M Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. 3.1.9-12.O Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. 3.1.9-12.Q Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during	➔ How do macromolecules interact to form structures and functions of organisms including; cellular respirations, DNA replication, coding of proteins, cellular structure? ➔ How do individuals, populations, communities and ecosystems interact with each other in Earth's biosphere? ➔ How do traits, DNA, and evolution relate to each other? ➔ How does nature naturally progress towards climax ecosystems?

replication, and/or (3) mutations caused by environmental factors. 3.1.9-12.W Construct an explanation based on evidence for how natural selection leads to adaptation of populations. 3.1.9-12.X Evaluate the evidence supporting claims that changes in environmental conditions may result in (1)increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.	
Technology and Engineering: 3.5.9-12.V Apply principles of human-centered design. 3.5.9-12.P Apply a broad range of design skills to a design thinking process.	➔ How has heredity led to the current traits of organisms?
Environmental Literacy and Sustainability: 3.4.9-12.D Apply research and analytical skills to systematically investigate environmental issues ranging from local issues to those that are regional or global in scope.	➔ How do biological principles inform our local, regional and national actions and laws?

Students will be able to… (SEP)	Students will know…. (DCI)	Students will apply…(CCC)
Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. Use mathematical and/or computational representations of phenomena or design solutions to support explanations. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions	Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.	*Systems and System Models* Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. *Energy and Matter* Changes of energy and matter in a system can be described in terms of energy and matter flows

to determine the merits of arguments. Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. 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 trade-off considerations. Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.	As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. A complex set of interactions within an ecosystem can keep	into, out of, and within that system. Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. *Scale Proportion and Quantity* The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. *Stability and Change* Much of science deals with constructing explanations of how things change and how they remain stable. *Cause and Effect* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. *Scientific Knowledge Assumes an Order and Consistency in Natural Systems* Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. *Cause and Effect* Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. *Creativity* Elaborates and articulates novel ideas and aesthetics.

	its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the	*Attention to Ethics* Assess technological products, systems, and processes through critical analysis of their impacts and outcomes. *Making and Doing* Demonstrates the ability to regulate and improve making and doing skills.

	expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. 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. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution,	

	introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	

Core Activities/Corresponding Instructional Methods/DOK Levels **20 Days**
The students will: ➢ Read and discuss Quick Facts - Cells and Cellular Organization. (DOK 1) ➢ Complete Quizlet Flashcards on Basic Biological Principles. (DOK 1) ➢ Complete and discuss Basic Biological Principles Practice. (DOK 1)
The students will: ➢ Read and discuss Quick Facts - Biochemistry. (DOK 1) ➢ Identify and define key images and terms of biochemical organization. (DOK 1) ➢ Complete and discuss Chemistry of Life worksheets. (DOK 1)

The students will: ➢ Read and discuss Quick Facts - Biometrics. (DOK 1) ➢ Identify and define key images and terms of Biometrics. (DOK 1) ➢ Complete and discuss Bioenergetics worksheets. (DOK 1) ➢ Complete and discuss Bioenergetics Boot Camp. (DOK 1)
The students will: ➢ Identify and define key images and terms of homeostasis and cell transport. (DOK 1) ➢ Read and discuss Quiz Facts - Cell Transport. (DOK 1) ➢ Read and discuss Homeostasis and Transport worksheets. (DOK 1)
The students will: ➢ Identify and define key images and terms of genetics. (DOK 1) ➢ Read and discuss Quick Facts - Genetics. (DOK 1) ➢ Read and discuss Genetics worksheets. (DOK 1)
The students will: ➢ Identify and define key images and terms of theory of evolution (DOK 1) ➢ Read and discuss Quick Facts - Evolution. (DOK 1) ➢ Read and discuss Evolution worksheets. (DOK 1)
The students will: ➢ Identify and define key images and terms of ecology. (DOK 1) ➢ Read and discuss Quick Facts - Ecology. (DOK 1) ➢ Read and discuss Ecology worksheets. (DOK 1)
The students will: ➢ Identify and define key images and terms of cell growth and reproduction. (DOK 1) ➢ Read and Discuss Quick Facts - Cell Division (DOK 1) ➢ Read and Discuss Cell Growth and Reproduction worksheets (DOK 1)

Correctives:
- Khan Academy Bioenergetics
- Khan Academy Homeostasis and Transport
- Khan Academy Cell Growth and Reproduction

Extensions:
- PhET Natural Selection Lab
- PhET Gene Expression Essentials
- PhET Molecule Polarity
- PhET Neuron
- PhET pH Scale

Assessments:

Diagnostic	Formative	Summative
• Keystone Scores	• Basic Biological Principles Practice Quiz • Bioenergetics Practice Quiz • Homeostasis and Transport Practice Quiz • Cell Growth and Reproduction Practice Quiz • Theory of Evolution Practice Quiz • Ecology Practice Quiz	• Basic Biological Principles Quiz • Bioenergetics Quiz • Homeostasis and Transport Quiz • Cell Growth and Reproduction Quiz • Theory of Evolution Quiz • Ecology Quiz

Unit 3: Energy Flow from Earth's Systems

How can we design more reliable systems to meet our communities' energy needs?

Standards (by number):	**Essential Questions:**
Science: 3.1.9-12.H Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.. 3.1.9-12.O Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce. 3.1.9-12.Q Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	➔ How can solar cells, wind turbines, solar ovens, generators, nuclear power, and fossil fuels be used to sustainably support the energy needs of society? ➔ What can we learn from a blackout in Texas about producing reliable energy for our communities? ➔ What structures in the system enable energy transfer from one source to multiple devices, buildings, and neighborhoods? ➔ Could the blackouts in Texas have been caused by a broken or short-circuited circuit? ➔ Where does electrical energy come from? ➔ How does energy transfer in wires?
Technology and Engineering: 3.5.9-12.C Develop a solution to a technological problem that has the least negative environmental and social impact. 3.5.9-12.E Evaluate how technology and engineering advancements alter human health and capabilities. 3.5.9-12.F Evaluate a technological innovation that arose from a specific society's unique need or want. 3.5.9-12.H Evaluate ways that technology and engineering can impact individuals, society, and the environment. 3.5.9-12.I (ETS) Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of	➔ Why do design solutions affect some people differently than others? ➔ What could have caused the disparities we saw in the blackouts in Texas? ➔ How can energy storage make our systems more reliable during an energy crisis?

constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	
Environmental Literacy and Sustainability: 3.4.9-12.I Analyze and interpret data on a regional environmental condition and its implications on environmental justice and social equity.	➔ What makes an energy source reliable? ➔ What decisions do we need to make to design more reliable systems to meet our community's energy needs?

Students will be able to… (SEP)	Students will know…. (DCI)	Students will apply…(CCC)
Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. The following element of this practice is intentionally developed across this unit: 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	Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within the 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. These relationships are better understood at the microscopic scale, at which all 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. Conservation of Energy and Energy Transfer The availability	*Stability and Change* For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. Much of science deals with constructing explanations of how things change and how they remain stable. Systems can be designed for greater or lesser stability. Elements from the following crosscutting concepts are also key to the sensemaking in this unit: Patterns Structure and Function Cause and Effect

trade-off considerations.	of energy limits what can occur in any system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. 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. Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	

Core Activities/Corresponding Instructional Methods/DOK Levels **32 Days**
The students will: ➢ Develop a model of energy transfer through systems to explain how energy manifests as electricity in our communities, including how changes to an otherwise stable system could cause blackouts. (DOK 3) ➢ Ask questions to clarify and define the problem of how our community can generate energy by designing systems to address both local and global challenges. (DOK 2)
The students will: ➢ Collect data from a designed system (a power strip) and a network of interconnected subsystems (multiple powerstrips) on the interactions needed for and failure points in the transfer of electrical energy. (DOK 4) ➢ Develop, revise, and use a model to identify analogous structures that affect the electrical energy transfers across and between different (sub)systems at different scales (a powerstrip versus a building). (DOK 4)
The students will: ➢ Develop and use a model based on evidence from our investigation in Lesson 2 to illustrate the energy flow between components of the electric grid system and energy loss from the system as a possible cause of the crisis in Texas. (DOK 3)

The students will: ➢ Analyze multiple types of data to identify characteristics of energy sources derived from Earth's systems that increase the reliability of the energy grid (a criterion for success), given that for the system to remain stable, it must be designed for energy supply to meet energy demand. (DOK 2)
The students will: ➢ Develop a model based on evidence to illustrate the energy and matter changes in a generator, including energy transfer through contact between moving parts and energy transfer at a distance through fields. (DOK 3) ➢ Design and build a generator system to transfer motion energy to light that meets agreed-upon criteria, manipulating variables and collecting data to identify failure points and improve performance. (DOK 4)
The students will: ➢ Integrate information from a reading alongside student-generated models and a computer simulation to examine smaller-scale mechanisms within the system and develop cause-effect relationships about motions of particles or energy stored in fields. (DOK 2) ➢ Use a simulation to model electron flow inside a wire in order to identify patterns, answer questions, and determine relationships between independent and dependent variables involving electrical energy transfer that can be interpreted to reengineer and improve the electric grid. (DOK 2)
The students will: ➢ Develop a model showing how insufficient supply entering the system could lead to reduced energy transfer into certain communities in Texas when the temperatures dropped, resulting in buildings losing power. (DOK 3) ➢ Develop and test a correlational hypothesis to investigate trade-offs inherent in making decisions about energy, and then consider limitations on this analysis to motivate seeking information about patterns at a smaller grain size. (DOK 4)
The students will: ➢ Integrate quantitative information, visual information, and audio (or text) to define some of the challenges and trade-offs associated with a drop in energy supply driven by cold weather, and consider additional trade-offs associated with making energy decisions. (DOK 4)
The students will: ➢ Develop an energy transfer model to predict the stability in the distribution of electric energy when batteries are present and absent from the system. (DOK 3) ➢ Apply ratios, rates, percentages, and unit conversions to calculate the costs and land area of use of a design solution to evaluate its feasibility for preventing an energy crisis like the one in Texas in 2021. (DOK 3)

The students will: ➢ Define the problem, and then interview various interested parties in our community to identify criteria that can help make decisions to improve the electricity infrastructure, including how it is designed for reliability (stability) and its social, cultural, and environmental impacts. (DOK 4) ➢ Analyze data generated by interviews with community members to specify criteria for success related to energy solutions, such as monetary cost, safety, and reliability, and weigh cost/benefit trade-offs related to social, cultural, and environmental impacts. (DOK 3)
The students will: ➢ Define a problem related to the challenge of improving our electrical grid, and then design, evaluate, and refine a solution, taking into account social, cultural, and environmental impacts (both intentional and unintentional), based on results from a computational model, scientific knowledge we have figured out over the unit, weighted criteria, and trade-off considerations. (DOK 4) ➢ Ask questions to identify and refine criteria for success for our design solutions, including reliability (stability) and social, cultural, and environmental impacts. (DOK 2)

Correctives:

- Chapter 6 notes, activities, worksheets, labs and study guides.

- For students who need additional support with reading comprehension, the skill of *summarizing* can be difficult because they have to separate details from main ideas and parse information into the most essential points. These students may benefit from developing a summary based on the following prompts: *What happened with the weather during the storm? What happened to the electricity? How were people impacted?*

- PHET Circuit Lab

- Have students build and decorate their own cardboard boxes, bringing some of their creative-crafting skills into the science classroom. The default suggestion is to prepare boxes ahead of time using *Preparing Cardboard Buildings* and distribute them to the student groups.

- Have students choose what building their boxes represent (a hospital, a store, a school, a detached house, an apartment complex) and label them. Students can add paper tents on top of the buildings they create or decorate the cardboard directly

- Play the podcast in your classroom and pause at intervals for a whole-group discussion of each set of embedded prompts. This may save time, particularly if the logistics of listening together are difficult.

Extensions

- This step in the lesson sequence is another opportunity for creative input from students outside of what is described here. They may want to make a sign, or spend more time decorating and labeling their buildings or the city itself. If students feel invested in their city, this setup can be used again in Lesson 3 and Lesson 7.

- The goal of this task is threefold: (1) to clarify that a short or broken circuit is not the only possible explanation for what happened in Texas, (2) to practice our new energy transfer modeling conventions, and (3) to encourage students to begin quantifying energy transfer in the system to answer their questions and understand the impact of energy loss. If the class comes up with alternative scenarios, they can model them in their notebook alongside, or instead of, Scenarios A-D. Scenario E also provides space for one alternative

- Show your class an example of the live forecast for your own community during the class. Access https://www.eia.gov/electricity/gridmonitor/dashboard/custom/pending and display it on-screen so everyone can see it. Search your region on the map. Doing this will help students see that the energy demand forecast goes into the future. Use https://www.youtube.com/watch?v=ocu9UKskKaM for guidance on how to find the electricity demand in a particular region.

- Have students gather around the Community Agreements poster and use sticky dots or check marks to indicate which agreements they think we should prioritize.

- Use the video https://youtu.be/ZMO0uWmszic to do these demonstrations if you are tight on time and/or space, but we highly recommend that you give students a chance to see the effect in Electric City in the classroom. If you do use the video, try playing it without sound and pausing it to ask students questions about what is happening. The narration of the video gives away much of the thinking that they should be doing themselves.

Assessments:

Diagnostic	Formative	Summative
• Initial Models • Driving Question Board	• Exit Ticket • Wire /simulation Investigation • Modeling Reliability • Testing Battery Storage Solutions • Exit Ticket • Progress Tracker • Self Assessment Discussion Rubric	• Motors Transfer Task • Design Challenge

Unit 4: Thermodynamics in Earth's Systems

How can we slow the flow of energy on Earth to protect vulnerable coastal communities?

Standards (by number):	**Essential Questions:**
Science: 3.2.9-12.B 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. 3.2.9-12.C 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. 3.2.9-12.E Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. 3.2.9-12.O 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 3.2.9-12.P Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). 3.2.9-12.Q	➔ What can the past help us figure out about what is causing sea level rise in the present? ➔ How does carbon dioxide contribute to climate change? ➔ What would happen if the Earth's ice melted? ➔ Why does warm salty water sink to melt a glacier? ➔ How does heat affect the amount of ice melt? ➔ How can we model what will happen to Earth's climate if humans make changes? ➔ How can we model what will happen to Earth's climate if humans make changes?

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. 3.2.9-12.R Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	
Technology and Engineering: 3.5.9-12.D Critique whether existing or proposed technologies use resources sustainably. 3.5.9-12.G Evaluate a technological innovation that was met with societal resistance impacting its development. 3.5.9-12.I (ETS) Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. 3.5.9-12.K (ETS) Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	➔ Why would some engineers want to sprinkle glass microbeads on the Arctic? ➔ How do feedback loops affect Earth's systems? ➔ How can we measure the energy transfer a berm prevents?
Environmental Literacy and Sustainability: 3.4.9-12.A	➔ How are sea levels rising and forcing people to move? ➔ What would happen if the Earth's ice melted?

Analyze and interpret how issues, trends, technologies, and policies impact agricultural, food, and environmental systems and resources. 3.4.9-12.C Analyze and interpret how issues, trends, technologies, and policies impact watersheds and water resources. 3.4.9-12.D Apply research and analytical skills to systematically investigate environmental issues ranging from local issues to those that are regional or global in scope. 3.4.9-12.E Plan and conduct an investigation utilizing environmental data about a local environmental issue. 3.4.9-12.H Design and evaluate solutions in which individuals and societies can promote stewardship in environmental quality and community well-being.	➔ How can we slow the flow of energy on Earth to protect vulnerable coastal communities?

Students will be able to… (SEP)	Students will know…. (DCI)	Students will apply…(CCC)
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. Construct and revise an explanation based on valid and	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. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. The fact that atoms are conserved, together with knowledge of the chemical	*Patterns* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Science assumes the universe is a vast single system in which basic laws are consistent. 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

reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Create a computational model or simulation of a phenomenon, designed device, process, or system. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. 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 trade-off considerations. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.	properties of the elements involved, can be used to describe and predict chemical reactions. Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. 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. Energy is a quantitative property of a system that	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. Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits. *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. *Attention to Ethics* Assesses technological products, systems, and processes through critical analysis of their impacts and outcomes. *Critical Thinking* Uses evidence to better understand and solve problems in technology and engineering, including applying computational thinking.

Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.	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. These relationships are better understood at the 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. 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. Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.	

	At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. 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). Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. The sustainability of human	

	societies and the biodiversity that supports them requires responsible management of natural resources. Resource availability has guided the development of human society. A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	

Core Activities/Corresponding Instructional Methods/DOK Levels 30 Days
Students will: ➢ Reason and draw conclusions from a variety of resources about causes of sea levels rising and if this trend will continue. (DOK 3) ➢ Identify benefits and drawbacks of infrastructure communities have designed and implemented to protect themselves. (DOK 3) ➢ Students will identify energy and matter in the context of rising sea levels. (DOK 1)
Students will: ➢ Describe how during the last million years, global temperatures seem to increase around the same time that ice volumes decrease and sea levels increase. (DOK 1)

- Understand how scientists have to use indirect sources of evidence to figure out what Earth's climate was like in the past. (DOK 1)
- Evaluate cause and effect relationships between changes in sunlight due to Earth's orbit and tilt can affect climate. (DOK 3)
- Evaluate cause and effect relationships between changes in sunlight due to solar activity can affect climate. (DOK 3)
- Describe how Volcanic activity can affect climate. (DOK 1)
- Describe how changes in carbon dioxide due to plant growth or human activity can affect climate and can help explain current temperature increases. (DOK 1)
- Compare and describe how climate is impacted when something changes energy flows into or out of Earth systems. (DOK 3)

Students will:

- Outline the variable and test and investigation to identify the directional relationship between the amount of carbon dioxide and temperature change in a defined model atmospheric system. (DOK 4)
- Develop a model based on evidence to predict how energy flows between the Sun, the atmosphere, and the cryosphere and how its absorption impacts climate. (DOK 3)
- Ask questions about the unexpected result that conservation of energy and matter lead to models that predict that global temperatures will continue to rise on average even if carbon dioxide emissions stop. (DOK 2)

Students will:

- Apply ratios and unit conversions at different scales to make predictions about the impact of human-caused ice melt on sea levels and human populations .(DOK 2, 3)
- Plan and carry out an investigation to revise a model to reflect that sea ice is in the ocean system (hydrosphere) and therefore does not change sea level, though losing it might have other negative effects. (DOK 3)

Students will:

- Ask questions to refine a model of the energy transfer into, out of, and within the system if proposed solutions prevent glacier ice melt in Disko Bay. (DOK 3)
- Use energy transfer consensus models to ask questions that challenge the suitability of the design solutions based on their current and future impacts. (DOK 4)

Students will:

- Plan and conduct a safe investigation with controlled variables and well-defined system boundaries to figure out how the reflection, absorption, storage, and reradiation of energy from the Sun affect climate. (DOK 4)
- Use mathematical representations to support a claim about whether the changes in energy flows and disrupted feedback loops caused by microbeads make them a viable solution to help prevent polar ice melt. (DOK 3)

Students will: ➢ Ask questions to clarify the role of positive and negative feedback loops involving the co-evolution of plants and other organisms with other Earth systems. (DOK 1)
Students will: ➢ Ask questions about the changing ice, waters, and lands of the circumpolar region that could be investigated in the field (using Indigenous Inuit and/or NASA methodologies) to frame a hypothesis about changes in energy and matter where glacial ice meets the ocean water at Ilulissat. (DOK 2) ➢ Read and listen to scientific and technical information from two authoritative sources--Inuit Indigenous Knowledge and research from the NASA OMG Project--and consider the usefulness of describing and analyzing the boundaries, initial conditions, inputs, and outputs of the Arctic system from these different perspectives. (DOK 1)
Students will ➢ Evaluate a question about the energy circulation in the ocean to see if it is testable and select appropriate tools to collect and record data in an investigation, considering predicted energy flows within the ocean system. (DOK 2) ➢ Apply function fits to data, consider limitations of data analysis, and consider model reliability to identify density as altering expected patterns of energy circulation in the ocean. (DOK 2)
Students will ➢ Plan and conduct investigations of energy transfer between objects in order to quantify conserved energy. (DOK 4) ➢ Use simple limit cases to test a simulation of a closed system in which energy and matter are conserved that shows how an uncontrolled system with two different-temperature objects eventually reaches uniform energy distribution. (DOK 2) ➢ Apply techniques of algebra and functions to quantify, describe, and mathematically model the energy flows that result in measurable temperature changes in order to quantify conserved energy. (DOK 3)
Students will ➢ Ask questions based on an existing model around how energy causes matter cycling in a system with conserved and transferred energy. (DOK 2) ➢ Make a directional hypothesis about how much energy transfer must be prevented as part of a system design. (DOK 3)

Students will ➢ Use multiple types of models of changes in energy and matter flows in order to predict the impact of a berm. (DOK 3) ➢ Support a claim with mathematical models, including unit conversions involving quantified changes in sea level, using energy conservation as a tool. (DOK 3) ➢ Create a checklist for a computational model that can predict how a defined system is influenced by resource availability and use by humans. (DOK 3)
Students will ➢ Ask questions to determine relationships in a predictive but limited model considering that new discoveries are always being made and that climate models suggest average global temperatures will continue to rise. (DOK 2) ➢ Use a computational model to support claims about the impacts of energy and matter flows amid complexity. (DOK 3) ➢ Plan an investigation to identify a problem with energy transfer in the geothermal heating system. (DOK 3)

Correctives:

- For students who benefit from additional reading support, you can prompt them to highlight specific parts of the text in different colors, e.g., highlight the "*who*" in yellow, the "*why*" in blue, and the "*where*" in orange. This will provide a focus for reading and clarify similarities and differences between the terms. *Who* = refugee, migrant, climate migrant; *Why* = fear of persecution for various reasons, any reason, displaced by the effects of climate change; *Where* = outside of their own country or residence.

- Chalk Talk can also be done virtually using a platform such as Jamboard. A physical method is preferred because (1) grouping students tightly around a poster encourages them to engage in conversation around the data, and (2) using physical materials pushes students to focus deeply on one of the items at a time. However, a digital Chalk Talk can have a lower barrier to participation for some students because it allows them to share their thoughts without turn-taking.

- You may also have students use 3 16.9 oz. plastic water bottles at their station each representing one of the conditions they are testing. This will require students to coordinate who will seal each of the bottles to ensure accurate results.

- For students who benefit from additional reading comprehension support, the Coherent Reading Protocol is well-suited for *Atmospheric Carbon Dioxide*. The Coherent Reading Protocol guides students to monitor their understanding after each chunk of text, identify the main idea, and connect the information in the reading to the lesson question. The

Coherent Reading Protocol can be found in the *OpenSciEd Teacher Handbook: High School Scie*nce.

- Share the simulation https://sealevel.nasa.gov/vesl/web/sea-level/slr-eustatic/ with students so they can explore the simulation individually before discussing it as a class.
- Invite students to do their own search for a simulation or scientific papers that could help them both check their calculations against other scientists' work and get a better understanding of what the potential impacts will be if Greenland's ice sheet melts. Ask students to share the resources they found, offering https://sealevel.nasa.gov/vesl/web/sea-level/slr-eustatic/ as an option if students do not.

Extensions:

- Ask students to reflect back on why people, including their own ancestors, have migrated in the past. How were these experiences similar to or different from those of climate migrants? How might climate migration cause there to be different patterns of where people live than we see today?

- Assign students to read https://ensia.com/features/climate-change-nonnative-invasive-species/ as home learning and begin the next class with a discussion of whether people should label non-human animals and other organisms that have moved or spread because of climate change as "invasive."

- Give students 15-20 minutes to analyze geological and historical data from your own region. Then discuss these prompts:
    - How has our area changed over time?
    - What effects would that have on the living and nonliving world?
    - How would our community be different if we were living under the different conditions we saw in the past?

- Because of common ideas about ozone influencing climate change, students may now wonder what ozone *does* do in the atmosphere and if it is a problem. You may wish to have students research these questions, as the 1987 Montreal Protocol, phasing out of chlorofluorocarbons (CFCs), and subsequent healing of the ozone layer represent an excellent example of people successfully working together to address an environmental issue originally caused by humans.

- As home learning, assign students to do value mapping (https://rpp.wtgrantfoundation.org/wp-content/uploads/2019/09/Value-Mapping_Nov2015.pdf) and reflect on what they would value in a solution to slow or prevent polar ice melt and sea level rise. This will provide ideas of what they are looking for in the microbeads solution in Lessons 6-7 and the berm solution in Lesson 9-12.

Assessments:

Diagnostic	Formative	Summative
● Initial Models ● Driving Question Board	● Exit Ticket ● Data Analysis ● Progress Tracker ● Carbon Dioxide Investigation ● Driving Question Board ● Sea Level Calculations ● Exit Ticket ● Discussion Mapping Tool ● Revising Prior Models ● Revisiting Questions ● Discussion Mapping/Assessment Template ● Investigation Question Development	● Thawing Permafrost Transfer Task ● Berm Model and Class Consensus Model ● Calculating Berm Impact ● Heat Pumps Transfer Task

Unit 5: Molecular Processes in Earth Systems
How can we find, make, and recycle the substances we need to live on and beyond Earth?

Standards (by number):	**Essential Questions:**
Science: 3.2.9-12.A 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. 3.2.9-12.B 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. 3.2.9-12.E	➔ How does water support life and chemical reactions? ➔ How can we find evidence of the water we need on the surfaces of other objects in space? ➔ How and why do water and other liquids interact with materials to make surface features? ➔ What patterns are there between the types of atoms and the number of bonds they form in the resources we need? ➔ Why is there a difference between the number of electrons an element has and the number of bonds an element forms?

Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. 3.2.9-12.F Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. 3.2.9-12.G Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. 3.2.9-12.N Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. 3.2.9-12.X Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.	➔ Why do we need water in so many reactions? ➔ How can we grow food in space? ➔ Which location(s) in the solar system has the elements we need and what relative amount is required to make any substance?
Technology and Engineering: 3.5.9-12.B Critically assess and evaluate a technology that minimizes resource use and resulting waste to achieve a goal. 3.5.9-12.C Develop a solution to a technological problem that has the least negative environmental and social impact. 3.5.9-12.D Critique whether existing or proposed technologies use resources sustainably. 3.5.9-12.F	➔ What substances would we need and how would we get them to live and work beyond Earth? ➔ Could another substance serve as a substitute for water for some of the processes we need to use it for in space? ➔ How can the ideas we developed be applied to making a possible substitute for another substance? ➔ How can we grow food in space? ➔ Which location(s) in the solar system has the elements we need and what relative amount is required to make any substance? ➔ Why can we recycle some of the substances we need and not others? ➔ What is the full impact of going to space?

Evaluate a technological innovation that arose from a specific society's unique need or want. 3.5.9-12.J Synthesize data and analyze trends to make decisions about technological products, systems, or processes. 3.5.9-12.N Analyze and use relevant and appropriate design thinking processes to solve technological and engineering problems. 3.5.9-12.Q Implement and critique principles, elements, and factors of design. 3.5.9-12.S Conduct research to inform intentional inventions and innovations that address specific needs and wants.	
Environmental Literacy and Sustainability: 3.4.9-12.B Apply research and analytical skills to evaluate the conditions and motivations that lead to conflict, cooperation, and change among individuals, groups, and nations. 3.4.9-12.G Analyze and evaluate how best resource management practices and environmental laws achieve sustainability of natural resources. 3.4.9-12.I Analyze and interpret data on a regional environmental condition and its implications on environmental justice and social equity.	➔ What substances would we need and how would we get them to live and work beyond Earth? ➔ How and why do water and other liquids interact with materials to make surface features? ➔ How can we tell what is in the atmosphere (and just below the surface) of objects in space? ➔ What are some more sustainable approaches we are developing to help us make the things we need off of Earth and on it? ➔ What is the full impact of going to space?

Students will be able to… (SEP)	Students will know… (DCI)	Students will apply…(CCC)
Use a model to predict the relationships between systems or	Each atom has a charged substructure consisting of a	*Patterns* Different patterns may be

between components of a system. 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. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. Use mathematical representations of phenomena to support claims. Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). Communicate technical information or ideas (e.g., about phenomena and/or the process of development and the design and performance of a proposed	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. Types of Interactions Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. 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. Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are	observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. *Stability and Change* Much of science deals with constructing explanations of how things change and how they remain stable. *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. *Energy and Matter* The total amount of energy and matter in closed systems is conserved. *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. *Interdependence of Science, Engineering, and Technology* Science and engineering complement each other in the cycle known as research and development (R&D). *Influence of Engineering, Technology, and Science on Society and the Natural World* Modern civilization depends on

process or system) in multiple formats (including orally, graphically, textually, and mathematically). Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Apply techniques of algebra and functions to represent and solve scientific and engineering problems. Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into	matched by changes in kinetic energy. In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. 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. Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. Photoelectric materials emit electrons when they absorb light of a high-enough frequency. Multiple technologies based on the understanding of waves and their interactions with matter	major technological systems. *Cause and Effect* Systems can be designed to cause a desired effect. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. *Critical Thinking* Uses evidence to better understand and solve problems in technology and engineering, including applying computational thinking. *Attention to Ethics* Assesses technological products, systems, and processes through critical analysis of their impacts and outcomes. *Optimism* Shows persistence in addressing technological problems and finding solutions to those problems. *Science Addresses Questions About the Natural and Material World* Not all questions can be answered by science. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.

account possible unanticipated effects. 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 trade-off considerations. Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).	are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. The decision to develop a new technology is influenced by societal opinions and demands. These driving forces differ from culture to culture. When evaluating solutions, it is important to consider a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	Many decisions are not made using science alone, but rely on social and cultural influences *Stability and Change* Feedback (negative or positive) can stabilize or destabilize a system.

	Meet a sophisticated design challenge by identifying criteria and constraints, predicting how these will affect the solution, researching and generating ideas, and using trade-offs to balance competing values in selecting the best solution. 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. A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. Resource availability has guided the development of human society. The sustainability of human	

	societies and the biodiversity that supports them requires responsible management of natural resources.	

Core Activities/Corresponding Instructional Methods/DOK Levels **30 Days**
The students will ➢ Define some of the criteria for living and working in places beyond Earth for longer periods of time and the constraints for taking all of the substances/materials we would need, and identify possible solutions for obtaining these substances/materials. (DOK 1) ➢ Develop and use a model to represent atom-level compositions of products and reactants and the changes and interactions that occur between the atoms in a chemical reaction that help explain why specific products form and not others. (DOK 3) ➢ Ask questions that arise from careful observation of images (at different scales) of solar system objects and particle-level models for different chemical process/reactions and/or ask question to clarify/seek additional information and relationships about ways to find, recycle, and/or make enough of the substances we need to live and work beyond Earth and on it. (DOK 2)
The students will ➢ Compare, integrate, and communicate information presented in different media or formats to identify patterns in water's ability to: absorb, store, and release large amounts of energy through its specific heat; transmit sunlight; and dissolve and transport materials. (DOK 2, 4)
The students will ➢ 3.A Make and defend a claim about the geologic processes that were most likely responsible for the formation of different surface features on Earth and other solar objects, using evidence from satellite images at different scales. (DOK 3)
The students will ➢ Design and conduct an investigation to determine the patterns to use as causal evidence to explain the interaction of water with Earth's surface compared to substances with similar properties. (DOK 3) ➢ Observe patterns at multiple scales to support movement between multiple types of models that use molecular and submolecular structures that explain the properties of matter like water. (DOK 2) ➢ Compare, integrate, and evaluate information from a reading, models, and an investigation to explain how water's polarity results in its unique bulk properties. (DOK 4)

The students will

- ➢ Analyze, compare, and integrate empirical evidence to identify patterns in the interaction (study) of a star's light or other light spectrum with substances present in a sample or on an object in space to answer scientific questions about how we can identify which locations have the substances or elements needed to live and work in space. (DOK 3)

The students will

- ➢ Use patterns from empirical evidence to develop, revise, and evaluate merits and limitations of models of an element tool using subatomic particles and properties. (DOK 2)

The students will

- ➢ Develop, compare, and move between various models of atomic structures to explain and account for differences in the numbers of electrons and bonds formed by different atoms. (DOK 3)
- ➢ Determine which atomic model best illustrates patterns in atomic structures at the atomic scale, which can be used to predict interactions between elements. (DOK 2)

The students will

- ➢ Use the periodic table to identify atoms with similar bonding patterns and to explain how differences in atomic structure could contribute to differences in electronegativity. (DOK 1)
- ➢ Explain bond stability, differences in three properties, and differences in molecular polarity of two molecules based on the relative strength of forces between atoms and molecules. (DOK 2)

The students will

- ➢ Use a variety of models and evidence (such as solubility and periodic trends in electronegativity and atomic radius) to
  - ○ describe the patterns and relationships between the parts of an atom and the bonds formed between atoms, (DOK 1)
  - ○ predict polarity differences, and (DOK 2)
  - ○ explain property differences based on the relative differences in the strength of forces between atoms and molecules. (DOK 2)

The students will

- ➢ Critically read scientific literature to identify the structures of different components and explain the transformations of matter with forces in a water-cleaning reaction. (DOK 1)

The students will

- ➢ Critically read and determine central ideas of a text to develop a model that explains how using different reactants leads to the development of different fertilizers which can be used to grow plants off of Earth. (DOK 1, 2)
- ➢ Develop and revise a model based on evidence to show the relationship between reactant and product components and that atoms are conserved in a chemical reaction system. (DOK 3)

The students will

- ➢ Create balanced chemical equations (computational models) using mathematical representations of elements to demonstrate that matter is conserved. (DOK 2)
- ➢ Gather, read, and interpret information presented in different formats and adapted from scientific literature to predict which object in space (system) would contain the quantities (large scale) of elements and compounds (atomic scale) needed to create the resources for survival. (DOK 2)

The students will

- ➢ Compare and integrate information about the molecular structure, substructures, and bonding patterns of various materials from a text, experimental videos, and a series of molecular models to answer two scientific questions:
    - recyclability as a function of matter's interactions at the bulk scale, including atomic forces, (DOK 3)
    - how this informs new engineering solutions for living and working beyond and/or on Earth in the future. (DOK 3)

The students will

- ➢ Synthesize multiple methods to compare arguments for the sustainable properties of materials based on the forces that determine bulk-scale interactions. (DOK 4)

The students will

- ➢ Evaluate competing arguments about human survival in space in light of matter conservation and the chemical structures of molecules and atoms, trade-offs, and ethics. (DOK 3)
- ➢ Create balanced and accurate chemical equations (computational models) uniting mathematical and molecular representations of covalently-bonded molecules to ensure matter is conserved. (DOK 2)

Correctives:

- Chapter 16 handouts and worksheets.
- Bonding baseball cards.
- To ensure that students can observe each other's results as they appear after applying the liquids, have students take pictures of their setups and upload them to a designated document, slide deck, or place in your learning management system.
- For this Navigation activity, you could also go back to the DQB and ask students which questions are about bonds or can be answered by figuring out more about bonds. Suggest that we figure out those questions next.
- If students struggle to recall the subatomic particles referred to or images used in slide B, then students can always return to the original simulation (https://lab.concord.org/embeddable.html#interactives/interactions/atom-builder.json) to review and discuss.
- Electronegativity and atomic radius are terms that students have now earned. Having students add a personal meaning/definition for each term to their periodic table will

probably make for a more useful reference than having students add them to their Personal Glossary. But you can give students that option if they prefer it.

- Students could also model ammonia and ammonium using molecular model kits. Have some available to support students who may benefit from using a different representation of the atoms involved while developing their models.
- Distribute the optional, *Transcript: Testing Plastics* if you want to provide a transcript for students as they watch https://youtu.be/pttxNzV_2U4.

Extensions:

- If students show interest in comparing the properties of water to the properties of other materials they have studied in *Electrostatics Unit*, take time to co-create a parallel poster. For example, you could discuss properties of metals, such as conductivity, and their importance for life. Additionally, you could present students with specific heat values of metals and have students use their understanding of specific heat to explain what happens to those metals as energy is applied to them. Take care not to develop a cause-effect relationship between conductivity and specific heat values, as the basis of these two material properties is different.
- If students quickly figure out how to model frost heaving and have extra time, encourage them to also try to model how water creates meanders and oxbow lakes.
- An additional handout, *Thinking About Aquaculture*, is included to help students consider other potential food sources by leveraging water's ability to transmit light. Since it mentions the existence of water oceans on some moons in our solar system, this handout may be placed after Lesson 4 or with Lesson 11.
- If students quickly figure out how to model frost heaving and have extra time, encourage them to also try to model how water creates meanders and oxbow lakes.
- Show students any common precipitation reaction, such as that of copper sulfate and calcium hydroxide. If you do so, ensure that you follow all safety guidelines. If students are not directly handling the materials, they do not need gloves or chemical aprons if they have indirectly vented chemical splash goggles and are seated 15 feet away from the demonstration, behind a safety shield.
- Research an additional location in the solar system, they can record their findings in the extra row provided in the table on *Search for Elements*. Students can access information about the following planets using the related links:
    - Venus: https://solarsystem.nasa.gov/planets/venus/in-depth/
    - Mercury: https://solarsystem.nasa.gov/planets/mercury/in-depth/
    - Saturn: https://solarsystem.nasa.gov/planets/saturn/in-depth/
    - Jupiter: https://solarsystem.nasa.gov/planets/jupiter/in-depth/
    - Neptune: https://solarsystem.nasa.gov/planets/neptune/in-depth/
- If students are interested in extended molecular structures of cement, they can check out the open-access chemical research paper: Mohamed, A.K., Moutzouri, P., Berruyer, P., Walder, B.J., Siramanount, J., Harris, M., Negroni, M., Galmarini, S.C., Parker, S.C., Scrivener, K.L, Emsley, L., & Bowen, P. (2020). The atomic-level structure of cementitious calcium aluminate silicate hydrate. *Journal of the American Chemical Society, 142*(25), 11060-11071. https://pubs.acs.org/doi/10.1021/jacs.0c02988#.

- Use materials other than ceramics (like concrete) or polymers, such as metals, electronic materials, or composites, you may wish to have them research these materials. Students can still use *Synthesis and Evaluation* to summarize findings and evaluate arguments, although additional time will need to be allowed for research.
- These articles intentionally reference careers such as *materials scientist, chemical engineering, food technology,* and *biochemical engineering.* You may have students research these and related careers through the Bureau of Labor Statistics Occupational Outlook Handbook: https://www.bls.gov/ooh/.
- The assessment boundary of the related NGSS Performance Expectation, HS-PS1-2, limits assessments to main group elements and combustion reactions. To keep within this assessment boundary, limit students to investigating N_2, O_2, CaO, SiO_2, or Al_2O_3. The unit materials have prepared students to balance larger compounds, if you wish to extend student thinking beyond this boundary.

Assessments:

Diagnostic	Formative	Summative
• Initial Reaction Model • Driving Question Board	• Exit Ticket • Analyze Atmospheric Spectra • Element Tool Model • Consensus Element Tool Model • Compare Atomic Models • Modeling Molecular Polarity • Fertilizer from Urine • Search for Elements • Recycling Ideas Organizer	• Sila-ibuprofen Transfer Task • Soap Scum Transfer Task

Unit 6: Energy from Chemical and Nuclear Processes

How can chemistry help us evaluate fuels and transportation options to benefit the Earth and our communities?

<u>**Standards (by number):**</u>	<u>**Essential Questions:**</u>
Science:	➔ What different fuels have we used, and do we currently use, for transportation?

3.2.9-12.A 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. 3.2.9-12.B 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. 3.2.9-12.H 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. 3.2.9-12.N Communicate scientific and technical information about why the molecular level structure is important in the functioning of designed materials. 3.2.9-12.O 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. 3.2.9-12.Q Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. 3.2.9-12.S 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.	➔ What is happening to the fuels inside the engine to make the vehicle move? ➔ How can diesel engines be working so differently from gasoline engines? ➔ Why do we need to put energy into the system to start the reaction? ➔ How and why is energy released when we burn carbon-based fuels? ➔ How does the amount of energy we put into the reaction system compare to the energy we get out? ➔ How can fuels release different amounts of energy when they all have bonds breaking and forming? ➔ How can we use hydrogen as a fuel and what are the impacts? ➔ Where is the energy coming from when we use uranium as a fuel?
Technology and Engineering: 3.5.9-12.B Critically assess and evaluate a technology that minimizes resource use and resulting waste to achieve a goal. 3.5.9-12.C Develop a solution to a technological problem that has the least negative environmental and social impact.	➔ How can diesel engines be working so differently from gasoline engines? ➔ Where is the energy coming from (and what are some trade-offs) when we use batteries to power vehicles? ➔ How can our knowledge of fuel trade-offs support our evaluation of future rocket fuels?

3.5.9-12.D Critique whether existing or proposed technologies use resources sustainably. 3.5.9-12.G Evaluate a technological innovation that was met with societal resistance impacting its development. 3.5.9-12.M Develop a device or system for the marketplace. 3.5.9-12.W Optimize a design by addressing desired qualities within criteria and constraints while considering trade-offs. 3.5.9-12.LL Analyze the stability of a technological system and how it is influenced by all of the components in the system, especially those in the feedback loop.	➔ How do we decide on the best transportation options for our future?
Environmental Literacy and Sustainability: 3.4.9-12.G Analyze and evaluate how best resource management practices and environmental laws achieve sustainability of natural resources. 3.4.9-12.A Analyze and interpret how issues, trends, technologies, and policies impact agricultural, food, and environmental systems and resources. 3.4.9-12.B Apply research and analytical skills to evaluate the conditions and motivations that lead to conflict, cooperation, and change among individuals, groups, and nations. 3.4.9-12.C Analyze and interpret how issues, trends, technologies, and policies impact watersheds and water resources. 3.4.9-12.D Apply research and analytical skills to systematically investigate environmental issues ranging from local issues to those that are regional or global in scope.	➔ How does our understanding of carbon-based fuels inform our decision-making? ➔ Where is the energy coming from (and what are some trade-offs) when we use batteries to power vehicles? ➔ Why do we use some fuels rather than others? ➔ How can we make transportation decisions to benefit our communities and Earth?

3.4.9-12.H Design and evaluate solutions in which individuals and societies can promote stewardship in environmental quality and community well-b	

Students will be able to… (SEP)	Students will know… (DCI)	Students will apply…(CCC)
Use a model to predict the relationships between systems or between components of a system. 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. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations. Use mathematical representations of phenomena to support claims.	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. Types of Interactions Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. 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.	*Patterns* Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. *Stability and Change* Much of science deals with constructing explanations of how things change and how they remain stable. *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. *Energy and Matter* The total amount of energy and matter in closed systems is conserved. *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. *Interdependence of Science, Engineering, and Technology*

Communicate scientific and technical information (e.g., about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations. Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Apply techniques of algebra and functions to represent and solve scientific and engineering	Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. 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. 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.	Science and engineering complement each other in the cycle known as research and development (R&D). *Influence of Engineering, Technology, and Science on Society and the Natural World* Modern civilization depends on major technological systems. *Cause and Effect* Systems can be designed to cause a desired effect. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. *Critical Thinking* Uses evidence to better understand and solve problems in technology and engineering, including applying computational thinking. *Attention to Ethics* Assesses technological products, systems, and processes through critical analysis of their impacts and outcomes. *Optimism* Shows persistence in addressing technological problems and finding solutions to those problems. *Science Addresses Questions About the Natural and Material World* Not all questions can be answered

problems. Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. 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 trade-off considerations. Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).	Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. Photoelectric materials emit electrons when they absorb light of a high-enough frequency. Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. Create a computational simulation to illustrate the	by science. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. Many decisions are not made using science alone, but rely on social and cultural influences *Stability and Change* Feedback (negative or positive) can stabilize or destabilize a system.

	relationships among management of natural resources, the sustainability of human populations, and biodiversity. The decision to develop a new technology is influenced by societal opinions and demands. These driving forces differ from culture to culture. When evaluating solutions, it is important to consider a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. Meet a sophisticated design challenge by identifying criteria and constraints, predicting how these will affect the solution, researching and generating ideas, and using trade-offs to balance competing values in selecting the best solution. 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. A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical	

	disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. Resource availability has guided the development of human society. The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.	

Core Activities/Corresponding Instructional Methods/DOK Levels **33 Days**
The students will: ➢ Develop a model based on evidence (chemical formula, energy released, and carbon dioxide emission) to illustrate the matter change, energy transfer, and force interaction relationships between the components of the system to explain how a fuel (matter) is used to provide energy in a vehicle system to make it move. (DOK 2) ➢ Ask questions that arise from and seek additional information about: patterns in data related to fuel use in transportation; attempts to explain how matter (fuel) and energy transfer in a vehicle to produce movement; and attempts to identify criteria and constraints to inform design solutions for next-generation vehicle fuel use. (DOK 2)
The students will: ➢ Construct and revise an explanation based on models showing the structure and function of vehicle components that explains how chemical processes release energy, allowing the vehicle to move. (DOK 2) ➢ Develop, revise, and use models based on evidence to identify relationships between changes in matter and energy transfers that take place in a vehicle as a result of the combustion of fuel. (DOK 3)

➢ Analyze data using CODAP to identify patterns in carbon-based fuel characteristics that optimize the successful movement of a vehicle when burned in an internal combustion engine. (DOK 3)
The students will: ➢ Evaluate the impact of the relationship between pressure, volume, and temperature of air (data) on the working model of a diesel engine by identifying energy transfer from the motion of the piston to the air particles in the cylinder as the cause of the temperature increase (effect). (DOK 3)
The students will: ➢ Develop and revise models based on evidence and use these to present and compare an argument for an explanation of where energy is transferred to and from and why energy is conserved within a system when bonds break and form. (DOK 3)
The students will: ➢ Respectfully provide critiques based on scientific arguments to determine that the cause of varying energy transfer from reactions is due to differences in energy stored in the fields between bonded atoms. (DOK 2) ➢ Apply scientific reasoning and models to claims to consider the relative scale of energy transfer into and out of fields in a closed system as the atoms in molecules change relative position. (DOK 2)
The students will: ➢ Develop a model based on evidence to illustrate energy transfer into or out of a chemical reaction system depending on energy transfer into and out of fields as particular bonds break and form. (DOK 3) ➢ Use mathematical models to show that matter is conserved during fuel combustion and to support claims about fuel efficiency in vehicles and the impacts of carbon-based fuel use. (DOK 3)
The students will: ➢ Compare and evaluate arguments about a new transportation technology (batteries and EVs) to reduce pollution while considering its impact on the transportation system.(DOK) 3 ➢ Use evidence from student investigations and research to propose a battery design that results in the largest energy output based on the types of solutions and metals used in the battery and the matter and force interactions between them. (DOK4)
The students will: ➢ Analyze data about greenhouse gasses from hydrogen production and evaluate their impact on the transportation system to optimize it relative to criteria of greenhouse gas emissions to preclude ecosystem degradation. (DOK 2)

The students will: ➢ Construct an explanation based on a variety of sources using structure-function relationships to show how protons and neutrons are conserved during nuclear fission while energy is released. (DOK2) ➢ Evaluate the impact of new data related to nucleus structures on the model of energy transfer in and out of fields during nuclear fission. (DOK 2) ➢ Apply scientific ideas, principles, and evidence to identify unanticipated effects of a transportation design solution that may result in problems in the system due to associated costs and risks .(DOK3)
The students will: ➢ Compare and evaluate competing rocket fuel options for future space missions specifying qualitative and quantitative criteria and constraints that account for societal want of space exploration and environmental impact.(DOK 3)
The students will: ➢ Compare and evaluate the potential impacts of two transportation options (current state vs. possible future state) caused by the engineering approach (shift, avoid, improve) as well as the availability and accessibility of the needed resources. (DOK 2) ➢ Present an oral and written argument for the need for specific subcategories of criteria that can be approached systematically, based on data and evidence, that shows differential effects such as benefits and costs resulting from changes in the transportation system. (DOK 2)
The students will: ➢ Analyze data using quantitative tools to evaluate future transportation options that satisfy requirements set by society, by using numerical patterns in evidence from radar charts and cost-benefit calculations. (DOK 4) ➢ Develop an argument for the best future transportation options that satisfy requirements set by society, by using numerical patterns in evidence and feedback from peers to refine arguments. (DOK 3)
The students will: ➢ Apply knowledge about the costs and benefits of resource extraction and energy and resource use and quantify them to propose vehicle systems or transportation goals designed to reduce carbon emissions and meet prioritized criteria and address trade-offs. (DOK 4)

Correctives:

- Chapter 17 notes, worksheets, and study guides.
- Gummy Bear Lab
- BTB can be combined with the ethanol in a watch glass; it will be more green than the blue color students see when BTB is added to tap water. There will be an immediate color change to yellow when the ethanol burns, but the color change is less striking. If using this method, it may be helpful to have a second reference BTB receptacle so that students can compare the colors before and after the reaction.

- The recommended method is described above, but this alternative may save a bit of time and will work if you are missing a fuel container like the tea candle holders.
- If students are not familiar with some of the ideas of kinetic molecular theory initially built in middle school and returned to in Polar Ice Unit, they can create a visualization using the following online simulation. Simply have students use the pump to add air molecules. Then have students make observations about the changes that occur when they manipulate the "heat and cool" mechanism: https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_all.html.
- In addition to the simulation, it may be valuable to have the two magnet marble and ruler system available to students, as well as a second system in which one of the magnet marbles is stronger than the other. Although it is difficult to break the strong bond in this system, it can help give students a physical sense of what is happening, especially for those students who do not connect with the simulation.
- If these questions are too complex or difficult in sentence form, consider distributing a piece of blank paper to groups of students to draw each of the bonds and their forces: C-O, C-H, and O=O (reactants) and O-H and C=O (products). This multimodal support will benefit students in identifying how matter and energy shift in a bond when a reaction occurs.
- Slide CC is optional and easily modified based on your students' needs. It is projected to take an additional 10 minutes of class time. The provided reference has all the calculations completed so that students can focus on the patterns in the last two columns of the table. You could modify this reference to have students perform some of the calculations themselves. For example, you might remove the content in rows 2 and 3 and have students perform the calculations for magnesium sulfate and potassium chloride in pairs (each partner focusing on one solution), using rows 1 and 4 as worked examples. A video example can also be found at: https://www.youtube.com/watch?v=7fHA17DOrBg.
- Students learned about neutrons in OpenSciEd Unit C.2: What causes lightning and why are some places safer than others when it strikes? (Electrostatics Unit). Students may have had questions in that unit about the role neutrons play, but they have not been a key part of students' explanations and models since then. If students do not remember neutrons, use a simulation such as https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_all.html to remind students about the different subatomic particles in an atom and their properties.
- For students who benefit from additional reading comprehension support, the Coherent Reading Protocol is well-suited for this text. This protocol guides students to monitor their understanding after each chunk of text, identify the main idea, and connect the information in the reading to the lesson question. The Coherent Reading Protocol can be found in the Teacher Handbook.

Extensions:

- Students who talked with people who have lived in the community a long time may have learned that public transit was once much more common in their area. Many communities, of various sizes, that are now auto-centric once relied more heavily on streetcar networks or intercity rail. You may encourage students who have questions in this subject to investigate it further, or coordinate with social studies colleagues to examine your area's history of transportation from a historical, economic, or human geography lens. As students investigate this history, encourage them to consider who is impacted, and how, when non-auto transportation options decrease.

- If students bring expertise about other mechanical components throughout the engine or vehicle to the table, you may incorporate them into the model. If students have additional questions about mechanical components that they cannot answer for each other, you may have them research vehicles in or out of class, depending on time constraints. You could also bring in a mechanic or automotive technology student as an expert to help answer students' questions. Such a visit might be best placed at the end of Lesson Set 2, as students could ask remaining questions about road vehicles that use different fuels.
- For more information about how fuel cells work, suggest watching a video. Slide E demonstrates a homemade hydrogen fuel cell being charged and then used. Slide F provides an opportunity to share additional similarities and differences between batteries and fuel cells.
- If you are required to teach the Ideal Gas Law ($PV = nRT$), you can add the number of moles of gas (n) to the Air Phenomena and Properties chart. Since the three phenomena from Lesson 2 all involve closed systems, students should readily conclude that n does not change.
- For Ideal Gas law, you can introduce it here by replacing the Combined Gas Law on slide J with the Ideal Gas Law ($PV = nRT$). To be consistent with the units for pressure (N/m^2) introduced earlier in the lesson, initially provide the units for the gas constant, R, in N·m/mol·K before defining it using other units (e.g., J/mol·K). For reference, R = 8.31 N·m/mol·K or 8.31 J/mol·K.
- If you introduced the Ideal Gas Law earlier and want to provide students with additional opportunities, you can ask them to determine the amount of fuel that needs to be injected to stoichiometrically react with oxygen in the diesel cylinder system. Students can use the initial conditions in Diesel Combustion Pressure to determine the moles of air if you provide volume in m^3. They can then use the fact that air is 21% oxygen to determine the moles of oxygen. Using the balanced equation for combustion for a given fuel, students can determine the moles of fuel needed. This can be further extended to a determination of the mass and volume of fuel injected using values for the fuel's molecular weight and density.
- Five White Solids Lab
    - If you wish to assess students' bond energy calculations, you may do so using this assessment. There are three levels to this extension, each increasingly difficult.
    - To assess bond energy calculations alone: Ask students to estimate how much energy would be transferred into or out of the system when a mole of their salt interacts with water. (29 kJ/mol for KCl, -120 kJ/mol for $CaCl_2$)
    - To also assess use of molar mass from Oysters Unit: Ask students to estimate how much energy should have been transferred into or out of the system given 5 g of salt. (1.95 kJ for KCl, -5.41 kJ for $CaCl_2$)
    - To assess ideas throughout the course: Ask students to do the above and use ideas from Polar Ice Unit to calculate the temperature change that should have occurred in the water, given ideal conditions. The specific heat of water is 4.18 kJ/(g * ºC). (18.7 ºC decrease for KCl, 51.8ºC increase for $CaCl_2$)

    - Note that students' estimates for (3) will reflect significantly greater temperature changes than observed. This is because energy transfers to the surrounding air, as well as the water, in this investigation.
- Conduct a voltmeter demonstration for two of the combinations of solutions and metals that students decided would result in the highest energy output.
- As with other non-fossil fuel technologies, job opportunities related to electric vehicles are on the rise. Direct interested students to https://www.bls.gov/green/electric_vehicles/#occupations to research this topic further.
- If students are interested in getting a national picture, encourage them to explore recharging and refueling options on this larger scale. Students should come to the same conclusions but may point out that some areas have better infrastructure to support the use of battery-powered or hydrogen fuel cell vehicles than others.
- Lise Meitner (pronounced "Leez MITE-ner") and Otto Frisch discovered nuclear fission while discussing some results from another scientist, Otto Hahn, who had encountered results he could not explain. While Hahn won the 1944 Nobel Prize in Chemistry, Meitner never received formal credit for her role. Direct students to https://www.aps.org/publications/apsnews/200712/physicshistory.cfm for more information about Meitner's story, including her flight from Nazi-controlled Austria.
- The second and third tabs introduce the idea of chain reactions and expand on the role of control rods in reactors respectively. Either or both could be used with a subset or all students after the jigsaw on day 3, which includes the reading Safety: Control Rods.
- Some students may have heard about subatomic particles smaller than neutrons and protons or wonder how these particles are able to interact with each other when neutrons have no charge. Only if these questions come up, you may encourage students to obtain and evaluate information about the relationship between quarks and color charge (a rough analogue to electric charge) as they relate to the strong nuclear force.

Assessments:

Diagnostic	Formative	Summative
• Initial Models • Driving Question Board	• Exit Ticket • Energy and Forces • Driving Question Board • Mapping between models • Predicting energy changes • Modeling Energy Changes • Fuel Energy Released • Class Consensus Model • Calculating Carbon Emissions • Discussion Mapping Tool • Battery Design • Transportation Arguments Draft	• Cold Pack Scenario and Assessment • Hot Pack Scenario and Assessment • Rocket Fuel Argument • STAMP Assessment • Final Design Proposal