PLANNED INSTRUCTION

A PLANNED COURSE FOR:

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

Curriculum writing committee:

Grade 8 Science

Date of Board Approval: June 2025

Marking Period Course Grade Weighting

Chapter Tests	40%
Mid-Chapter CheckPoint	30%
Homework/Classwork	10%
Quizzes	20%
Total	100%

Curriculum Map

Overview:
This course will provide an exploration of main themes in physical science that include, but are not limited to, the study of matter and its properties; energy transfer and transformations; motion and forces; interactions between matter at the atomic and molecular level, and the application of scientific principles to better understand the physical world.

Although the content of the courses will be consistent at all levels, the manner in which it is administered will be determined based on the needs and the capabilities of the students. Each teacher will choose the most appropriate pedagogical methodologies to accommodate the nature of the students enrolled in this course. This curriculum is designed to maximize student engagement while catering to students with diverse learning styles.

Time for the Course: One full year, meeting daily for ~46 minutes

Goals:

1. **Marking Period One: Over a 45-day period of time, students will aim to understand:**
   UNIT 1: Thermal Energy (~30 days)
   - Open Systems versus Closed Systems
   - How parts of a system affect the whole
   - Kinetic Theory of Matter
   - Flow of Matter and Energy through a System

- Relationship between Kinetic Energy and Temperature
- Light Absorption and Energy Transfer

UNIT 2: Contact Forces (~15 Days)

- Forces
- Energy transfer during collisions
- Elastic collisions and deformation

2. **Marking Period Two: Over a 45-day period of time, students will aim to understand:**

UNIT 2 (continued): Contact Forces (~15 Days)

- Kinetic energy versus potential energy
- Friction
- Principles of engineering design

UNIT 3: Sound Waves (30 Days)

- Evidence of Relationship between Sound Waves and Kinetic Energy
- Amplitude and Frequency of Sound Waves
- Relationship between state of matter and sound waves
- Impact of frequency and amplitude of sound waves on motion

3. **Marking Period Three: Over a 45-day period of time, students will aim to understand:**

UNIT 4: Forces At a Distance (~30 Days)

- Principles of magnetism and magnetic fields
- Electromagnetism
- Energy transfer via forces at a distance

UNIT 5: Chemical Reactions and Matter (~15 Days)

- Chemical and Physical properties of matter
- Chemical and Physical changes

4. **Marking Period Four: Over a 45-day period of time, students will aim to understand:**

UNIT 5 (continued): Chemical Reactions and Matter (~15 Days)

- Chemical composition of mixtures and pure substances
- Density
- Rearrangement of particles in a chemical reaction

UNIT 6: Chemical Reactions and Matter (~30 Days)

- Energy transfer during chemical reactions
- Design process in engineering

Big Ideas

Big Idea #1: The total amount of matter and energy in the universe remains the same but is constantly changing form.

Big Idea #2: When objects touch, they exert forces on each other, causing changes in motion and sometimes deformation, which can be explained and predicted using the concepts of forces such as friction.

Big Idea #3: All objects have an effect on other objects, even without being in direct contact with them.

Big Idea #4: Developing a solution to a problem requires the engineering process, which is based on understanding, assessing, and modifying systems.

Unit 1 Curriculum Map

Overview: What keeps different cups or containers from warming up or cooling down? Students begin this unit by experimenting whether a new plastic cup sold by a store keeps a drink colder for longer than the regular plastic cup that comes free with the drink. Students find that the drink in the regular cup warms up more than the drink in the special cup. This prompts students to identify features of the cups that are different, such as the lid, walls, and hole for the straw, that might explain why one drink warms up more than the other.

In this unit, students investigate the different cup features they conjecture to explain the phenomenon, starting with the lid. They model how matter can enter or exit the cup via evaporation. However, they find that in a completely closed system, the liquid inside the cup still changes temperature. This motivates the need to trace the transfer of energy into the drink as it warms up. Through a series of lab investigations and simulations, students find two ways to transfer energy into the drink: (1) the absorption of light and (2) thermal energy from the warmer air around the drink. They are then challenged to design their own drink container that can perform as well as the store-bought container, following a set of design criteria and constraints.

Big Ideas:

- All forms of matter exist as a result of the combination or rearrangement of atoms.
- The total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave pattern of changing electric and magnetic fields that interact with matter.

Textbook and Supplemental Resources: Unit 1 Materials Folder, Unit 1 Video Links, OpenSciEd 6.2 Thermal Energy and ThinkCentral Science Fusion textbook series

Unit 1: Thermal Energy

Standards (by number)	Essential Questions: ● How do particles combine to form the variety of matter one observes? ● What is meant by conservation of energy? ● How is energy transferred between objects or systems? ● What is light? ● How can one explain the varied effects that involve light? ● What other forms of electromagnetic radiation are there?

	● How can containers keep stuff from warming up or cooling down?
Science:	3.2.6-8.B Develop a model that predicts and describes changes in the particle motion, temperature, and state of a pure substance when thermal energy is added or removed. 3.2.6-8.M Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. 3.2.6-8.N Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. 3.2.6-8.O Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. 3.2.6-8.R Develop and use a model to describe how waves are reflected, absorbed, or transmitted through various materials.
Technology and Engineering:	3.5.6-8.II Predict outcomes of a future product or system at the beginning of the design process. 3.5.6-8.O Interpret the accuracy of information collected. 3.5.6-8.AA Adapt and apply an existing product, system, or process to solve a problem in a different setting. 3.5.6-8.J Use tools, materials, and machines to safely diagnose, adjust, and repair systems. 3.5.6-8.X Defend decisions related to a design problem. 3.5.6-8.U Evaluate and assess the strengths and weaknesses of various design solutions given established principles and elements of design. 3.5.6-8.P (ETS) Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

	3.5.6-8.E Consider the impacts of a proposed or existing technology and devise strategies for reducing, reusing, and recycling waste caused by its creation. 3.5.6-8.D Analyze how the creation and use of technologies consumes renewable, non- renewable, and inexhaustible resources; creates waste; and may contribute to environmental challenges. 3.5.6-8.C Hypothesize what alternative outcomes (individual, cultural, and/or environmental) might have resulted had a different technological solution been selected. 3.5.6-8.H Evaluate trade-offs based on various perspectives as part of a decision process that recognizes the need for careful compromises among competing factors. 3.5.6-8.Z Analyze how different technological systems often interact with economic, environmental, and social systems.
Environmental Literacy and Sustainability:	3.4.6-8.G Obtain and communicate information to describe how best resource management practices and environmental laws are designed to achieve environmental sustainability.

Students will know…. (DCI)	Students will be able to… (SEP)	Students will apply…(CCC)
Gasses and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. The changes of state that occur with variations in temperature or pressure can be described	Developing and Using Models: Develop a model to predict and/or describe phenomena. Constructing Explanations and Designing Solutions: Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. Planning and Carrying Out Investigations: Plan an investigation individually and	Cause and effect: Relationships may be used to predict phenomena in natural or designed systems. Energy and Matter: The transfer of energy can be tracked as energy flows through a designed or natural system. Scale, Proportion, and Quantity: Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among

and predicted using these models of matter. The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary) The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule. (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. (secondary) Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends	collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.	different types of quantities provide information about the magnitude of properties and processes. Structure and Function: Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

on the types, states, and amounts of matter present. Energy is spontaneously transferred out of hotter regions or objects and into colder ones. Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. A sound wave needs a medium through which it is transmitted.		

When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. However, because light can travel through space, it cannot be a matter wave, like sound or water waves.		

Core Activities and Corresponding Instructional Methods

Core Activities/Corresponding Instructional Methods/DOK Levels
Unit Question: How can containers keep stuff from warming up or cooling down?
Lesson Set 1 (Lessons 1-6) - How do some cup features close off the system to keep a drink cold or warm and why does it still warm up?
Lesson 1 1. Students will define what a system is. (DOK 1) 2. Students will compare and contrast two different systems of temperature regulation. (DOK 2) 3. Students will formulate a list of factors that affect temperature regulation in a closed system. (DOK 2)

Lesson 1 Slides
Lesson 2 1. Students will investigate characteristics that are necessary for a system to maintain its temperature. (DOK 3) 2. Students will conduct research into how changing features would affect a system's ability to maintain its temperature. (DOK 4) 3. Students will analyze patterns from their investigation to determine which features are successful and unsuccessful in maintaining a systems temperature. (DOK 3) Lesson 2 Slides
Lesson 3 1. Students will compare how the previously identified features that keep a system cold will also keep a system hot. (DOK 2) 2. Students will analyze how different features of a common temperature regulation system (ex: a cup) work. (DOK 3) Lesson 3 Slides Lesson 3 Student Investigation Plan Handout
Lesson 4 1. Students will relate surface area to temperature change of a hot liquid. (DOK 2) 2. Students will determine the effect of surface area on the loss of mass of a hot liquid. (DOK 3) 3. Students will explain how mass is lost in liquids and gases in an open system. (DOK 3) Lesson 4 Slides Lesson 4 Progress Tracker Handout Lesson 4 Manipulative Map for Matter Handout Lesson 4 Procedure: Measuring Changes in Mass in the Cups Handout Video: Time-Lapse Water in a Glass Video: Slow Motion of Stem and Evaporation Lesson 5 1. Students will define the three main states of matter (solid, liquid, gas). (DOK 1) 2. Students will compare and contrast the energy levels and particle arrangements in solids, liquids, and gases. (DOK 2) 3. Students will investigate the process of condensation to refute a claim that water droplets on the outside of a cup comes from inside of the cup. (DOK 3) Lesson 5 Slides Lesson 5 Water Droplet Investigation Handout Lesson 5 Assessment Cold Lemonade on a Hot Day Lesson 5 Assessment Answer Key Lesson 6

1. Students will model how phase changes can lead to the loss of mass in part of a system but mass in the whole system is conserved. (DOK 3) Lesson 6 Slides Lesson 6 Particle Representations for Matter in the Cup System Handout Lesson 6 Analogy Map for Chips and Marbles Handout Lesson 6 Lesson 6 Rubric Rubric for Model Lesson 6 Assessment: Explaining the Effect of Different Lid Designs Lesson 6 Assessment Scoring Guide
Lesson Set 2 (Lessons 7-14) - How and why does energy from outside the system enter the cup system to warm up the cold water?
Lesson 7 1. Students will hypothesize about the impact that light, heat, and cold have on the temperature change of a closed system. (DOK 3) Lesson 7 Slides Lesson 8 1. Students will describe how different factors (examples include but are not limited o a substance's color and material) affect the amount of light that is transmitted or reflected through a system. (DOK 2) Lesson 8 Slides Lesson 8 Investigating Light's Effect on Warming Up Water Handout Lesson 8 Explaining Temperature Changes in Each Cup Handout
Lesson 9 1. Students will carry out an investigation to determine how energy in the form of heat is transferred between two systems. (DOK 4) 2. Students will determine the factors that cause differences in temperature changes between two systems. (DOK 3) Lesson 9 Slides Lesson 9 Class Investigation: Heat or Cold through the Cup Wall Handout Lesson 9 Small-Group Investigation: Heat or Cold through the Cup Wall Handout Lesson 9 Data Set and Analysis: Heat or Cold across the Cup Wall Handout Lesson 9 Sample Data Sets for Water Bath Lab Handout Lesson 10 1. Students will compare and contrast the particle movement of hot and cold liquids. (DOK 2) 2. Students will conclude that particles move faster in substances with higher temperatures. (DOK 1) Lesson 10 Slides Lesson 10 Reading on James Joule's Experiment Handout Video: Peppermint Candy in Different Water

Lesson 11 1. Students will explain the relationship between particle movement and temperature using kinetic energy. (DOK 2) 2. Students will predict how kinetic energy connects to earlier investigations on temperature changes in open and closed systems. (DOK 3) Lesson 11 Slides Lesson 11 Teacher Reference Evidence Cards 1 Simulation: Molecular View of a Gas Lesson 12 1. Students will observe how the kinetic energy of individual particles in a substance differ and is constantly changing. (DOK 2) 2. Students will define "temperature" as a measure of the average speed of the particles in a sample of matter. (DOK 1) Lesson 12 Slides Lesson 12 Particle Interactions in Gases Handout Simulation: Gas Particle Motion Lesson 13 1. Students will analyze particle speeds before and after a collision. (DOK 3) 2. Students will investigate the effects of collisions on particle speed in different situations to simulate interactions between particles in a gas, a liquid, and a solid. (DOK 4) 3. Students will evaluate how temperature affects particle interactions in solids. (DOK 3) Lesson 13 Slides Lesson 13 Particle Collisions within and between Solids Handout Lesson 13 Investigating Particle Collisions in Different States of Matter Handout Lesson 13 Key for Investigating Particle Collisions in Different States of Matter Simulation: Conduction in Solids (Full) Simulation: Conduction in Solids (Reduced) Lesson 14 1. Students will revise previous models regarding temperature regulation systems to include newly learned insights, including kinetic energy. (DOK 4) Lesson 14 Slides Lesson 14 Handout Evidence Sorting Chart Handout Lesson 14 Modeling What Is Happening at the Cup Wall Handout Lesson 14 Icing Injuries Assessment Lesson 14 Rubric for Model in Lesson 14 Icing Injuries Assessment Lesson 14 Assessment Scoring Guide
Lesson Set 3 (Lessons 15-18) - How can we design a container to keep a substance cold?
Lesson 15

1. Students will explore the features of temperature regulation systems such as cups that make them effective. (DOK 2) 2. Students will summarize the mechanisms of energy transfer. (DOK 2) Lesson 15 Slides Lesson 15 How Styrene, Neoprene, and Cardboard Sleeves Work Handout Lesson 15 How Double Walls Work Handout Lesson 15 Handout Final Cup Consensus Handout Lesson 15 Evaporative Cooling Handout Lesson 15 Features of Cups that Keep Drinks Cool Handout Lesson 15 How Light Warms Up Matter Handout
Lesson 16 1. Students will design and construct cups that aim to minimize energy transfer. (DOK 4) 2. Students will evaluate the effectiveness of their designs. (DOK 3) Lesson 16 Slides Lesson 16 Cold Cup Design Challenge Handout Lesson 16 Price Check Test Handout Lesson 16 Diameter Test Handout Lesson 16 Bright Light and Temperature Test Reference Handout Lesson 16 Regular Light and Temperature Test Reference Handout Lesson 16 Environmental Impact Test Handout Lesson 16 Peer Evaluation Feedback Handout Lesson 17 1. Students will modify and retest their cup designs based on peer feedback and results. (DOK 4) Lesson 17 Slides
Lesson 18 1. Students will develop a consensus model to indicate which cup design features should be included to minimize or maximize energy transfer. (DOK 4) 2. Students will demonstrate their understanding by taking an assessment. (DOK 2) Lesson 18 Slides Lesson 18 Assessment Disaster Blanket Design Lesson 18 Assessment Key Lesson 18 Handout Let's Answer Questions from our Driving Question Board

Words that “May Be Encountered” throughout the Unit:

Absorption	Condensation	Kinetic energy
Air-insulated	Conduction	Mean
Calorimeter	Control variable	Molecule
Closed system	Heat	Open system

Porous	Thermal conductor	Thermodynamics
Specific heat	Thermal energy	Vacuum-insulated
Styrofoam	Thermal expansion	Variable
Temperature	Thermal insulator	

Correctives:

Lesson 1: If the engineering design is introduced too early, students become focused on their design ideas and whether their designs work without first establishing a principled reason for developing those designs. This unit is sequenced so that students consider the designs currently used for cups and related systems before developing their own designs. Students will design their own cup towards the end of the unit

As students observe the Cold Cup Test on day 1, they may notice the condensation that occurs on the outside of the regular cup. Encourage students to include in their models their ideas about how those water droplets form, but avoid spending too much time on condensation in this lesson. Students will investigate whether water leaves the inside of the cup through the wall during Lesson 5.

Lesson 2: We are only interested in the features of the cup from the anchoring phenomenon discussed in lesson 1 (presence or absence of a lid, number of walls, thickness and/or type of cup materials, presence or absence of a straw) that played a significant role in keeping a drink cold. Avoid allowing students to explore all design features available today for this investigation (styrofoam, vacuum sealed, etc.).

Lesson 3: Students are not designing the cup at this point, but exploring existing design features, how they work, and why they work. Ideas do not need to be scientifically correct at this point, the goal is to brainstorm ideas and create a need to investigate these ideas.

Lesson 4: This lesson does not explain that molecules are made out of atoms, that solids are made of particles, or that gas particles are in constant and random motion. Students will only develop an understanding of how water particles move from the liquid to the air in this lesson, all others will be developed in later lessons or units.

Lesson 5: Time does not need to be spent on explaining the process of condensation, students are not expected to understand this process for this unit, just know that it occurs.

Lesson 6: Lesson does not explain how molecules are made out of atoms, this understanding will be developed in later lessons or units.

Lesson 8: This investigation only focuses on the absorption of light as energy transfer on the macroscale, students will explore light absorption at the particle level in lesson 15.

Lesson 9: This lesson serves as an initial source of evidence that heat and cold cross the walls of the cup while the matter stays in place, not an explanation of how thermal energy is transferred.

Lesson 10: Students will gain an understanding of the relationship between kinetic energy and heat in the next lessons (11 & 12).

Lesson 14: Focus should be on describing what is happening in terms of energy rather than attempting to calculate or quantify the amount of energy transferred.

Lesson 15: Students will not use a particle model of light to understand this investigation, no learning about electrons or photons is included. Model of light will be limited to energy transfer of the particles into Kinetic Energy.

Lesson 16: Avoid modifying cups, using a hot liquid, or using any other alternative methods until the class has gone through at least 2 design cycles in the challenge

Lesson 17: The second design cycle should be used for students to work with their original design to modify features they believe will help them better achieve their goal, they should not completely redesign their cup at this point.

Extensions:
To extend or enhance the unit, consider the following

- Consider opening up the design challenge to other devices in which conduction is the primary means of energy transfer, such as coolers or lunch boxes.

- Involve students more in setting up the engineering design challenge to name their criteria and constraints and to identify how to test their devices against the criteria and constraints.

- Students could also interview stakeholders, such as other students, teachers, and family members to decide what criteria should be prioritized most.

Assessments: Assessments for Unit 1, Summary Table Template

Diagnostic	Formative	Summative
Diagnostic assessments can be in the form of the following: ● KWL charts ● Concept mapping ● Open-ended questioning ● Drawing diagrams/model making ● Quick quizzes on key concepts drawing diagrams to explain a process ● "Think-Pair-Share" discussions on the phenomena in question ● Analyzation of real-world data to identify variables and potential relationships	The following can be used for formative assessments throughout the unit: ● Progress Tracker ● Short Quizzes ● Exit Tickets ● Graphic organizers ● Lab notebooks with observations/journal entries ● CERs ● Illustration of a concept/Comic strip explanation ● Peer feedback	To evaluate students' mastery of the unit's scientific concepts, the following assessments can be utilized to measure their understanding: ● Two-part Student Assessment/Mid-Point Assessment ● Disaster Blanket Design Assessment ● Self-Assessment and Peer Feedback ● Project presentation ● Unit test ● Research paper essay

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Unit 2 Curriculum Map

Overview: The common experience of dropping and breaking a phone/mobile device anchors learning in the Contact Forces unit as students explore a variety of phenomena to figure out, "Why do things sometimes get damaged when they hit each other?"

Student questions about the factors that result in a shattered cell phone screen lead them to investigate what is really happening to any object during a collision. They make their thinking visible with free-body diagrams, mathematical models, and system models to explain the effects of relative forces, mass, speed, and energy in collisions. Students then use what they have learned about collisions to engineer something that will protect a fragile object from damage in a collision. They investigate which materials to use, gather design input from stakeholders to refine the criteria and constraints, develop micro and macro models of how their solution is working, and optimize their solution based on data from investigations. Finally, students apply what they have learned from the investigation and design to a related design problem.

Big Ideas:

- A change in motion of interacting objects can be explained and predicted by forces.
- Energy can be modeled as either motions of particles or as being stored in force fields.
- Animals have external and internal sensory receptors that detect different kinds of information that then gets processed by the brain.

Textbook and Supplemental Resources: Unit 2 Materials Folder, Unit 2 Video Links, OpenSciEd 8.1 Contact Forces and ThinkCentral ScienceFusion textbook series

Unit 2: Contact Forces

Standards (by number):	Essential Questions: • How can one predict an object's continued motion, changes in motion, or stability? • What is energy? • How do organisms detect, process, and use information about the environment?
Science:	3.2.6-8.G Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. 3.2.6-8.H Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. 3.2.6-8.L Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass and to the speed of an object.

	3.1.6-8.H Gather and synthesize information about how sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.
Technology and Engineering:	3.5.6-8.N (ETS) - Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. 3.5.6-8.P (ETS) - Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
Environmental Literacy and Sustainability:	

Students will know…. (DCI)	Students will be able to… (SEP)	Students will apply…(CCC)
For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. All positions of objects and the directions of forces and motions must be described in	Constructing Explanations and Designing Solutions: Apply scientific ideas or principles to design an object, tool, process or system. Planning and Carrying Out Investigations: Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to support a claim. Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings.	Systems and System Models: Models can be used to represent systems and their interactions - such as inputs, processes and output - and energy and matter flows within systems. Stability and Change: Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. Scale, Proportion, and Quantity: Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and

an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.	Obtaining, Evaluating, and Communicating Information: Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.	processes. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural systems.

Core Activities and Corresponding Instructional Methods

Core Activities/Corresponding Instructional Methods/DOK Levels
Unit Question: Why do things sometimes get damaged when they hit each other?
Lesson Set 1 (Lessons 1-6) - How do objects interact when they make contact in a collision?
Lesson 1 1. Students will predict what would happen at the moment of impact and immediately after a collision in which a) an object breaks or b) an object doesn't break. (DOK 3)
Lesson 2 1. Students will develop a model to represent their understanding of energy transfer and forces that occur in a collision after viewing a series of videos. (DOK 3) 2. Students will define "force." (DOK 1) 3. Students will differentiate between balanced and unbalanced forces. (DOK 1). Video: Golf Ball Colliding with CD Case

[Video: Carts with Rubber Stoppers about to Collide] [Video: Carts with Metal Rings Colliding]. Lesson 3 1. Students will hypothesize whether or not all solid objects bend during a collision and will argue their claim. (DOK 3) 2. Students will conclude that all solids bend during a collision after viewing a series of videos. (DOK 2) Video: Car Collision Showing Bumpers Video: Golf Club Hitting a Golf Ball Video: Baseball and Bat Collision Video: Strength Testing of a Concrete Bridge Lesson 4 1. Students will make a model of the relationship between applied force, elasticity, and inelastic behavior of solids. (DOK 3) 2. Students will describe the effect that a material's shape and thickness have on deformation, elastic limit, and breaking point. (DOK 2)
Lesson 5 1. Students will conduct an investigation to discover the relationship between speed, mass, and force, changing the variables to understand how each impacts the other. (DOK 3) 2. Students will utilize a free body diagram to identify the forces acting on different objects in a collision. (DOK 2) 3. Students will connect kinetic energy and the amount of force an object can produce during a collision. (DOK 3) Video: Carts Colliding with a Brick Video: Carts with Different Masses Colliding Lesson 6 1. Students will apply their knowledge of forces, kinetic energy, and damage on a mid-unit assessment. (DOK 3)
Lesson Set 2 (Lessons 7-10) - How are changes in energy related to force interactions?
Lesson 7 1. Students will model how manipulating mass, speed, and kinetic energy impacts the amount of damage sustained during a collision. (DOK 3) 2. Students will relate the mass and speed of a moving object to its kinetic energy. (DOK 2) 3. Students will distinguish between independent and dependent variables. (DOK 1) Simulation: Collision Simulation Video: Condition A-Regular Speed and Mass Video: Condition B-Regular Speed and Double Mass

Video: Condition C-Double Speed and Regular Mass
Lesson 8 1. Students will review how contact forces cause energy transfer in a system using a model. (DOK 2) Lesson 9 1. Students will used their previously developed model to identify friction as a contact force that occurs when two objects touch. (DOK 2) 2. Students will identify surface texture as a source of friction. (DOK 1) 3. Students will conclude that energy can be transferred to and from collisions between objects and particles in the air (air resistance). (DOK 2) Simulation: Microscopic Friction Simulation
Lesson 10 1. Students will be assessed on collision-related phenomenon. (DOK 2)
Lessono Set 3 (Lessons 11-15) - What can we design to better protect objects in a collision?
Lesson 11 1. Students will utilize their collision-related knowledge for a related practical application (will vary based on teacher discretion). (DOK 3) Lesson 12 1. Students will explore various factors such as material, size, and structure that reduce peak forces in a collision. (DOK 2)
Lesson 13 1. Students will analyze how applied force and the damage that results from a collision can be manipulated. (DOK 4) Video: Cart and Brick Collision-No Rings Video: Cart and Brick Collision-1 Ring on Brick Video: Cart and Brick Collision-1 Ring on Cart Video: Cart and Brick Collision-2 Rings on Brick Video: Cart and Brick Collision-2 Rings on Cart Lesson 14 1. Students will engage in the engineer-design process to demonstrate how factors such as trade-offs and impact of stakeholder considerations influence the final outcome. (DOK 4)
Lesson 15 1. Students will propose a solution to a collision-based problem using a set of criteria and constraints while considering trade-offs. (DOK 4) Video: Cheerleading Competition Routine

Words that "May Be Encountered" throughout the Unit:

Air resistance	Deform	Net force
Axon	Elastic limit	Peak force
Breaking point	Fluid Friction	Rolling friction
Collision	Force	Sliding friction
Concussion	Free body diagram	Static friction
Contact force	Friction	Stored (potential) energy
Damage	Line of best fit	

Correctives:

Lesson 1: Terms such as force, energy, and motion are introduced in Lesson 2.

Lesson 2: Wait until Lesson 6 to connect the ideas of energy and forces together, when contact forces are discussed.

Lesson 3: Students will not differentiate between elastic and inelastic conditions at this point. "Deformation" will be used in the next lesson to describe how shape changes in an object after a collision.

Lesson 4: The spring-like behavior of solids should be considered and discussed in this lesson.

Lesson 5: Students will not be using free body diagrams as this unit focuses on forces in one dimension. The amount of force required to change the motion of an object will be explored in Lesson 7.

Lesson 6: The effects of changing mass and speed on kinetic energy will be investigated in Lesson 7.

Lesson 7: Focus of this lesson is to establish a relationship between net force and changes in motion, not identifying the mathematical relationship ($KE= 1/2mv^2$).

Lesson 8: Students will not be identifying energy transfers due to phenomena such as sound or infrared radiation. In addition, the model developed will not include forces such as gravity and normal force.

Lesson 9: Forces due to friction and air resistance will be taken into account, but some points of contact will still not be covered, this sets students up for future lessons as they will observe multiple forces as well as net force.

Lesson 10: Some students may acknowledge that some materials maintain their shape or protect objects better in a collision. Students can use these ideas beginning in the next lesson and for the remainder of this unit.

Lesson 11: This lesson will not explain why some materials are able to reduce peak forces they protect, the ideas generated will be used in Lessons 11-14 for discussion and comparison.

Lesson 12: Students may identify common properties of materials that are able to reduce force efficiently, but they will not alter their designs until later lessons. They will not make any conclusions as to what material is better at this point. In addition, data collected is focused on forces parallel to motion, gravity and normal force are not discussed.

Lesson 13: Students will be developing an understanding of the relationship between net force, time, and amount of change in an object. This will help them better understand momentum, but momentum is not the focus of this lesson or unit.

Lesson 14: Consequences of design changes in regards to cultural, economical, or stakeholder issues will not be a priority. Environmental impacts are listed but time does not need to be spent on these variables.

Lesson 15: This lesson is the formal end of this unit, Lesson 16 is an optional extension for classes that have a strong interest in building and testing their prototypes. If extension is utilized, it's best to be done immediately after Lesson 15.

Extensions:
To extend or enhance the unit, consider the following

Lesson 3: Consider letting students investigate the deformation of a table and other rigid materials in small groups using the laser setup. If this option is utilized, consider all proper safety precautions when using glass with students, such as safety goggles, gloves for potential sharp edges, and proper distribution and cleanup procedures that minimize encounters with any potential broken glass or other materials. See the materials preparation section of this lesson for more guidance.

Lesson 3: Add in additional slow-motion videos in areas of student interest, such as a football making contact with the ground for classrooms that have several students engaged in football.

Lesson 4: Expand the investigation to allow multiple groups to test multiple conditions. This would involve an increased number of materials and increased class time.

Lesson 5: Allow students to spend more time at each investigation station. Ask students to test out each station with increased mass, increased speed, and with a variety of moving and non-moving carts.

Lesson 6: Ask students to also revisit the related phenomena. Ask students to pick a related phenomena and explain the outcomes of the related phenomena (damage, no damage) using our science ideas. At this point, students should be able to construct a partial explanation for their related phenomena.

Lesson 10: Ask students to once again revisit their related phenomena and attempt to explain the outcomes of the collisions. At this point, students should be able to explain the forces on each object and the energy transfer that occurs in the collision.

Lesson 12: Consider allowing students to test a complete CD case in addition to a section of CD case plastic. Allow students to explain why a CD case that has space for air between the cover and backing reduces peak force more than a section of plastic.

Lesson 16: Conduct the optional Lesson 16 iterative design process and/or expand the iterative design process by involving those from the community to share their own personal protective design issues and allow students to develop a real-world solution to a problem within the community. Consider holding a design fair where the community can explore student's designs and offer feedback.

Assessments: Formative Assessments for Unit 2, Summary Table Template

Diagnostic	Formative	Summative
Diagnostic assessments can be in the form of the following: ● Preassessment: Initial Model in science notebook ● Driving Question Board ● KWL charts ● Concept mapping ● Open-ended questioning ● Drawing diagrams/model making ● Quick quizzes on key concepts drawing diagrams to explain a process ● "Think-Pair-Share" discussions on the phenomena in question ● Analyzation of real-world data to identify variables and potential relationships	The following formative assessments for Unit 2 can be found in the following document and may also include the following additional assessments: ● Progress Tracker ● Short Quizzes ● Exit Tickets ● Graphic organizers ● Lab notebooks with observations/journal entries ● CERs ● Peer feedback ● L2, Part 3: Plan Cup Investigations ● L2, Part 4: Carry Out Cup Investigations ● L2, Part 5: Analyze	To evaluate students' mastery of the unit's scientific concepts, the following assessments can be utilized to measure their understanding: ● Two-part Student Assessment/Mid-Point Assessment ● Disaster Blanket Design Assessment ● Self-Assessment and Peer Feedback ● Project presentation ● Unit test ● Research paper essay

	Class Data ● L2, Part 7: Order the Cups by Performance ● L3, Part 3: Analyze Hot Water Data ● L3, Part 6: Agree Upon Procedures for Our Investigation	

Unit 3 Curriculum Map

Overview: In this unit, students develop ideas related to how sounds are produced, how they travel through media, and how they affect objects at a distance. Their investigations are motivated by trying to account for a perplexing anchoring phenomenon — a truck is playing loud music in a parking lot and the windows of a building across the parking lot visibly shake in response to the music.

They make observations of sound sources to revisit the K–5 idea that objects vibrate when they make sounds. They figure out that patterns of differences in those vibrations are tied to differences in characteristics of the sounds being made. They gather data on how objects vibrate when making different sounds to characterize how a vibrating object's motion is tied to the loudness and pitch of the sounds they make. Students also conduct experiments to support the idea that sound needs matter to travel through, and they will use models and simulations to explain how sound travels through matter at the particle level.

Big Ideas:

- Waves are repeating patterns of motion that transfer energy and information without transferring matter.
- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave pattern of changing electric and magnetic fields that interact with matter.

Textbook and Supplemental Resources: Unit 3 Materials Folder, Unit 3 Video Links, OpenSciEd 8.2: Sound Waves, and ThinkCentral ScienceFusion textbook series

Unit 3: Sound Waves

Standards (by number):	Essential Questions: • What are the characteristic properties and behaviors of waves? • What is light? • How can one explain the varied effects that involve light? • What other forms of electromagnetic radiation are there?
Science:	3.2.6-8.Q Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. 3.2.6-8.R Develop and use a model to describe how waves are reflected, absorbed, or transmitted through various materials.

Technology and Engineering:	3.5.6-8.Q: Apply a technology and engineering design thinking process. 3.5.6-8.M Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. 3.5.6-8.N Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. 3.5.6-8.P (ETS) - Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
Environmental Literacy and Sustainability:	

Students will know…. (DCI)	Students will be able to… (SEP)	Students will apply…(CCC)
A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. A sound wave needs a medium through which it is transmitted. When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials	Using Mathematics and Computational Thinking: Use mathematical representations to describe and/or support scientific conclusions and design solutions. Developing and Using Models: Develop and use a model to describe phenomena.	Patterns: Graphs and charts can be used to identify patterns in data. Structure and Function: Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

(e.g., air and water, air and glass) where the light path bends. A wave model of light is useful for explaining brightness, color, and the frequency dependent bending of light at a surface between media. However, because light can travel through space, it cannot be a matter wave, like sound or water waves.		

Core Activities and Corresponding Instructional Methods

Core Activities/Corresponding Instructional Methods/DOK Levels
Unit Question: How can a sound make something move?
Lesson Set 1 (Lessons 1-6) - How are different sounds made?
Lesson 1 1. Students will observe a phenomenon that shows sound can cause objects to move. (DOK 1) Video: Truck Sound System Playing Music
Lesson 2 1. Students will investigate how vibrations and sounds are related using a series of videos. (DOK 2) Video: Slow Motion Guitar Strings Video: Slow Motion Drums Video: Slow Motion Speaker Video: Slow Motion Tuning Fork Vibration Video: Slow Motion Insect Flight at Night Video: Slow Motion Bee in Flight Lesson 3 1. Students will relate sound and deformation, as well as force and the volume of the resulting sound. (DOK 2) Simulation: Feeling the Sound

Lesson 4 1. Students will analyze motion graphs of different volumes of sound to identify patterns and trends. (DOK 3) Simulation: Turn It Up! Video: Music Box Being Played Lesson 5 1. Students will use mathematical representations of Position versus Time graphs generated from a tool used to scale up the vibrations of an object to describe wave patterns and support scientific conclusions about how objects move when they make higher-pitch and lower-pitch sounds. (DOK 4) Simulation: Hitting the High Notes
Lesson 6 1. Students will apply their knowledge on a summative mid-unit assessment. (DOK 3) Video: Slow Motion Harp
Lesson Set 2 (Lessons 7-11) - How does sound travel?
Lesson 7 1. Students will test how sound travels through the air in both open-air and air-tight settings. (DOK 2) 2. Students will make predictions about the “material” that is moving between a sound and our ears when a sound is produced. (DOK 3) Lesson 8 1. Students will conclude that sound needs matter to travel through. (DOK 2) 2. Students will recognize that sound cannot travel in a vacuum. (DOK 2) Video: Phone Ringing in a Vacuum Chamber
Lesson 9 1. Students will review the three states of matter and the motion of their particles in relation to particle collisions. (DOK 1) Lesson 10 1. Students will describe the relationship between pitch, loudness, and motion of particles in a medium. (DOK 2) Simulation: Visualizing Sound in a Medium Lesson 11 1. Students will demonstrate their knowledge of the cause of sounds and how they can make other things move. (DOK 2)
Lesson Set 3 (Lessons 12-14) - What happens at the sound receiver?

Lesson 12

1. Students will learn about the structure of the ear. (DOK 2)
2. Students will relate the structure of the ear to movement caused by sounds and how that ultimately sends signals to the brain. (DOK 2)

Link: Online Tone Generator
Video: Otoscope Demonstration
Video: Hair Cell Vibrating
Video: Cochlear Animation with Narration

Lesson 13

1. Students will connect the concepts of sound waves, including amplitude and frequency, to energy transfer.

Video: Pump up the Bass to Douse a Blaze

Lesson 14

1. Students will demonstrate their understanding by taking an assessment. (DOK 2)

Words that "May Be Encountered" throughout the Unit:

Amplitude
Cochlea
Compression
Cymbal
Detector
Eardrum
Frequency
Laser
Loudness
Matter
Medium
Outlier
Particles
Peak
Pitch
Receiver
Reflect
Soundwave
Stereocilia
Valley
Vibration
Wavelength

Correctives:

Lesson 1: It's important to keep pushing students to define what sound waves are, how they travel, or what is causing things not near the speakers to vibrate as they investigate. Students may have questions about how our ears work, this will be discussed later in the unit.

Lesson 2: In future lessons we will get to the idea that because the object making the sound initially deforms in the direction the force is traveling, the particles of the medium get compressed and then expand, bumping into their neighbors, and thus the resulting compressions and decompressions result in a sound wave.

Lesson 3: In this lesson, we do not dig any deeper into why these solid objects are springy; we are only looking for evidence that they do move that way. Recognizing that particles in a solid are held together by the forces of mutual attraction and repulsion (which act like springs) is necessary to understand why any medium transmits sound, but that discussion develops in later lessons.

Lesson 4: The graphs produced by the motion detector have the shape of waves, however, we do not call the graphs waves, but rather a graph of the motion of the stick.There is no representation of wavelength yet on this graph. Wavelength will appear as a characteristic of a pattern of energy and matter in the medium in Lesson 10.

Lesson 5: As students explore musical instruments, they should note that objects of shorter length play at higher pitch. On a guitar string, when a player holds a string against a fret, the player is shortening the length of the string that is free to vibrate and thus can play higher-pitch sounds. In the music box and on the xylophone, the shorter tines and shorter bars play higher pitches. It is not necessary for students to understand why shorter objects play higher notes because it requires better understanding of waves than students are likely to have at this time.

This lesson does not compare the amount of energy in changing the amplitude versus frequency of sounds. This will be addressed in Lesson 14 after looking at the human ear.

Lesson 6: Students will not be developing new concepts in this lesson. This is a chance for students to use and apply what they have been learning to this point.

Lesson 7: In this lesson, we aren't yet concerned with students coming to a full understanding of how sound is traveling. This question will fuel later investigations and should be emphasized when it comes up so it will loom large in students' minds as they move forward through the unit.

Encourage multiple representations at this point in the unit. At this point, it's fine for students to continue to show wavy lines or curves moving between sound source and receiver so long as there is consensus after this lesson that those symbols don't represent matter moving from one location to another.

Lesson 8: We want students to identify that sound can travel through a liquid, regardless of whether there is air dissolved in it. It is not in the scope of this unit to delve into the exact composition of different kinds of media.

For the purposes of this lesson, students will not yet be exploring the differences among different states or types of matter. This lesson leverages the pattern that the substances that sound can travel through (i.e., air, water, and solids like glass or plastic) are all made of matter. Future lessons will provide students with opportunities to explore how sound moves through these different media.

Lesson 9: Though students will draw models for the differences in particle spacing for solids, liquids, and gases, students will really only be simulating how particles collide within the spacing of liquids and gases. Simulating collisions in a gas is difficult to visualize and the difference in density between compressed and decompressed regions of particles is so small that it would be difficult to see in the simulation.

Lesson 10: The task for this lesson is to help students develop a model of what is traveling across the room. The simulation is helpful in that regard, but students will typically require a good deal of assistance in making sense of the simulation.Take time to make sure students understand what each part of the simulation represents. And make sure that students have time to grasp the importance of the motion of the particles in the medium.

Lesson 11: Students will continue to develop the idea that the energy put into the system by louder sounds results in greater-amplitude vibrations, which results in greater particle density changes.Help students connect this to the idea that the particles don't move from the sound source to the plastic wrap—only the energy moves.

Lesson 12: The websites linked in Information from the Experts include some specific anatomical terms for the structures of the ear. We focus on the following (which are explained in the reading itself): ear canal, eardrum, inner ear bones, cochlea, basilar membrane, hair cells, and stereocilia. Other more-complex terms are not necessary for students to know and use at this point (unless they are particularly interested in that aspect of science).

Lesson 13: For the purposes of this lesson, students focus on mean and median as simple measures to identify patterns across data from multiple groups, and the emphasis is on those broad patterns.

Lesson 14: This assessment provides an image of the ear and specifically asks students to zoom in on a part of the eardrum, thereby keeping the focus on explaining what is happening with the sound waves and their impact instead of on all the mechanics behind how we hear something.

Extensions:
To extend or enhance the unit, consider the following:

Lesson 6- In supplemental investigation 6A students can use a camera phone and wooden coffee stirrers to explore the relationship between how changing one variable (e.g. length of stick, thickness of sticks) affects the frequency of vibrations in the video to try to address this. It is currently designed as a differentiation option for students and teachers. Supplemental investigation 6B provides students with an opportunity to explore how our voices can make different kinds of sounds.

Several readings are included that could extend the learning. Some readings, such as the Big Ben reading (Lesson 3) is at a slightly higher lexile and could be used independently for those students who are at a higher reading level or in pairs or small groups for those needing more support. Similarly, in lesson 12, there are 2 additional readings. The second reading allows students to connect what they learned about the human ear to variations in the structure and range of hearing (function) in different animals (explaining a new phenomena) (Lexile 1200-

1300). Finally, a third optional reading is included to provide a differentiation option about how humpback whales hear and produce sound (Lexile 1000-1100).

All lessons: Remove scaffolds provided with Science and Engineering Practices as a way to give students more independent work with the elements of these practices.

Assessments:[**Assessments for Unit 3**], [**Summary Table Template**]

Diagnostic	Formative	Summative
Diagnostic assessments can be in the form of the following: ● Initial Model: Student Activity Sheet ● KWL charts ● Concept mapping ● Open-ended questioning ● Drawing diagrams/model making ● Quick quizzes on key concepts drawing diagrams to explain a process ● "Think-Pair-Share" discussions on the phenomena in question ● Analyzation of real-world data to identify variables and potential relationships	The following can be used for formative assessments throughout the unit: ● Progress Tracker ● Short Quizzes ● Exit Tickets ● Graphic organizers ● Lab notebooks with observations/journal entries ● CERs ● Illustration of a concept/Comic strip explanation ● Peer Feedback; Self-Assessment ● Student Handout Model ● Self-Assessment for Classroom Discussions	To evaluate students' mastery of the unit's scientific concepts, the following assessments can be utilized to measure their understanding: ● Student Assessment ● Individual Models

Unit 4 Curriculum Map

Overview: This unit launches with a slow-motion video of a speaker as it plays music. In the previous unit, students developed a model of sound. This unit allows students to investigate the cause of a speaker's vibration in addition to the effect.

Students dissect speakers to explore the inner workings, and engineer homemade cup speakers to manipulate the parts of the speaker. They identify that most speakers have the same parts–a magnet, a coil of wire, and a membrane. Students investigate each of these parts to figure out how they work together in the speaker system. Along the way, students manipulate the components (e.g. changing the strength of the magnet, number of coils, direction of current) to see how this technology can be modified and applied to a variety of contexts, like MagLev trains, junkyard magnets, and electric motors.

Big Ideas:

- All forces between objects, regardless of size or direction, arise from only a few types of interactions.
- Forces between objects can result in transfer of energy between these objects.

Textbook and Supplemental Resources: Unit 4 Materials Folder, Unit 4 Video Links, OpenSciEd 8.3: Forces at a Distance and ThinkCentral Science Fusion textbook series

Unit 4: Forces at a Distance

Standards (by number):	Essential Questions: ● What underlying forces explain the variety of interactions observed? ● How are forces related to energy?
Science:	3.2.6-8.I Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. 3.2.6-8.K Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. 3.2.6-8.P Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
Technology and Engineering:	3.5.6-8.A: Research information from various sources to use and maintain technological products or systems. 3.5.6-8.B: Use instruments to gather data on the performance of

	everyday products. 3.5.6-8.C Hypothesize what alternative outcomes (individual, cultural, and/or environmental) might have resulted had a different technological solution been selected. 3.5.6-8.D Analyze how the creation and use of technologies consumes renewable, non- renewable, and inexhaustible resources; creates waste; and may contribute to environmental challenges. 3.5.6-8.E Consider the impacts of a proposed or existing technology and devise strategies for reducing, reusing, and recycling waste caused by its creation. 3.5.6-8.F: Analyze examples of technologies that have changed the way people think, interact, live, and communicate. 3.5.6-8.G: Analyze how an invention or innovation was influenced by the context and circumstances in which it is developed. 3.5.6-8.H Evaluate trade-offs based on various perspectives as part of a decision process that recognizes the need for careful compromises among competing factors. 3.5.6-8.I: Examine the ways that technology can have both positive and negative effects at the same time. 3.5.6-8.J Use tools, materials, and machines to safely diagnose, adjust, and repair systems. 3.5.6-8.K: Use devices to control technological systems. 3.5.6-8.L: Design methods to gather data about technological systems. 3.5.6-8.M Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. 3.5.6-8.N Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

	3.5.6-8.O Interpret the accuracy of information collected. 3.5.6-8.P (ETS) Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. 3.5.6-8.Q: Apply a technology and engineering design thinking process. 3.5.6-8.R: Develop innovative products and systems that solve problems and extend capabilities based on individual or collective needs and wants. 3.5.6-8.S: Illustrate the benefits and opportunities associated with different approaches to design. 3.5.6-8.T: Create solutions to problems by identifying and applying human factors in design.
Environmental Literacy and Sustainability:	

Students will know…. (DCI)	Students will be able to…(SEP)	Students will apply…(CCC)
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. Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object,	Asking Questions and Defining Problems: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. Planning and Carrying Out Investigations: Conduct an investigation and evaluate the experimental design to produce data to serve as the	Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. Systems and System Models: Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.

or a ball, respectively). A system of objects may also contain stored (potential) energy, depending on their relative positions. When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	basis for evidence that can serve as the basis for evidence that can meet the goals of the investigation. Developing and Using Models: Develop a model to describe unobservable mechanisms.	

Core Activities and Corresponding Instructional Methods

Core Activities/Corresponding Instructional Methods/DOK Levels
Unit Question: How can a magnet move another object without touching it?
Lessons Set 1 (Lessons 1-6) - How can a magnet and a coil of wire interact through forces at a distance?
Lesson 1 1. Students will analyze the parts of a sound production system (ex: a speaker) (DOK 3) Video: Dissecting a Speaker
Lesson 2 1. Students will determine that an electromagnet can produce attractive or repulsive forces based on the magnet's orientation. (DOK 2) Lesson 3 1. Students will hypothesize the cause-and-effect relationship between energy transfer and magnets. (DOK 3) Video: Sound Source in a Vacuum Chamber Lesson 4 1. Students will identify the three-dimensional shape around a magnet as the magnetic field. (DOK 1) Simulation: Magnetic Fields Video: 3D Magnetic Field Lines

Video: 3D Magnetic Field Viewer

Lesson 5

1. Students will identify the characteristics of a magnetic field and the behavior of magnets. (DOK 2)

Simulation: Magnetic Fields

Lesson 6

1. Students will develop a model to demonstrate that magnetic fields can produce movement between objects without touching. (DOK 3)
2. Students will conclude that like forces repel while unlike forces attract. (DOK 2)

Lesson Set 2 (Lessons 7-9) - How does energy transfer through electromagnets, and across the space between magnets?

Lesson 7

1. Students will investigate how changing the distance between two magnets changes the amount of energy that can be transferred into and out of a magnetic field. (DOK 3)

Lesson 8

1. Students will explore the relationship between electric current and the strength of a magnetic field. (DOK 2)

Simulation: Turn It Up!
Simulation: Hitting the High Notes
Simulation: Circuit Construction

Lesson 9

1. Students will construct a class consensus model to explain the relationships between electric current and a magnetic field, and how that could produce motion. (DOK 3)
2. Students will explore how magnetic fields and kinetic energy are related. (DOK 2)
3. Students will research real-world examples of the interaction between electricity and magnetism (ex: maglev trains) (DOK 2)

Simulation: Magnetic Fields
Simulation: John Travoltage

Lesson 10

1. Students will analyze graphs and data from an investigation to determine the relationship between distance and the magnetic force exerted by two magnets. (DOK 3)

Lesson 11

1. Students will investigate the factors that cause changes in the strength of the magnetic forces. (DOK 2)

Lesson 12
1. Students will be assessed on their knowledge of magnetic fields and electric currents. (DOK 2)

Words that "May Be Encountered" throughout the Unit:

Attraction	Electromagnetism	Quantitfy
Compass	Ferromagnetic	Repulsion
Current	Linear	Semiconductor
Diaphragm	Magnet	Solenoid
Electric charge	Magnetic field	South-pole (of a magnet)
Electric circuit	Magnetic force	Speaker
Electric current	Magnetic levitation	Static electricity
Electricity	Non-linear	Voltage
Electromagnet	North-pole (of a magnet)	Wire

Correctives:

Lesson 1: Students may believe the speaker works because there are similar particle collisions happening in the air between the magnet and the wire. Over time students leave this model behind and figure out that the magnet and wire interact with each other even in a vacuum where no air exists between them (Lesson 3).

Lesson 2: Students will have established the idea of equal and opposite forces on two objects in contact with each other in the Collisions Unit. If you feel that students need to review the existence of equal and opposite force pairs before this lesson, consider doing so in the context of contact forces.

Some students may think that nonmetals can be attracted to and/or will attract a magnet since they may have seen magnets with a plastic or rubber coating (e.g., refrigerator magnets);Introduce the plastic cup from the homemade speaker either as a demonstration or as an object to test in the lab in order to eliminate this possibility.

Students may explain that the force is being transferred through particle collisions in the air or that the magnet simply pushes or compresses the air, which then pushes the coil and cup. This is a productive line of reasoning that we will investigate in Lesson 3, so do not correct this idea yet.

Students will see that the coil of wire acts like a magnet when it is connected to a battery. They may not yet think of the coil as magnetic, but they will begin to notice that the patterns they see in a magnet are also seen in the coil as an effect of the battery. But they will not dig deeper into what this means until Lesson 8. Do not comment on students' use of vocabulary like “electricity,” “current,” or “electrical force” at this point. These ideas will be developed later. Right now, focus on the cause-effect relationship rather than the mechanistic explanation: When we connect the wire to a battery, then the wire acts like a magnet.

Lesson 3: Encourage students to elaborate on what exactly they mean by “field.” Even if some students have accurate descriptions of “fields” prior to or during the lesson, they can still experience this lesson as a means of gathering evidentiary support for their predictions about the role of air in energy transfer through magnetic forces. Students will not describe or map a field in this lesson.

Lesson 4: Students start thinking about where the energy comes from that is transferred by the forces in a magnetic field, but they do not understand this idea yet. Sketched magnetic field lines, a visual tool to help us communicate about a magnetic field, are not introduced in this lesson or unit. However, students may come up with this representation on their own.

Lesson 5: Students may need a paper copy of the simulation in order to connect the dots between forces from magnetic fields and the compass, they may not use magnetic field lines in their diagrams.

Lesson 6: While the doorbell functions similar to the speaker, do not focus on the vibration or the alternating current portion of the process. These items will be introduced in the next lesson.

Lesson 7: Students should recall from the “Broken Things” unit that changes in motion are a result of a net force being exerted on an object, if not, they should begin to connect these ideas in order to explain their results. Lesson 9 will solidify their understanding of this connection.

Lesson 8: Changing batteries results in students changing the voltage, which is a change in potential energy. This lesson stops at this point, as voltage and resistance are not covered ion this lesson.

Lesson 9: This lesson does not define energy in terms of work, but explains how forces exchange energy. Students are not expected to understand the mathematical relationship between force and energy in this lesson.

Lesson 10: Explain that force is due to gravity in order to help students understand why weight is a measure of force. In OpenSciEd Unit 8.4 Earth in Space, students will get the chance to make these connections. We do not recommend spending time on this here.

Lesson 11: Throughout this unit, the magnetic field is represented with pointers to indicate direction of forces in the field to avoid misconceptions and to reinforce that a magnetic field is a continuous three-dimensional invisible physical object around a magnet.

Lesson 12: This unit is about forces at a distance, but the focus is only on magnetism, not on electricity or gravity. In the next OpenSciEd unit, the Space Unit, students will get the opportunity to dig into gravitational interactions and will apply their ideas about fields from this unit to that context.

Extensions:
To extend or enhance the unit, consider the following:

Lesson 2: Draw on students' experiences with magnets to help them see why this content is relevant to them. Consider asking students to each bring in a magnet from their own refrigerator or locker to test in this investigation. Would one of those magnets also make the speaker work? If there is time, try it. If students bring in magnets, give some space for them to share the magnet with the class and where it came from. Is it from a family trip? Is it sent from a relative who lives elsewhere? Is it an advertisement from a local company? Is it a picture of a loved one? Use these examples to highlight how common magnets are in our lives across a variety of contexts, even when we don't notice them.

Lessons 8-12: These lessons include guidance on how to provide a coherent enrichment experience for students who are interested in learning more about electricity or who have met and exceeded the performance expectations. These might also be helpful if your state has standards in addition to those laid out in the NGSS related to electricity and circuits. Look for guidance with heading "Electricity extension opportunity" to find optional enrichment support over the next four lessons. There may also be optional handouts associated with this enrichment. For more details on these opportunities, see the reference document titled *Electricity extension opportunity*.

All lessons: Remove scaffolds provided with Science and Engineering Practices as a way to give students more independent work with the elements of these practices.

Assessments:Assessments for Unit 4, Summary Table Template

Diagnostic	Formative	Summative
Diagnostic assessments can be in the form of the following: ● Initial models ● Driving question board ● Student notebooks ● KWL charts ● Concept mapping ● Open-ended questioning ● Drawing diagrams/model	The following can be used for formative assessments throughout the unit: ● Progress tracker ● Short quizzes ● Exit tickets ● Graphic organizers ● Lab notebooks with observations/journal	To evaluate students' mastery of the unit's scientific concepts, the following assessments can be utilized to measure their understanding: ● Doorbell Midpoint Assessment Midpoint ● Electromagnetic Summative Assessment

making ● Quick quizzes on key concepts drawing diagrams to explain a process ● "Think-Pair-Share" discussions on the phenomena in question ● Analyzation of real-world data to identify variables and potential relationships	entries ● CERs ● Illustration of a concept/Comic strip explanation ● Peer feedback ● Magnets Interaction Lab ● Self-Evaluation: Engaging in Classroom Discourse ● Student Hypothesis ● Reading Summary: Finding the Way ● Investigation ● Investigation Plan ● Hypothesis and Variables Handout ● Making Sense of Investigation Results ● Two Column Chart with Readings ● Speaker System Model ● Cause-Effect Table	

Unit 5 Curriculum Map

Overview: Students' conceptual understanding of chemical reactions for middle school science is foundational to much science learning. Understanding atomic level reactions is crucial for learning physical, life, earth, and space science. Even more importantly, they open up new windows of curiosity for students to see the world around them. By seventh grade, students are ready to take on the abstract nature of the interactions of atoms and molecules far too small to see.

To pique 8th grade students' curiosity and anchor the learning for the unit in the visible and concrete, students start with an experience of observing and analyzing a bath bomb as it fizzes and eventually disappears in the water. Their observations and questions about what is going on drive learning that digs into a series of related phenomena as students iterate and improve their models depicting what happens during chemical reactions for middle school science. By the end of the unit, students have a firm grasp on how to model simple molecules, know what to look for to determine if chemical reactions have occurred, and apply their knowledge to chemical reactions to show how mass is conserved when atoms are rearranged.

Big Ideas:

- All forms of matter exist as a result of the combination or rearrangement of atoms.
- The atoms of some substances combine or rearrange to form new substances that have different properties.
- Energy can be modeled as either motions of particles or as being stored in force fields.

Textbook and Supplemental Resources: Unit 5 Materials Folder, Unit 5 Video Links, OpenSciEd Unit 7.1 Chemical Reactions & Matter and ThinkCentral ScienceFusion textbook series

Unit 5: Chemical Reactions & Matter

Standards (by number):	Essential Questions: • How do particles combine to form the variety of matter one observes? • How do substances combine or change (react) to make new substances? • How does one characterize and explain these reactions and make predictions about the substances? • What is energy? • How can we make something new that was not there before?

Science:	3.2.6-8.A Develop models to describe the atomic composition of simple molecules and extended structures. 3.2.6-8.D Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. 3.2.6-8.E Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. 3.1.6-8.H Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass and speed of an object.
Technology and Engineering:	3.5.6-8.Q: Apply a technology and engineering design thinking process. 3.5.6-8.R: Develop innovative products and systems that solve problems and extend capabilities based on individual or collective needs and wants. 3.5.6-8.S: Illustrate the benefits and opportunities associated with different approaches to design.
Environmental Literacy and Sustainability:	

Students will know…. (DCI)	Students will be able to… (SEP)	Students will apply…(CCC)
Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Solids may be formed from molecules, or they may be	Developing and Using Models: Develop a model to describe phenomena. Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings. Developing and Using	Scale, Proportion, and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Patterns: Macroscopic patterns are related to the

extended structures with repeating subunits (e.g., crystals). Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change. Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	Models: Develop a model to describe unobservable mechanisms. Analyzing and Interpreting Data: Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	nature of microscopic and atomic level structure. Scale, Proportion, and Quantity: Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Core Activities and Corresponding Instructional Methods

Core Activities/Corresponding Instructional Methods/DOK Levels
Unit Question: How can we make something new that wasn't there before?
Lesson Set 1 (Lessons 1-6) - What is in the bath bomb that causes a gas to form?
Lesson 1 1. Students will observe a simple chemical reaction (examples include but are not limited to a bath bomb or a homemade volcano; at teacher discretion). (DOK 1) 2. Students will hypothesize the causes of the phenomena observed during the chemical reaction. (DOK 2)

Video: Store-Bought Bath Bomb in Water
Video: Store-Bought Bath Bomb in Water #2
Video: Bath Bomb Samples in Water

Lesson 2

1. Students will continue to make arguments from evidence and observations about the origin of the gas produced during a chemical reaction. (DOK 3)

Lesson 3

1. Students will produce a list of properties that can be used to describe matter. (DOK 1)
2. Students will differentiate between and provide examples of physical and chemical properties of matter. (DOK 2)

Lesson 4

1. Students will continue to investigate the causes of the gas produced during the chemical reaction observed in the anchoring phenomenon. (DOK 3)

Lesson 5

1. Students will conduct an investigation to demonstrate the relationship between the density of a substance and its ability to float or sink when surrounded by a different substance. (DOK 3)
2. Students will identify an unknown substance using different physical and chemical properties. (DOK 2)

Video: Flammability of Gas from a Bath Bomb
Video: Flammability of Air and Helium
Video: Density of the Gas from the Bath Bomb
Video: Density of Helium

Lesson 6

1. Students will continue to use physical and chemical properties to explain phenomena and identify substances on an assessment. (DOK 2)

Video: Elephant Toothpaste Part 1
Video: Elephant Toothpaste Part 2

Lesson Set 2 (lessons 7-14) - How can a new substance be made that wasn't there before?

Lesson 7

1. Students will summarize and reflect on their ideas to conclude that new substances can be produced during a chemical reaction. (DOK 2)

Lesson 8

1. Students will use a model to deduce that when new substances form from old substances, the particles of the old substances might break apart and/or stick together to form new combinations of particles. (DOK 3)

Lesson 9

1. Students will conduct an investigation to measure and collet data on the mass and volume of a gas produced by heating water. (DOK 3)
2. Students will graph this data to demonstrate that the ratio of the mass to volume is constant and is a physical property called density. (DOK 3)

Video: Heating Water Investigation

Lesson 10

1. Students will conduct an investigation to demonstrate that matter is neither created nor destroyed, it just changes form. (DOK 3)

Video: Flame Test with Electrical Energy

Lesson 11

1. Students will examine evidence to explain how the arrangement of atoms in a particular substance is unique to that substance and that the particles that make up old substances can be broken apart and the atoms that make them up can be rearranged to form new molecules to make new substances. (DOK 3)

Lesson 12

1. Students will use data and models to demonstrate that the amount of matter at the beginning (in the reactants) is the same amount of matter at the end of the reaction (in the products). (DOK 3)
2. Students will relate the law of conservation of mass/matter to chemical processes that involve the rearrangement of particles in a reaction but do not result in a gain or loss of mass/matter. (DOK 2)

Lesson 13

1. Students will relate the structure of cells in the nose to their function of receiving chemical signals transmitted by odors. (DOK 2)
2. Students will explain how perception of different scents is the result of a combination of signals that the brain receives from different nerve cells. (DOK 3)

Lesson 14

1. Students will apply their knowledge of properties and chemical reactions ut properties to explain a related phenomena (ex: pollution and erosion on marble of the Taj Mahal). (DOK 3)

Words that "May Be Encountered" throughout the Unit:

Acid rain	Calcium carbonate	Density
Algae	Carbon dioxide	Dissolve
Argon	Chemical process	Epsom salt
Atom	Chemical reaction	Flammability
Baking soda	Citric acid	Helium

Hydrogen
Insoluble
Iron
Malic acid
Marble
Meniscus
Methane
Mixture
Neon
Nitric acid
Nitrogen
Odor
Oxygen
Phase change
Pollutants
Product
Propane
Property
Reactant
Solubility
Soluble
State of matter
Substance
Sulfur
Sulphuric acid
Viscosity

Correctives:

Lesson 1: It is not important in this unit that students understand whether dissolving is a physical change or a chemical reaction. It is not important that they figure out what happens to the particles that make up the solid bath bomb as the solid dissolves, beyond the idea that the solid is breaking into little pieces too small to see. It is, however, productive to represent dissolving in the consensus models as "breaking into pieces of matter too small to see and mixing into the water." Do not try to label those as a specific kind of particle.

Lesson 2: Although the previous lesson elicited student ideas about the particulate nature of gases, that is not the focus of this lesson. That understanding will be revisited and refined further in later lessons.

Lesson 3: Students will not measure the boiling point or melting point of substances. They also will not measure or calculate density at this time. In this unit we will not be exploring pressures' relationship to boiling of a substance. We will assume boiling points are constant.

Lesson 4: It is not yet important that students determine that this is a chemical reaction. At this point, they only have a partial understanding of this idea: that certain combinations of substances, when mixed together, may cause a new substance to form. But they will need some additional data to support their new understanding about this idea.

It is not important that students understand the role of water in this process. Students already know that water causes baking soda to dissolve (break into smaller pieces), and that it does the same for citric acid. It could be reasonable to assume that one or both substances must be broken down into smaller pieces in order for the gas to appear.

Lesson 5: Students will not calculate the density of a gas. They will compare relative densities based on evidence of sinking and floating of that gas in room air. Density will be calculated for different substances when they work with clear liquids in later lessons.

Lesson 6: The reaction that occurs during the elephant's toothpaste investigation is exothermic and gets extremely hot initially. The focus in this assessment avoids any reference to temperature or energy changes in the system, and this aspect of the phenomenon should not be introduced. Energy changes in chemical processes will be a focus of the work students will be doing in their next unit *OpenSciEd Unit 7.2: How can we use chemical reactions to design a solution to a problem?*

Lesson 7: Students may use the word "atoms" interchangeably with particles and/or molecules at this point but we are not introducing the idea of atoms in this lesson, nor the distinction between them and molecules. If students raise the idea of atoms independently, it is unlikely they have ever thought about why atoms are needed to explain certain phenomena in the world—in particular why they are needed to account for how new substances can be formed and what evidence we have for their existence.

The reason why you will want to avoid introducing these ideas now is that this lesson and the next few lessons are designed to give students opportunities to dig deeper into their own prior ideas and build on ideas the class develops and pursues through investigations. By the end of this lesson set, students will develop a conceptual understanding of how the idea of atoms and atom rearrangement are necessary for explaining the formation of new substances in chemical processes.

Lesson 8: In this lesson, students do not figure out what kind of gas results from boiling and from electrolysis--they will figure that out in the next lesson. Though there are two different types of energy being added to water (thermal and electrical) this is not the focus of these few lessons. We will refer to both instances as adding energy to water. In the next unit, *OpenSciEd Unit 7.2: How can we use chemical reactions to design a solution to a problem? (Homemade Heater Unit)*, students will investigate the relationship between adding energy and chemical reactions.

Lesson 9: We do not introduce the fact that 1 mL is equivalent to 1 cubic centimeter, though you can make this connection if you wish.

We do not distinguish that the gas coming out of the flask from the heated water is likely a mixture of the gas above the water (air) and the water vapor released from the gas in the water bubbles when they reach the surface.

Lesson 10: In this lesson, we will not name the particles as "atoms" or "molecules." That vocabulary is developed in the next lesson. We will not develop the idea that water is made of two hydrogen particles and one oxygen particle. Some students may introduce the idea that they have heard that water particles are made of oxygen and hydrogen, based on a common reference they may have seen before that "water is H_2O." Encourage students to work with whatever ideas come to mind in their explanations, but don't establish this as a convention yet for referring to water.

It is not important that students identify either of the gases produced through electrolysis. It is only important that they have enough evidence to argue that they are not the same substance (based on the flammability test results).

Instead of using pure distilled water in the electrolysis production, you are making a solution of magnesium sulfate and distilled water. The dissolved particles of magnesium sulfate help speed up the process of electrolysis that produces the hydrogen and oxygen gas. Avoid introducing and describing the role of this additional substance to students, as it is peripheral to the source of the matter that the gases form from (the water molecules). Additional guidance is provided in a callout in the lesson if you run out of distilled water and need to use tap water instead.

No attempt is made to introduce electrons, ions, or bonds in this process. All of these ideas are above grade level.

Lesson 11: We use the word “compound” as an adjective to describe a type of particle that is made of more than one smaller piece (atom) in a way that is analogous to how the term is used for describing “compound words” in language, rather than emphasizing the scientific definition of a “compound,” which is a substance composed of two or more separate elements. We do not introduce the word “element” in this lesson.

Some of the molecular models students work on in day 2 show representations of the bonds between atoms within molecules as lines. Other models do not represent bonds. No effort is made to discuss what the lines in the models show, other than as a geometric arrangement and orientation. Bonds are a concept that is not introduced in this unit. They are not discussed in other OpenSciEd units either, as they are a high school disciplinary core idea.

Lesson 12: While students will be able to explain many parts of the chemical reactions, there will still be parts of the reactions that students cannot explain. The molecular structures of the substances in the reactions are simplified and ionic compounds are represented as individual particles rather than as extended structures. Students will not know that the ionic compounds dissociate in water

Balancing chemical equations is an idea that is above grade band. A balanced equation was introduced in the middle of day 2 in the lesson to provide a model that could be used to support the idea that matter is conserved because the total number of each type of atom is conserved in chemical reaction. There is no further work with working with balanced equations in this unit.

Water is included as a reactant in the chemical equation representing the reactants and products in the chemical reaction between baking soda. This serves to help reserve a spot for water playing a role in this process, without addressing what that role is (Is it a catalyst? Does it break down and then re-reform? etc.). No attempt is made to discuss the role of water further in this process.

Lesson 13: We are not getting into the other ways a human receives messages through the other sensory receptors. And we will not be going into the relationship between such signals and memories.

Other units in the OpenSciEd curriculum address other parts of the related DCI LS1.D, where each receptor responds to different inputs. Electromagnetic receptors are addressed in *OpenSciEd Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*. Mechanical receptors are addressed in *OpenSciEd Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)* and *OpenSciEd Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*. The related lessons that engage students in developing and using this idea also have students develop and use the related SEP of LS1-8 (Gather and communicate information) and the related CCC (cause and effect).

Lesson 14: It is not expected that students who answer question E on part 2b of the assessment will reason out that oxygen was taken out of the atmosphere in the chemical reaction. But some students may. Those students may inquire as to whether they can investigate whether this actually happens. You may want to provide that opportunity for extension if students inquire about this.

No attempt is made to explain why there is a (II) or (III) in the name of iron (II) sulfate or iron (III) nitrate. Balanced chemical equations are referenced in question F of part 2b, and though the idea of what the numbers in such an equation represent was introduced in Lesson 11, understanding what balanced equations represent is not a focus of that assessment question. Its focus is on planning investigations to collect related property data to support or refute the ideas that different substances might be produced from reactions between substances in acid rain and iron.

Extensions:
To extend or enhance the unit, consider the following

Lesson 6: This lesson is a transfer task in which students watch two video clips of the Elephant Toothpaste investigation and read second hand data from this investigation. If there is interest and time, this investigation could be done as a demonstration in class. This would allow students to use first hand data and observe this investigation closer up.

Lesson 10: If you have the supplies, you could have students work in small groups and conduct the electrolysis investigation with their small group.

Assessments: Assessments for Unit 5, Summary Table Template

Diagnostic	Formative	Summative
Diagnostic assessments can be in the form of the following: ● KWL charts ● Concept mapping ● Open-ended questioning ● Drawing diagrams/model making ● Quick quizzes on key concepts drawing diagrams to explain a process ● "Think-Pair-Share" discussions on the phenomena in question ● Analyzation of real-world data to identify variables and potential relationships ● Initial Model Handout ● Driving Question Board ● Student Self-Assessment Discussion Rubric	The following can be used for formative assessments throughout the unit: ● Progress Tracker ● Short Quizzes ● Exit Tickets ● Graphic organizers ● Lab notebooks with observations/journal entries ● CERs ● Illustration of a concept/Comic strip explanation ● Peer feedback ● Construct an argument in student notebooks ● My Predictive Explanations for the Gas from a Bath Bomb ● Individual argument on notebook paper (or digital)	To evaluate students' mastery of the unit's scientific concepts, the following assessments can be utilized to measure their understanding: ● Individual argument on notebook paper/in student notebooks (or create digital) ● Explaining another phenomenon OR Alternate: Explaining another phenomenon ● Explaining New Aspects of the Anchoring Phenomena ● Part 1: Explaining Marble Changes in the Taj Mahal and Part 2a: Explaining Marble Changes in the Taj Mahal OR Part 2b: Explaining Iron Changes in the Taj Mahal

Unit 6 Curriculum Map

Overview: In this 21-day unit, students are introduced to the anchoring phenomenon—a flameless heater in a Meal, Ready-to-Eat (MRE) that provides hot food to people by just adding water. In the first lesson set, students explore the inside of an MRE flameless heater, then do investigations to collect evidence to support the idea that this heater and another type of flameless heater (a single-use hand warmer) are undergoing chemical reactions as they get warm. Students have an opportunity to reflect on the engineering design process, defining stakeholders, and refining the criteria and constraints for the design solution.

In the second lesson set, students develop their design solutions by investigating how much food and reactants they should include in their homemade heater designs and go through a series of iterative testing and redesigning. This iterative design cycle includes peer feedback, consideration of design modification consequences, and analysis of impacts on stakeholders. Finally, students optimize their designs and have another team test their homemade heater instructions.

Big Ideas:

- The atoms of some substances combine or rearrange to form new substances that have different properties.
- People should gather, synthesize, and analyze information before drawing conclusions when assessing a technological product, system, or process.
- Decisions made about technology and engineering involve consideration of costs, benefits, and tradeoffs.

Textbook and Supplemental Resources: Unit 6 Materials Folder, Unit 6 Video Links, OpenSciEd Unit 7.2 Chemical Reactions & Energy and ThinkCentral ScienceFusion textbook series

Unit 6: Chemical Reactions & Energy

Standards (by number):	Essential Questions: • How do substances combine or change (react) to make new substances? • How does one characterize and explain these reactions and make predictions about them? • How can information be used to evaluate technological products, systems and processes? • How do costs, benefits, and tradeoffs factor into decisions made about technology and engineering? • How can we use chemical reactions to design a solution to a problem?
Science:	3.2.6-8.F Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.
Technology and Engineering:	3.5.6-8.P Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. 3.5.6-8.N Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. 3.5.6-8.M Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. 3.5.6-8.Q: Apply a technology and engineering design thinking process. 3.5.6-8.R: Develop innovative products and systems that solve problems and extend capabilities based on individual or collective needs and wants. 3.5.6-8.S: Illustrate the benefits and opportunities associated with different approaches to design.
Environmental Literacy and Sustainability:	

Students will know…. (DCI)	Students will be able to… (SEP)	Students will apply…(CCC)
Some chemical reactions release energy, others store energy. ETS1.B: Developing Possible Solutions: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. ETS1.B: Developing Possible Solutions: A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. Models of all kinds are important for testing solutions. ETS1.C: Optimizing the Design Solution: The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. ETS1.B: Developing Possible Solutions: Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. ETS1.C: Optimizing the Design Solution: Although one design may not perform the best across all tests, identifying the characteristics	Constructing Explanations and Designing Solutions: Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings. Developing and Using Models: Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. Engaging in Argument From Evidence: Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	Energy and Matter: The transfer of energy can be tracked as energy flows through a designed or natural system. (TEP) Critical Thinking: Defends technological decisions based on evidence. (TEP) Optimism: Shows persistence in addressing technological problems and finding solutions to those problems.

of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.		

Core Activities and Corresponding Instructional Methods

Core Activities/Corresponding Instructional Methods/DOK Levels
Unit Question: How can we use chemical reactions to design a solution to a problem?
Lesson Set 1 (Lessons 1-5) - How can we heat up food when we don't have our typical methods available?
Lesson 1 1. Students will observe a chemical reaction-based phenomenon (ex: using a flameless heater for prepacked MREs) that will then be used to drive the engineering and design process. (DOK 2) Video: Opening an MRE Video: Person Eating an MRE
Lesson 2 1. Students will investigate how energy transfers from the system of atoms rearranging themselves during a chemical reaction to surrounding systems. (DOK 3) Video: Time-Lapse of MRE Heater Video: Time-Lapse of Handwarmer Heater Video: Contents of MRE Heater Video: Contents of Handwarmer Heater Lesson 3 1. Students will explore how combining different substances can lead to a change in temperature during a chemical reaction. (DOK 2) 2. Students will determine that some chemical reactions release energy into their surroundings (exothermic) while others absorb energy from their surroundings (endothermic). (DOK 2) Video: Doubling Reactants of Food Lesson 4 1. Students will continue to engage in the engineering-design process. (DOK 3)

Lesson 5 1. Students will investigate the factors that will impact the effectiveness of their design proposals. (DOK 3) 2. Students will outline the steps of the cyclical design process (Define, Develop, Optimize) that engineers use to design solutions. (DOK 1)
Lesson Set 2 (Lessons 6-10) - How can we make decisions about the optimal design for our homemade flameless heater?
Lesson 6 1. Students will collaborate to design a proposal to the phenomenon-based design problem. (DOK 3) Video: Massing an MRE
Lesson 7 1. Students will identify strengths and weaknesses in their designs and that of their classmates. (DOK 3) Lesson 8 1. Students will analyze and evaluate how changes to the proposed designs during the engineering process could impact stakeholders. (DOK 4) Lesson 9 1. Students will continue to be engaged in the engineering process by optimizing their products while adhering to a set of constraints and criteria. (DOK 3)
Lesson 10 1. Students will be assessed on their understanding of the design process using a related phenomenon. (DOK 2)

Words that "May Be Encountered" throughout the Unit:

Cascading consequences	Optimize	Stakeholders
Endothermic	Prototype	Trade-offs
Exothermic	Research	

Correctives:

Lesson 1: While students will notice that this flameless heater causes food to heat up, they do not yet name this an *exothermic process*. That term is added to the Word Wall in Lesson 3, after students also have experience with exothermic and endothermic processes.

This unit will focus a great deal on energy transfer between systems, but in this lesson, students may or may not identify the heater and food as two distinct systems; and they may not yet name energy transfer as the cause of the food heating up. That thinking may begin here but will be further developed throughout the unit, beginning in Lesson 2.

Lesson 2: A common partial understanding students may have is that during an exothermic reaction (when the thermometer detects a temperature increase), energy is being put into the chemical reaction (the system of atoms that are rearranging) in order for it to feel warmer. This seems logical because in *Cup Design Unit* students learned that when objects heat up, energy is being transferred to them, for example, how energy from sunlight transfers into a clear cup, increasing the temperature of the liquid in the cup. The key to understanding why we measure a temperature increase is to focus on the system the thermometer is actually measuring.

While we will eventually tie this back to *Bath Bombs Unit* and show the atoms in each of the substances rearranging, we will not be zooming in to that scale in this lesson. We will broadly discuss that atoms are rearranging in a chemical reaction, but we won't add the specific products and reactants to our model until the next lesson.

Additionally, it is out of grade band for students to explain *why* energy is transferred to or from the system of reactants (the atoms that are rearranging to form products). This unit will only acknowledge that energy transfer coincides with atoms rearranging and use this idea to inform our designs.

Lesson 3: The mechanism for *why* energy transfer occurs in the patterns that it does involves the bonds and bonding energies between atoms in the system of substances that we're testing. Students will figure out in high school why these patterns occur because bonds between atoms are beyond the middle-school grade-band goal.

Also, there is no need in this unit to label energy in the chemical reaction system as "potential energy". Thinking about energy as energy without labeling the forms of energy at first has been shown to be helpful for students' sensemaking around this crosscutting concept. In OpenSciEd, 8th grade students will have opportunities to think about potential and kinetic energy within various systems.

In the root killer and aluminum reaction, there are two additional reactions going on besides the $3CuSO_4 + 2Al \rightarrow 3Cu + Al_2(SO_4)_3$. This lesson does not get into these side reactions, but here are the explanations for these reactions in case students are curious about why saltwater is needed or are trying to account for the hydrogen gas. The saltwater is needed to remove an outer layer of aluminium oxide on the aluminum foil to expose pure aluminium so that the main reaction with the $CuSO_4$ can begin. Also, it can be observed that hydrogen gas is simultaneously released from the reaction when aluminum metal foil is added to the $CuSO_4$ solution. If the pH of the solution is measured, it is found to be slightly acidic. Therefore, there are free hydrogen ions in solution, which cause the side reaction of hydrogen ions with the aluminum surface to form hydrogen gas and aluminum ions. Due to the limited concentration of hydrogen ions, this reaction consumes only a small amount of the aluminum.

Lesson 4: The amounts of aluminum and copper sulfate reactants were chosen based on the stoichiometry of the chemical reaction. Stoichiometry can be used to find the right proportion of reactants needed to *completely* react one reactant with the other reactant, resulting in no leftover reactants when the reaction takes place. In this case, when the *molar* ratio of $CuSO_4 \cdot 5H_2O$ to Al is 1.5 (3:2), the reactants are present in more or less stoichiometric amounts, i.e., neither is present in excess (this is approximate, as we are not accounting for any Al_2O_3 on the surface of the aluminum foil). Therefore, the combination of 0.5 grams of Al to 5.5 grams of $CuSO_4$ yields the greatest temperature change. This explanation is beyond grade band; however, students should qualitatively see that, for the other proportions of the reactants tested in this lesson that do not perform as well, there is an excess of one of the reactants (e.g., excess foil left over or the solution remains blue with less copper forming).

Students may want to test additional proportions of reactants. If you choose to test other combinations of reactants, be sure to conduct multiple trials of those combinations, in addition to those listed in *Investigation Procedure for Proportion of Reactants*.

Lesson 5: Students will not do a thorough analysis of the Stakeholder Survey results until Lesson 6. It is not important to focus on concerns about foodborne illness because students conclude that stakeholder-users will heat ready-to-eat food.

Lesson 6: The challenge of building a successful homemade flameless heater should not be viewed as a competition. Rather, the whole class is working to accomplish this task with the end goal of helping others. By sharing ideas within teams and among teams, many or all teams will be able to design an optimal solution by the end of the unit. If you hear talk in this lesson or future lessons about teams "winning" (maybe because they hit more of the criteria on the Design Testing Matrix), step in to adjust that thinking: we are working together to figure out how to make the best versions of heaters that we can in our groups.

In Lesson 7, teams will have the chance to compare their design with other teams in order to find and share the most promising ideas that can be used to optimize their design. However, the hope is that the motivation for this sharing time comes from the students. Therefore, it is not announced by the teacher in Lesson 6 that teams will compare designs next time.

Lesson 7: Sharing current design solutions with others and engaging in reciprocal feedback is an important aspect of engineering design. Students may be very excited and have new ideas about how to optimize their designs. Although it is productive for students to be thinking about their priorities for design modifications, decisions about specific changes should wait until a systematic look at potential consequences of any change is done in the next lesson.

In the spirit of collaboration, sharing of design performance should not be a competition. Teams should stay focused on sharing what worked or didn't work and collaboratively agree on the most promising design solutions. The norm-setting step is important for reminding students that giving and receiving feedback takes vulnerability. Critiques should be focused on design performance not team members or their actions.

Lesson 8: Students will be considering feedback about their designs in this lesson, but they will not yet address the feedback that was given about their instructions. When they write their final instructions in Lesson 9 they will revisit this feedback. With regard to design changes, we are not limiting students to a single change because it will likely be obvious that they should change 2-3 things based on what they learned in previous lessons. However, this is not a complete design overhaul. The idea is to use what they have learned to modify their design, not to start over from scratch.

Lesson 9: Students will be considering feedback about their designs in this lesson, but they will not yet address the feedback that was given about their instructions. When they write their final instructions in Lesson 9 they will revisit this feedback. With regard to design changes, we are not limiting students to a single change because it will likely be obvious that they should change 2-3 things based on what they learned in previous lessons. However, this is not a complete design overhaul. The idea is to use what they have learned to modify their design, not to start over from scratch.

Lesson 10: Parts of this assessment are not able to explicitly target DCIs included in this unit, such as the following: (1) ETS1.B A solution needs to be tested and then modified on the basis of the test results in order to improve it and (2) ETS1.B Models of all kinds are important for testing solutions.

These DCIs were addressed throughout the course of the unit and culminated in Lesson 9 with students' final optimal designs.

Extensions:
To extend or enhance the unit, consider the following

Lesson 1: If time allows, you may want to provide more context about the development of

MREs. The video available at the PBSSoCal website (link on Unit Overview Materials) explains how the US military's goal with MREs is to not only provide proper nutrition to the troops but to give them a sense of comfort and home with this food, as well.

Lesson 2: Students may question temperature change if the amount of hand warmers used changed. Give students an opportunity to test additional hand warmers, and give students an opportunity to wonder about and investigate the cost of this option to get adequate temperature changes to warm food.

Lesson 3: Students may notice that there are a lot of bubbles on the steel wool when it is submerged in vinegar. Vinegar is used to clean the surface of the steel wool by removing oils left on it after manufacturing. Iron in the freshly cleaned steel surface slowly starts to react with vinegar to produce hydrogen. As an extension activity, students can collect some of the gas and conduct a flammability test as in *OpenSciEd Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit)*. The root killer and aluminum foil in saltwater reaction also produces small hydrogen bubbles due to the sodium chloride disrupting the oxide layer on the foil; though, this may not be noticeable since it will occur inside of the closed cup. Therefore, this reaction could also be subject to a flammability test. The bubbles produced by the reaction of baking soda and vinegar contain carbon dioxide gas that will extinguish a flame and therefore is not flammable.

Lesson 6: Like developing classroom norms, you could choose to have students develop their own list of teamwork expectations. Knowing that they will be working together to create a successful design, what do they need from each other to make that happen? As students suggest expectations, you can fill them in on a shared document (such as the digital version of *Teamwork Self-Assessment*) and then print that out to add to their notebooks and to use as a self-assessment at the end of this lesson (and again in Lesson 9).

Assessments: Assessments for Unit 6, Summary Table Template

Diagnostic	Formative	Summative
Diagnostic assessments can be in the form of the following: ● KWL charts ● Concept mapping ● Open-ended questioning ● Drawing diagrams/model making	The following can be used for formative assessments throughout the unit: ● Progress Tracker ● Short Quizzes ● Exit Tickets ● Graphic organizers	To evaluate students' mastery of the unit's scientific concepts, the following assessments can be utilized to measure their understanding: ● Team Designs: Design Must Haves and

• Quick quizzes on key concepts drawing diagrams to explain a process • "Think-Pair-Share" discussions on the phenomena in question • Analyzation of real-world data to identify variables and potential relationships • Initial Models • Progress Tracker • Initial design solutions	• Lab notebooks with observations/journal entries • CERs • Illustration of a concept/Comic strip explanation • Peer feedback • Designs Questions Boards • Energy Transfer ModelsTeam Designs: Design Must-Haves and Engineering Design Rubric • Teamwork Self-Assessment	Engineering Design Rubric • Sea Turtle Assessment