NOTE: Many links lead to files available to Baltimore City Public School teachers only. Please email caplanb@caryinstitute.org for copies.

Thermochemistry (v08)
What determines the temperature in Baltimore?

Unit 6 discusses the question "What determines the temperature in Baltimore?" to address the concepts of temperature, heat, Earth structure, and climate.

Students assess current temperature conditions and propose an explanation of why Baltimore is not boiling hot or freezing cold. From there, they explore heat energy sources and effects from microscopic to macroscopic scales. At the microscopic scale students examine the thermochemistry concepts needed to design a chemical handwarmer. Through this process they study concepts of thermochemistry, including endothermic and exothermic reactions, heat capacity, and calorimetry. At the macroscopic scale, students apply thermochemistry concepts to the heat energy found within the earth's structure by exploring the concepts of radiation, convection, and conduction within the earth's core, mantle, and crust. Finally, students examine the effects of the largest energy source for the planet, the sun's radiation, through examining thermal radiation, global and local albedo, and the Urban Heat Island effect. Throughout the unit students continually develop models of heat and energy flow within calorimeters, the earth, and urban heat islands.

Common misconceptions/errors from the 2018-2019 Unit 6 Assessment. (Based on the most common incorrect U6 Assessment responses.)

- Modeling energy flow
- Kinetic vs Potential energy in chemical bonds
- Endothermic and Exothermic
    - Phase change process-energy flow patterns
    - Reading and analyzing graphic representations of energy
    - Diagraming energy flow within a system
- Calorimetry
    - Structure and function of the calorimeter
    - Energy flow within the calorimeter
- $Q=mc\Delta T$
    - Calculations
    - Heat capacity/specific heat
        - Impact on rate of temperature change
        - Impact on amount of temperature change
- Tectonics
    - Convection currents-cause and mechanics of how they work
    - Plate motion based on convection currents
    - Plate motion direction

Icon Key: STEM 41 discussion/questioning/ check for understanding prompt incorporating Cross Cutting Concepts

Activities that have specific ties to the Science and Engineering Practices

Lesson (45 min)	Description	Standards
1. Thermal Exploration	The key idea students will be asked to consider/master is "Why is the temperature outside what it is today?" Initially, students will look at global influences—such as the planet's internal heat, and the cold of space. Through exploration using IR thermometers, students will then develop a basic heat model showing heat in terms of the globe and in terms of the local materials they measured with the IR thermometers.	
What determines the temperature of objects around the school?	• **Opening Activity- Thermal Exploration:** Students will explore the local landscape to determine what types of items are warmer or colder. ○ Ask students "What could make objects outside be different temperatures?".	**NGSS Dimensions:** • PS3.D HS1

- Focus on what possible mechanism(s) could explain them being different temperatures
- Take students outside to record temperatures of various objects in their schoolyard using the IR thermometers.(SEP1)
    - Students are collecting data to inform them regarding the question "What affects the temperature of Earth's surface?".
    - Challenge students to find the highest and lowest temperatures in the schoolyard.
    - Ask students to record their data and save their data sheets for later in the unit.
    - Possible locations students could check:
        - under a car,
        - asphalt in the sun,
        - asphalt in the shade,
        - leaves,
        - grass in the middle of a field,
        - grass surrounded by bushes,
    - Have students design their data table for recording their data.
        - Should include:
            - Material
            - Location
            - Temperature
    - *Sample data table:*

Object/Material	**Location**	**Temperature (°C)**
Grass	Front lawn	
Concrete	Sidewalk	
Etc.		

- Resource for students who need help designing their data table: Thermal Exploration Data Table
- Share data and discuss patterns students observe once you return to the classroom.

- **Why are objects, in Baltimore, the temperature they are?** Teacher or student led discussion of the collected data with focus on what might be causing differences in the data. (SEP1)
    - Ask students:
        - What may be causing the differences in our data?
        - Where might the heat in the objects we observed come from?
    - Survey the students for responses. Possible survey methods include using Poll Everywhere,

- SEP1 HS8
- CCC4 HS3

Goggle forms, or white-boards.
        - Allow all possible answers that address the question.
- **Optional Review:** Students have a chance to review the concepts of heat and temperature if needed.
    - Students use their own words to write definitions of temperature and heat.
        - **Teacher Notes:**
            - Students should have learned about temperature in middle school (MS-PS3-4).
            - This activity is intended as a brief pre-assessment so the teacher can remind/reteach as necessary.
            - Temperature: How hot or cold a substance is based on the average kinetic energy of the molecules in a substance. (how fast the molecules in a substance are moving on average)
            - Heat: The transfer of thermal energy from a warmer substance to a cooler substance. (the transfer of energy from faster moving molecules to slower moving molecules)
    - Refer students to the different types of energy (see Types of Energy Graphic) and ask which of these could be involved in determining the temperature of the objects they observed in the schoolyard.
- **Initial Thermal Models:** Throughout the unit, students will be modeling the flow of thermal energy within objects and systems. This is their first attempt and will be used as a base for further modifications.
    - Students use the template to draw a model of an object from their field study (e.g., a rock, plant, section of sidewalk, car) using arrows to show inputs and outputs of energy. They should label where energy is stored and write an explanation of their diagram.(CCC4)
        - Students will draw and label arrows to show the energy inputs and outputs they think affect the temperature of their object. Each student model should all be different (see Sample Student Model A for an example).
        - **Teacher Note:** See the Modeling Template – Teacher Instructions for additional information.
    - Have students examine at least three other students' models and give feedback.
    - The instructor will generate a generic model, on chart paper, and ask for student input on what should be diagramed based on common ideas from their observed models. Keep this generic model in the room for later additions and edits as students develop their understanding of thermal models.
        - **Teacher Notes:** The file Generic Heat Model Anchor Chart shows a fully completed anchor chart. It would be expected that the initial form of this chart, as you and your students would create at this point in the lesson sequence, might only have one or

	two arrows on it. As you continue throughout the unit you will add to the chart, building the complexity of the model. ○ Collect and save student models for future use. • **Discussion Question** ○ Why isn't the Inner Harbor Boiling?/Why aren't we frozen? ▪ **Discussion Prompt**: How does energy flow determine temperature of objects? (CCC4) ○ Students can write or diagram/model their proposed explanation or have class discussion that pulls in information from class activities. • **Homework:** Read about cold weather at M&T Bank Stadium Cold Weather Football Sub-Zero Homework and research suggested methods for staying warm and healthy at a mid-winter football game and write one paragraph on how you would stay warm at the stadium. ○ **Teacher Note:** For those students who do not have internet access, print out the article: ▪ Ravens-Bengals Season Finale Is Coldest Home Game in Ravens History.	
2. Internal Energy Source: Chemical Reactions	Students begin the Sub-Zero activity by examining a number of different reactions that cause temperature change and equilibrium. Students will be tasked with modeling what is happening within the reactions to cause the temperature to change. (Long term goal of the Sub-Zero activity is for students to design a hand warmer that can be used at a mid-winter Raven's game. Keep this in mind as you introduce the activity.)	
What chemical combinations produce heat?	• **Opening Activity:** Students will engage with each other by sharing the ideas from their homework assignment about how to stay warm at M&T Bank Stadium when it is cold during a Raven's game. ○ Select a random student to share their paragraphs about staying warm at M&T Bank Stadium for a Raven's game. ○ Ask the class if anyone knows a way that chemistry could help make fans more comfortable. Introduce chemical hand warmers. ▪ **Teacher Notes:** • Have students think about sources of energy to warm the hands, hopefully using the models from Lesson 1. • These sources could include: ○ The sun ○ Heating system in the stadium (hot air or radiative heat from Heated water pipes, etc.) ○ Mechanical friction from rubbing hand together ○ Chemical reactions ▪ The most obvious examples of chemical reactions are fire and respiratory oxidation in their cells that releases heat.	**NGSS Dimensions:** • PS3.D HS1 • SEP6 HS1 • CCC2 HS1

- This final mechanism can inspire the transition needed at the beginning of this part of the unit. Guiding the students to think about chemical bond energy and chemical reactions inside a system as a source of heat for that system and ultimately other chemical reactions besides biological respiration, that can be used to make handwarmers.

- **Explore Equilibrium with Endothermic & Exothermic Reactions:** Student groups will explore endothermic or exothermic chemical reactions and share their findings in the class. (SEP6)
    - Have half of the class looks at an endothermic reaction, while the other half of the class looks at an exothermic reaction.
        - Exothermic Reactions (in the presence of water):
            - Acetic acid ($C_2H_4O_2$) + sodium bicarbonate ($NaHCO_3$) ➞ sodium acetate ($NaC_2H_3O_2$) + water (H_2O) + carbon dioxide (CO_2)
            - Sodium bicarbonate ($NaHCO_3$) + calcium chloride ($CaCl_2$) ➞ calcium carbonate ($CaCO_3$) + sodium chloride (NaCl) + water (H_2O) + carbon dioxide (CO_2)
            - Additional Exothermic Reaction Examples
        - Endothermic Reactions (in the presence of water):
            - In the presence of water: citric acid ($C_6H_8O_7$) + sodium bicarbonate ($NaHCO_3$) ➞ sodium citrate ($Na_3C_6H_5O_7$), water (H_2O), and carbon dioxide (CO_2)
            - Additional Endothermic Reaction Examples
        - See Exothermic, Endothermic, & Chemical Change for a more in depth investigation.
    - Students will define the system.
    - Students then mix the reactants and use Vernier temperature probes to watch what happens to temperature over time.
    - Students will share their data with another group that did the other reaction type and answer the question, “What happened to the temperature over time?”

- **Sub-Zero Task A: (Pages 2- 4 of student packet):** With the goal of designing a useable handwarmer, students will test their chosen chemical combination for heating ability. (SEP6)
    - **Teacher Notes:**
        - **Sub-Zero Prep**: Student Packet-copy a packet per student. This packet contains all of the student work, data tables, and model sheets for the entire activity.
        - Teachers can either keep the packets in the room for students to pick up each day they are to be used or allow students to hold on to them and collect them at the end

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<td>of the activity sequence.
▪ Sub-Zero Teacher Guide-Modifications have been made to the “story line” of this original activity to make it more Baltimore region specific. The student work no longer refers to crabbing in the Bering Sea. Instead students are asked to develop a means of staying warm at a Raven’s game.
○ Students will select one dissolution and one chemical reaction, from Table A, to analyze for its ability to heat its surroundings.
○ Next, they will draw the molecular level of compounds before and after the chemical process.
○ Finally, students will explain why the chemical reaction occurs or what chemical property leads to dissolution.
▪ Encourage students to use knowledge of outer electron states and patterns of chemical properties from previous units in their explanations.
• Teacher Note: The evidence statements, on pages nine and ten of the Sub-Zero Teacher Guide, provide detailed expectations for student models and explanations.
○ Discussion Prompt: What do you predict would happen if [change to one component of complex system] to [component that has an indirect, rather than direct, connection to the first component]?(CCC2)
• Homework: Complete the explanation from Sub-Zero Task A if it was not completed in class.</td>
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<td>3. Conservation of Thermal Energy</td>
<td colspan="2">Students continue with the Sub-Zero investigation (Task B is a laboratory activity). In it, they will be testing the use and accuracy of a coffee cup calorimeter by predicting the final temperature of a mixture of two samples of water, and then comparing it to the actual temperature achieved in the lab. This is a necessary step to aid in the design of the hand warmer.</td>
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<td>What happens to thermal energy when two samples of water at different temperatures interact?</td>
<td>• Opening Activity: Engage students’ curiosity by having them observe the interactions between hot and cold water. (This may be done completely as a demonstration if time and/or materials are limited.)
○ Demo mixing 100 mL of 100 °C water (add red food coloring) with 100 mL of 50 °C water (add yellow food coloring).
○ Discussion Prompt: What is happening to energy in this system? (CCC5)
▪ Have students draw before and after diagrams showing what they think is happening to the thermal energy and write predictions for the final temperature.
▪ Hot Water Modeling sheet.
○ Allow the class to do the experiment themselves to determine their final temperature as a test of their prediction.
○ Introduce the term “thermal equilibrium” to describe what the students observed.
• Sub-Zero Task B (Page 5-8 of student packet): Students will test the accuracy of a coffee cup</td>
<td>NGSS Dimensions:
• ESS2.C HS1
• SEP3 HS1
• CCC5 HS2</td>
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	calorimeter. (SEP3) ○ Determine whether a coffee cup calorimeter will give you accurate data. ▪ Measure (more than once) the final temperature for when 50 mL of 100 °C water is mixed with 50 mL of 50 °C water. ○ Students construct an argument supporting or refuting the claim that the system is isolated from the surroundings and describe the final system conditions at the point of highest solution temperature. ▪ Arguments should contain a claim, evidence, and an explanation of the reasoning. ▪ Students should calculate % discrepancy between the ideal and actual final temperatures. • Provide students with the "ideal" final temperature of 75°C. ▪ The evidence statements, on Sub-Zero Teacher Guide page 10-11, provide detailed expectations for student responses. • **Closing:** Students will summarize and generalize their findings from the laboratory. ○ Students should be able to use evidence from their experiment to show that $q_{gain} = - q_{lost}$ in an ideal, isolated system. ○ Add concepts to the Class Generic Heat Model as appropriate. • **Homework:** Students may need to complete their arguments (including claim, evidence, and reasoning) and thermal energy models as homework.	
4. Heat Capacity	Students will explore the concept of heat capacity through observation of the temperature change of differing materials.	
How do different materials react to heat?	• **Opening Activity:** Students will begin their study of heat capacity by investigating the thermal conductivity of metals and plastics. ○ I'm Melting! Investigation where students investigate the heat conductivity of different materials. This can be done in groups or as a demonstration. ▪ **Materials:** • Beaker • Plastic spoon • Metal spoon • 2 Beads • Hot plate • Water • Butter/shortening • Stopwatch ○ Or show the video Amazing Ice Melting Blocks (Educational Innovations: 00:21)	**NGSS Dimensions:** • ESS2.C HS1 • SEP3 HS1 • CCC5 HS2

- Ask students to speculate what could cause the different rate of melting.
- Do not explain anything. The purpose is to intrigue students with materials that clearly respond unexpectedly to heat.

  - Discussion Prompt: What is happening to energy in this system? (CCC5)

- **Student-Designed Experiment:** Students will design the protocols for an investigation of temperature change in different pure substances. This investigation will involve substances cooling as they sit out after being heated or cooled in a water bath. Then they will compare the differences between substances to begin to develop the idea of specific heat capacity.
  - Students design and conduct an experiment using equal-masses of pure substances to investigate the temperature of different materials as they are heated or cooled. (SEP3)
    - General concepts: Given substances at 0 C and 100 C How long does it take for each to come to room temperature when removed from their hot and cold-water baths?
  - **Teacher Notes:**
    - Provide students with IR Thermometers, computers, masses, and an experimental design template (if necessary). and at least two different pure substances (i.e. copper and aluminum samples).
      - Save time for the investigation by having the samples already at 0 °C (in an ice-water bath) and 100 °C (boiling water bath).
    - A variety of templates could be used.
      - The ADI Laboratory Investigation Proposal C is for direct measurements/observations.
      - The ADI Laboratory Investigation Proposal A is for comparing two competing hypotheses.
    - Students need to end up with a graph showing temperature as a function of time for at least two different substances (ex: copper & aluminum).
    - Questions the teacher might use to help students who are having troubles in designing their laboratory procedures include:
      - What are you trying to figure out?
      - What variables are you measuring?
      - What will be the constant for all of your samples?
      - What do you expect to see?
      - Why aren't the temperature changes different for ___________?
    - Students should discover that ΔT is different for different materials. Ideally, they will also discover that ΔT is directly proportional to time/heat.
      - Students should be able to compare the graphs of temperature as a function of time and see that different materials take different times for the same ΔT.

- Encourage students to make charts showing the times for various temperature changes (see following example).

	Substance A	Substance B
Time (s)	T (°C)	T (°C)
0		
5		
10		
15		

- **Homework:** Complete a lab write-up including a CER conclusion.

5. Calorimetry – Part 1

Students investigate the concepts and properties of calorimetry via a POGIL and then complete their analysis of Sub-Zero Task B. **Teacher Note:** You have two scheduled days for this topic.

How are thermal energy, heat, and mass related?

- **Opening Activity:** Introduce students to the basics of calorimetry using a video demonstration.
  - Show a short video of a calorimetry experiment (pick one).
    - Video Demonstration Calorimetry (YouTube-1:32).
    - Burning foods to measure calories (YouTube-4:08)
  - Tell the students that they are going to use data from calorimetry experiments to figure out how thermal energy, heat, and mass are related.
- POGIL ***Calorimetry*** **Models 1 & 2 (Key & Resources)**: Students will explore the concept and processes of calorimetry. (SEP5)
  - Group students into groups of 3 and review your POGIL roles and practices.
  - Read the opening prompt with the students.
  - Have students complete Model 1 (numbers 1-2).
  - Discussion Prompt**:** How does energy flow within the system?(CCC4)
  - After discussing their observations, allow students to complete Model 2 (numbers 3-6).
  - The purpose of this POGIL activity is to relate heat energy and temperature through the lens of specific heat.
- **Homework:** Video Worksheet-Calorimetry: Crash Course Chemistry

NGSS Dimensions:
- PS3.D HS1
- SEP5 HS2
- CCC4 HS3

6. Calorimetry – Part 2

Students investigate the concepts and properties of calorimetry via a POGIL and then complete their analysis of Sub-Zero Task B. **Teacher Note:** This is your second scheduled day for this topic.

How are thermal energy, heat, and mass related?

- **Opening Activity:** Engage students' memory from Lesson 5 by creating a quick quiz or online game.
  - Utilize a teacher generated review quiz/game (such as Kahoot! or Quizizz) to review concepts with the students.
- POGIL ***Calorimetry*** **Models 3 (Key & Resources)**: Students will explore the concept and processes

NGSS Dimensions:
- PS3.D HS1
- SEP5 HS2

	of calorimetry. (SEP5) ○ Students will complete the POGIL Model 3. ○ Discuss the key concepts with the class. ○ Point out that the equation from the video and the equation in the POGIL are the same but use different symbols for heat and specific heat capacity. ○ Discussion Prompt: Could you use the model to reliably predict the temperature changes in a different substance? (CCC4) • **Quantitative analysis of Task B:** Students will complete the analysis portion of task B. ○ Use the formulas $\mathbf{q_{gain} = - q_{lost}}$ and $\mathbf{q = mc\Delta T}$ to determine the q value for the system in Task B (data collected in Lesson 3). • **Homework:** **Specific Heat Capacity Worksheet**	• CCC4 HS3
7. Hand Warmers – Part 1	Students begin gathering data for to aid in their design of the chemical hand warmers in Task C. Lab teams choose two chemical combinations to test, gather and record results, and analyze the data.	
Which reactions/solvations could be used for hand warmers?	• **Opening Activity:** Engage students' prior experience as you begin the design process for handwarmers. ○ Ask students to think about which chemical reactions/solvations could be used for hand warmers as they complete Model 3 for the Calorimetry POGIL and Sub-Zero Task C. • **Sub-Zero Task C**: Students will experimentally determine temperature changes for reactions/solvations. ○ Have students identify the question under investigation, including if thermal energy is released when chemical bonds are broken during a chemical process. ○ Students will then follow the given procedures for the experiment. ○ Have students collect temperature data as the basis of evidence for whether thermal energy is produced. ○ Students will analyze the data for the change in temperature for each mass amount on the scatterplot.(SEP4) ○ Students should specify that they chose quantities for each solid compound that would allow them to extrapolate changes that might occur if quantities became too large or too small. ▪ **Teacher Note:** You may want to have each group test a different solvation and share the results with the class to save time. • **Class Generic Heat Model***:* Student will edit their heat model. ○ Add to the model as appropriate. • **Homework:** Complete graphs / data analysis if more time is needed.	**NGSS Dimensions:** • ESS2.C HS1 • SEP4 HS1 • CCC4 HS3

8. Thermal Energy in Chemical Systems	Students will complete model and graph energy change, based on their results from Task C, to complete Task D of the Sub-Zero activity.	

How does energy move between the system and its surroundings?	• **Opening Activity:** Ask students to consider systems, and how energy moves between the system and its surroundings as they complete Sub-Zero Task D.
	  ○ Class Discussion on the motion of energy between systems, and how it applies to Task D.
	• Sub-Zero Task D**:** Using the data from their experiment and the information provided students will create models and graphs of what is happening at the molecular level to illustrate the change in energy of the system before and after the chemical reactions in your experiment occurred. (SEP4)
	  ○ In this activity you will have the students create models and graphs of what is happening at the molecular level to illustrate the change in energy of the system**.**
	  ○ Students should create models to illustrate the change in energy of the chemical system at the molecular level by:
	    ▪ labeling, and describing the components of the model. Including:
	      • The chemical species participating in the reaction, both before and after the reaction.
	      • The bonds that are broken during the course of the reaction and the new bonds that are formed.
	      • The relative bond energy at the start of the reaction and at the end of the reaction.
	      • The relative amount of thermal energy at the start of the reaction and at the end of the reaction.
	    ▪ describing the relationships between components of the model. Including:
	      • Arrows showing the movement of energy between the thermal energy of the molecules and the bond energy.
	      • A change in the bond energy over the course of the experiment that reflects a reciprocal change in the thermal energy of the system (e.g., bond energy goes down and thermal energy goes up).
	      • Any transfer of thermal energy to the surroundings.
	    ▪ describing the following connections.
	      • The change in energy of the system, which can be observed at a large scale, is driven by the total change in bond energy from the reactants to the products, which is reflective of changes happening at much smaller scale.
	      • A change in bond energy is accompanied by a change in thermal energy of the system, reflecting a transfer of energy.
	      • No energy is lost during the chemical reaction, just transformed, so that the
		NGSS Dimensions:
		• PS3.B HS5
		• SEP4 HS1
		• CCC4 HS3

	total energy of the system remains the same. • **Homework:** Complete the model for Sub-Zero Task D if it was not completed in class.	
9. Final Temperatures – Part 1	Students will complete Task E and F of Sub-Zero by comparing theoretical and actual lab-based results to determine if the data collected is accurate enough to use as a basis for further predictions about future outcomes. **Teacher Note:** You have two scheduled days for this topic.	

How accurately can we predict temperatures?	• **Opening Activity:** Have students look at their temperature measurements and consider the accuracy of their work.
	  ○ Ask your students to consider the accuracy of their temperature predictions as they complete Sub-Zero Task E and Task F.
	• Sub-Zero Task E**:** Students will be comparing the theoretical and actual temperature change from their experiment and developing a mathematical equation can be used to predict the change in temperature based on the mass of the compound.
	  ○ Have the students compare theoretical temperature changes to their experimental data. (SEP4)
	    ▪ Students should represent the data on the plot and include trendlines (line of best fit) for both the measured data and for the theoretical data for each reaction.
	    ▪ Students will then write equations that represent each of the trendlines for the measured and theoretical data for each reaction.
	• **Final Temperature Mini-Lesson-Derivation of a Final Temperature (T_f) Equation:** Using direct instruction, show students how the final temperature of a system is determined mathematically.
	  ○ Take students through the derivation of final temperature so that they can understand how scientists determined the final equation below. The key understanding that students need include:
	    ▪ the relationship between the T_f equation and the $q=mc\Delta T$ equation.
	    ▪ how to use the T_f equation.
	  ○ Outline of derivation:
	    ▪ $q_A = -q_B$ ← heat gained by object/substance A is the heat lost by object/substance B
	    ▪ $m_Ac_A\Delta T_A = - m_Bc_B\Delta T_B$ ← plug in $q = mc\Delta T$ for object/substance A & B
	    ▪ $m_Ac_A(T_f - T_{Ai}) = - m_Bc_B(T_f - T_{Bi})$ ← plug in $\Delta T = T_f - T_i$ for object/substance A & B, note T_f is the same for both objects/substances since both objects come to equilibrium
	    ▪ $m_Ac_AT_f - m_Ac_AT_{Ai} = - m_Bc_BT_f + m_Bc_BT_{Bi}$ - ← distribute
	    ▪ $m_Ac_AT_f + m_Bc_BT_f = m_Bc_BT_{Bi} + m_Ac_AT_{Ai}$ ← move the terms containing T_f to one side of the equation
	    ▪ $T_f(m_Ac_A + m_Bc_B) = m_Bc_BT_{Bi} + m_Ac_AT_{Ai}$ ← separate out T_f
	    ▪ $T_f = (m_Bc_BT_{Bi} + m_Ac_AT_{Ai})/(m_Ac_A + m_Bc_B)$ ← solve for T_f
		NGSS Dimensions:
		• PS3.B HS5
		• SEP4 HS1
		• CCC5 HS2

	• **Problem Solving Practice:** ○ The teacher should select conduction problems (with solids or fluids) where students must use mathematical models to predict final temperatures. ▪ Ex: Heat & Temperature Worksheet, see **problems 16-20** ○ The teacher should model how to solve at least one problem. ○ Students complete the remaining problems independently.	
10. Final Temperatures – Part 2	Students will complete Task E and F of Sub-Zero by comparing theoretical and actual lab-based results to determine if the data collected is accurate enough to use as a basis for further predictions about future outcomes. **Teacher Note:** This is your second scheduled day for this topic.	
How accurately can we predict temperatures?	• **Opening Activity:** Engage students' prior knowledge with a review activity. ○ Review Thermochemistry topics with a short teacher made interactive game. (i.e. Kahoot! or Quizizz) • **Extra Practice Problems:** *Give students more time to practice using the thermochemistry equations.* ○ Thermochemistry practice problems • **Sub-Zero Task F:** Students will determine whether the experimental temperature change is good enough to make accurate predictions. (SEP4) ○ In this activity students will: ▪ make a claim that includes that the experimental temperature change is similar enough to the theoretical temperature change to make accurate predictions. ▪ support the claim by identifying and describing evidence, including the similarities between the locations of the experimental points with the theoretical points and/or the similarities between the slope and intercept of the equations for the trendlines. ▪ describe the relevance of the evidence to the claim. ▪ synthesize the evidence and their evaluations, including reasoning that because the data points/trendlines are so similar, the predicted numbers are likely to be close enough to the measured numbers in a new experiment of different amounts or different reactions. • **Homework:** Thermochemistry Calculations practice worksheet.	**NGSS Dimensions:** • PS3.B HS5 • SEP4 HS1 • CCC5 HS2
11. Hand Warmers Part 2	Students will complete the Sub-Zero Design Challenge by determining the amount of materials needed to produce the heat required for their hand-warmer (Task G) and then defend their design in Task H.	
Which chemical reactions could be used to make safe hand warmers?	• **Opening Activity:** Introduce the concept of consumer safety to the students and ask them how it applies to their design. ○ Ask students to define/describe the concept of Consumer Safety. ○ Ask them to consider consumer safety as they complete Sub-Zero Task G and Task H. • **Sub-Zero Task G:** Students continue with their design process for their handwarmers by determining	**NGSS Dimensions:** • PS3.B HS5 • SEP5 HS2 • CCC3 HS1

	the mass needed to produce the desired temperature change. ○ Students create equations from the trendlines and correctly use them to solve for mass to achieve the temperature change for a maximum of 49 °C for each substance tested. • **Sub-Zero Task H:** Students make their final claim on the safety and viability of their design. ○ Students make a claim that includes that the chemical process is or is not a viable and safe option for use in hand warmers. ○ Students identify and describe the following as evidence: ▪ The change in temperature values using the trend line equation and/or trends in the data from the plot ▪ The amount of mass, or quantity of material, required to cause the temperature change as calculated using the trend line equation. ○ Students evaluate and synthesize the evidence using any of the following lines of reasoning: ▪ The reaction creates too low of a temperature change to be useful as a hand warmer with any mass of reactant. ▪ The reaction creates too high of a temperature change to be safe as a hand warmer even with small amounts of reactant. ▪ A reasonable temperature change requires too much reactant to be practically used as a hand warmer. ▪ The change in temperature is reasonable—that is, not too high or too low given a range in reactant amounts that are practical for use in a hand warmer. ○ In their evaluation, reasoning, and synthesis, students cite their molecular models as further evidence, describing how patterns observed at the molecular scale serve as evidence for why the reactants behaved as they did. • **Homework:** To prepare for Lesson 10: Taking the Temperature of Earth's Core Close Reading Activity	
12. Internal Energy Source: Inside Earth, Day 1	This lesson shifts the focus from the molecular level to the Global. The objectives of these lessons are for students to understand that 1) a significant portion of the heat within the earth comes from Radioactive decay and gravitational collapse, 2) Material in the earth is not static, this movement causes seismic waves that travel through earth and cause earthquakes, 3) the earth's interior structure can be determined by studying seismic waves, 4) Lab simulations can help us determine the temperature of the layers of the earth, and 5) the Inner earth is composed of layers of increasing density and temperature. **Teacher Note:** You have two scheduled days for this topic.	
How do we know the inside of the earth has hot liquid in it?	• **Opening Activity: What is inside an egg?** The teacher will use an egg to engage students in thinking about ways to "see" items that are not visible, such as the center of an egg or the center of the Earth. ○ Hold up an egg. ○ Ask: "How could you figure out what is inside the egg without breaking it?" ▪ Have students work in groups design an experiment. ▪ Encourage kids to be creative.	**NGSS Dimensions:** • ESS2.A HS2 • SEP2 HS6 • CCC4 HS3

        - This is a thought experiment so there are no budget or equipment constraints.
            - Teacher Resource:
                - How I Candle Eggs (YouTube: 5:24).
                - X-rays PowerPoint
    - State: "The earth is like a round egg, and we live on the shell."
        - Consider drawing a large circle and making a dot that is label it as Baltimore.
        - What could we use to "see" the inside of the earth?
            - Guiding thoughts—What type of energy passes through the earth that we can detect? Equate this concept to the light passing through the egg and lead the discussion toward earthquakes and seismic waves.

- **Determining and Measuring Earth's Layered Interior (Will take two class periods):** Using seismic data from the 2010 magnitude 7 earthquake in Haiti , students will examine how geologists know the composition of the layers of the Earth. (SEP2)
    - Students will examine seismic evidence to determine that the Earth must have a layered internal structure and to estimate the size of Earth's core.
    - **Teacher Notes:**
        - Click the green "Download All" button to retrieve the resources: Teacher Guide, PowerPoint, and excel data graph.
        - Before undertaking this activity, students should know what earthquakes are, understand the basics of seismic waves and their propagation, and be able to explain how seismograms are created.
        - Preparations:
            - The activity breaks the class into two groups-there are different materials for each group. Some copies are in color—they work in black and white as well.
            - Teachers have options for class organization:
                - Break the class into two major groups
                - Small groups of 4 with 2 members for each activity group.
            - Materials for groups:
                - Rulers
                - Meter sticks
                - Protector
                - Tape
    - Discussion Prompt: How does energy flow within the system?(CCC4)
- **Homework:** Complete the Geoblox Pie Slice of Earth model and the Questions worksheet for Pie Slice of Earth.(KEY)

<table>
<tr><td>13. Inside Earth, Day 2</td><td colspan="2">Students will complete the activity “Determining and Measuring Earth’s Layered Interior” then connect the structure of the earth to how the magnetic field of the earth is formed. Teacher Note: This is your second scheduled day for this topic.</td></tr>
<tr><td>Why does it matter what is inside Earth?</td><td>

- **Opening Activity- Density column demo:** Use a density column to ignite a discussion on the different behaviors of matter based on their density.
    - Ask students “What causes the earthquake waves to move at different rates through the earth? Density
    - Demo:
        - Mix water, sand, iron filings in a jar with a lid.
        - Ask students to predict what will happen after you shake the system and allow it to settle.
        - Shake and allow to settle.
        - Show layers and discuss why they formed as they did.
        - Have students look at their Pie Slice of Earth. Then ask student to answer the following questions:
            - Which layer would you predict to be the densest?
            - Which layer would you predict to be the least dense?
            - Explain your reasoning?
- **Determining and Measuring Earth’s Layered Interior (Continued):** Using seismic data from the 2010 magnitude 7 earthquake in Haiti , students will examine how geologists know the composition of the layers of the Earth. (SEP2)
    - Students pick up where they left off and continue to examine seismic evidence to determine that the Earth must have a layered internal structure and to estimate the size of Earth's core.
    - After comparing and discussing the predicted data and the observed data, students use a second scale model to further interpret these results. This can be completed as a facilitated symposium if time permits (See “Optional Files” on web page).
    - Discussion Prompt: What is estimated, rather than observed directly, in the model?
- **Optional recap- Virtual Tour of Earth’s Interior:** If needed, show students the Layers of the Earth video to tie the ideas together for the students.
    - Layers of the Earth (IRIS 6:20)
- **Magnetic Fields & Pole Reversals:** Teacher led discussion on how the motion of the different layers of the earth produces the Earth’s magnetic field and why it is important.
    - Ask students “Why does it matter that the earth has a spinning magnetic core?”
    - Show a video that answers the question and shows mentions pole reversals:
        - Measuring Earth’s Vital Magnetic Field (European Space Agency-first 1:55 only)
        - Magnetic Field Reversal (Science Channel-2:34).

</td><td>

NGSS Dimensions:

- ESS2.A HS2
- SEP2 HS6
- CCC1HS5

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</table>

	○ Have students explain to each other why it matters that the earth's core is spinning. • **Homework:** Why Does the Earth Have Layers? Video Homework	
14. Convection	Students will explore the process of convection with the goal of understanding: 1) the general behavior of fluids, 2) the outer core, mantle, bodies of water, and the atmosphere all regularly behave like fluids, 3) heat energy is transferred in fluids by diffusion, conduction, and convection/advection, and 4)where gravity is at work, cooled/more dense materials move downwards into the fluid forming convection cells.	
How is heat transferred within fluids, such as water bodies or the earth's interior?	• **Opening Activity:** Engage student's prior knowledge/real world experience with the idea of convection by discussing a convection oven. ○ Show students a picture of a convection/toaster oven and ask students how they work. ○ If necessary, explain that convection ovens use fans to move hot air from the heating elements to evenly cook the food. ▪ Optional video explanation: What is a convection oven? How it works?(YouTube 1:10) • **Vocabulary Development:** Student's build vocabulary by defining key terms. ○ Ask students to use their own words to write definitions for what they think a fluid is. ○ Fluid: a substance that has no fixed shape and yields easily to external pressure; a gas or a liquid • **Convection Experiment:** Students will investigate the behavior of water when it is headed from a single point, observing motion and the development of convection patterns. (SEP2) ○ Convection Lab Student Sheet ○ Martials needed: ▪ Styrofoam cups ▪ Clear plastic boxes ▪ Food coloring ▪ Ice cubes with food coloring ▪ Hot water ▪ Sawdust (or other granular floating material—black pepper would work as well.) ○ Discussion Prompt: What caused the patterns you observed? How do you know that the hot water and ice caused the water motion observed? How could you test it?(CCC2) ○ Optional Videos: ▪ Convection Currents (You Tube-3:04) (a bit over-hyped, but it relates the motion of ocean water and tectonic plates). Discuss how the rising and falling of fluids are caused by density differences, and how it makes a complete cycle. ▪ Convection Experiment (You Tube-2:41). Discussion here relates to movement of air; emphasize this happens in various Earth systems. • **Homework:** Ask students use the template to draw a model of the Earth's internal structure with	**NGSS Dimensions:** • ESS2.C HS1 • SEP2 HS3 • CCC2 HS1

	layers and convection processes included. ▪ Students should be able to show that convection moves heat around in the mantle. ▪ Student models should all be different (see Sample Student Model D for an example).	
15. Convection inside Earth (Plate Tectonics)	Students will examine global earthquake and volcano data to develop an understanding that convection within the Earth's mantle is the mechanism behind plate tectonics, earthquakes, and volcano formation.	
How does convection affect the surface of Earth?	• **Opening Activity:** Engage students' interest in earthquakes by playing music. ○ Play the audio from Carol King - I Feel the Earth Move (YouTube 3:09). • **Modeling the Cycling of Matter Inside Earth:** Connect convection currents to plate motion using a demonstration with Rheoscopic fluid. ○ Use Rheoscopic fluid model of the earth showing plate movement to model convection inside earth (YouTube 2:31) . ○ Relate the video to the lab activity from lesson 15 on convection currents. Point out the motion of the sawdust/pepper on the surface of the water compared to the bits of paper in the video. • **Global Earthquake Data:** Students will explore the locations of plate boundaries based on the locations of earthquakes and volcanoes. (SEP4) ○ Show students one of the following videos to help them better visualize how convection currents within earth cause plate tectonics. They should see, in the video, that earthquakes and volcanoes are more likely at tectonic plate boundaries. Please note that the earth's mantle is "predominantly sold but in geological time it behaves as a viscous fluid". ▪ Plate Tectonics (BBC-1:08) is a narrated video that shows convection currents moving tectonic plates and resulting volcanic eruptions. However, the crust appears too mushy. ▪ Spreading in the South Atlantic is a 11s animation showing how, over 130 million years, convection currents in the mantle moved South America away from Africa to form the South Atlantic Ocean. ▪ Ocean-Content Subduction is a 13s unnarrated animation that doesn't show the complete convection current but accurately depicts a volcano. ○ Global Earthquake, Volcano, and Tectonic Plate worksheet (Sample) ▪ Students look at a map of global earthquakes and volcanoes and draw likely tectonic plate boundaries on a blank map. ▪ Discussion Prompt: What patterns do you observe in the data presented on the map? (CCC1) ▪ After students have completed their map show them the map of tectonic plate boundaries. Have them compare the tectonic plate boundaries they drew to the ones	**NGSS Dimensions:** • ESS2.B HS1 • SEP4 HS1 • CCC1 HS5

	on the map and make corrections/modification to their map. ▪ **Teacher Notes:** • It is important to note that volcanism is a form of advective heat transfer, moving heat by buoyancy and pressure with the physical upward (or lateral) movement of molten rock (lava, magma). • Volcanoes are also a release point of heat from the inner earth as new crust is formed. • Additional Teacher Resources: What drives the movement of tectonic plates? This resource gives additional information on other forces that move tectonic plates. • **Click & Learn online activity:** Students use the interactive site to develop a more complete understanding of the process of plate tectonics. ○ Students will work through the Dynamic Earth Interactive. ▪ Have students take notes as they work through the activity ▪ Requires devices with Adobe Flash installed. ○ Teacher Resource video: ESS2B – Plate Tectonics & Large-Scale System Interactions (Bozeman Science 6:12) provides a nice concept summary for teachers, including what students should have learned previously. • **Global Heat Model:** Students update their models from Lesson 14's homework . ○ Ask student to edit/modify their models as needed, based on the material they learned today. • **Homework:** Complete Currents in the Earth System Reading Activity.	
16. Conduction	Students will utilize a computer simulation to study the process of conduction and compare the conductivity of differing materials.	
What happens when two objects, at different temperatures, touch?	• **Opening Activity:** Engage students' prior knowledge by asking student what happens if you put your tongue on a cold pole? ○ Ask, "What happens when two substances at different temperatures touch?" ○ Show A Christmas Story – Tongue Stuck to Pole (YouTube-2:14) from 1:10-2:14 to illustrate how heat flows from warmer substances to cooler substances. • **Simulation:** Students will investigate the conductive properties of materials using a computer simulation. (SEP2) ○ Use the Energy2D simulation from the Concord Consortium. ▪ The simulation is free. ▪ It can be downloaded and installed on school computers without requiring an administrator password.	**NGSS Dimensions:** • PS3.B HS5 • SEP2 HS3 • CCC5 HS2

	◦ Students will design an experiment to rank which of four materials (copper, glass, rubber, oak wood) is the best heat conductor and make a claim, provide evidence from the simulation, and explain their reasoning for their conclusion. ◦ Energy 2D Student Sheet ◦ Discussion Prompt: What is happening to energy in this system?(CCC5) • **Conduction through Earth's Crust:** Students connect the information from the simulation to the Earth's structure and behavior. ◦ Students read about geothermal gradients and use the template to update their global heat models to show conduction through Earth's crust. ▪ Student models should all be different (see Sample Student Model C for an example). ▪ See the Modeling Template – Teacher Instructions for additional information. ▪ Earth Heat Flow Map – for teacher information. • **Global Heat Model:** Students will make a final version of their global heat models by editing their current version and completing the explanation portion of the model sheet. ◦ Model sheet template. • **Homework:** Complete model if extra time is needed.	
17. External Energy Source: Energy from the Sun – Part 1	This lesson shifts the focus from the global level to the Solar. The objective of this lesson is for students to understand that hot objects (like the sun) emit shortwave (light) radiation that can travel through a vacuum and anything that is transparent. This radiation can either be reflected or absorbed by surfaces. The percentage of reflected radiation is the "albedo." Absorbed radiation will increase the temperature of the surface of the object. This heat energy is then released as long wave (infrared) radiation. **Teacher Note:** You have two scheduled days for this topic.	
What happens to radiation when it reaches the Earth?	• **Opening Activity:** Students will explore the effect of sunlight on surfaces by completing the Energy from the Sun activity. ◦ Energy from the Sun: (weather permitting) ▪ Give students a piece of paper and a magnifying glass (or other lens). You will also need black markers for students to share and stop watches. ▪ Go outside somewhere with direct sunlight that is also shielded from the wind. ▪ Directions/hints for students: • Make 2 circles. Leave one "white"(○) and fill one in solid "Black."(●) • Place your paper on the ground so you don't burn yourself. • Use the lens to focus light from the sun onto one of the spots on your paper. • Hold the lens so you have the smallest possible point of light. • Use a timer to see which circle burns fastest. • Discussion Question: Why would one catch fire faster than the other? ◦ **Teacher Note:** The key point is that the "white" circle should take longer to burn because it is reflecting more of the solar energy than	**NGSS Dimensions:** • PS3.D HS4 • SEP4 HS1 • CCC4 HS3

the "black" circle.

- Energy from Hot Objects: (bad-weather option)
  - Plug in an incandescent light bulb and heat up various other materials (a chunk of metal, a rock…).
  - Warn students that the objects are hot, and they will burn themselves if they touch them. Then allow students to take turns seeing if they can feel the heat without touching the objects or test them using the IR thermometers.
  - Discussion question: Why are they different temperatures if they have been sitting under the same light?

- **How much radiation does Baltimore get from the sun?** The teacher will lead a discussion on the amount of energy that Baltimore receives from the sun.
  - Ask students, "Where does the sun get its energy from?"
    - Students should know that nuclear fusion of hydrogen atoms provides the sun with power
    - **Teacher Note: Accepted power output =** 3.846×10^{26} W.
  - How much radiation from the sun reaches Earth's surface on average, per square meter?
    - Average value: 184 W/m^2.
    - **Teacher Notes**: The Value 184 W/m^2 can be found on this Energy Flow diagram by adding the absorbed and reflected solar energy at the surface.
  - Calculate the annual average power radiated by the sun to reach Baltimore City.
    - Students can look at this map to determine the average power radiated by the sun per square meter to reach the surface of Earth near Baltimore (180-200 W/m^2).
    - Students can look at the Wikipedia article on Baltimore to find the area of the land (210 km^2) and water (29 km^2).
      - Total Area: 210 km^2 + 29 km^2 = 239 km^2 = 2.39×10^8 m^2
      - Sample Calculation: $P_{Balt.} = (190\ W/m^2)(2.39 \times 10^8\ m^2) = 4.5 \times 10^{10}$ W
    - Student Worksheet: Energy in Baltimore
  - Students use the template to create a thermal models for Baltimore. (SEP4)
    - Models might include:
      - A general outline of a Baltimore-style city-scape.
      - Park or other urban-typical green areas.
      - Arrows with labels quantifying how much solar radiation is reaching Earth and Baltimore
    - Student models should all be different (see Sample Student Model B for an example).
    - See the Modeling Template – Teacher Instructions for additional information.
  - Create a Generic Heat model, for the class, based on student input.

	▪ Discussion Prompt: What part of the system does the model show? Why are these parts shown? What parts of the system are not shown in the model? Why are these parts not shown?(CCC4) ▪ Keep model up for further additions. • **Homework:** Students may complete their model if they need more time.	
18. External Energy Source: Energy from the Sun – Part 2	This lesson shifts the focus from the global level to the Solar. The objectives of this lesson are for students to understand that hot objects (like the sun) emit shortwave (light) radiation that can travel through a vacuum and anything that is transparent. This radiation can either be reflected or absorbed by surfaces. The percentage of reflected radiation is the "albedo". Absorbed radiation will increase the temperature of the surface of the object. This heat energy is then released as long wave (infrared) radiation. **Teacher Note:** This is your second scheduled day for this topic.	
What happens to radiation when it reaches the Earth?	• **Opening Activity:** Engage student's prior knowledge by using a review game. ○ Students review the concepts from yesterday using an interactive quiz type game, such as Kahoot, Quizlet Live, or Quizizz. • **Where does that heat go?: S**tudents will investigate the impact of color on the absorption and reflection of heat energy and its application to heating the city. ○ Lab Activity: Albedo Lab ▪ Special Material Preparation: You will need the incandescent lamps used in Biology and construction paper (Black and White will show the most dramatic differences, but dark and light combinations in different colors will show interesting variations. It is suggested that each group have different colors combinations of "dark and light" to increase variation and discussion.) along with the more traditional materials listed on the lab sheet. • **Teacher Notes**: Topic Resources: ○ Global Albedo, ○ What is Albedo, ○ Surface Albedo ▪ Discussion Prompt: How does energy flow within the system?(CCC4) • **Optional Albedo Lab Extension:** Students will extend their investigation by going outside. ○ Students go outside with the IR thermometers and investigate the effect of shade on pavement. ○ Materials needed: ▪ IR thermometers ▪ Carboard sheets ▪ Stopwatch • **Student Heat Models:** Students will update their Baltimore energy models based on the	**NGSS Dimensions:** • PS3.D HS4 • SEP4 HS1 • CCC4 HS3

	information from today's activity. (SEP4) ○ **Teacher Note:** In the past, students have had a hard time differentiating between reflected heat and heat radiated from buildings. It might be useful to discuss the differences and get students to create unique symbols to show the difference in their models. • **Class Generic Heat Model:** Add to the class model, as appropriate, based on student input. • **Homework:** Have students read the article: Dust linked to increased glacier melting, ocean productivity and then explain, in writing or through image diagrams, how the volcanic dust and sediment is able to increase the rate of melting of the glacier.	
19. Thermal Radiation – Part 1	The objective of this lesson is for students to understand that materials differ not only in how much energy they can reflect, but also in how much absorbed energy is needed to increase their temperature (Specific Heat). This property also influences the rate at which materials lose heat when exposed to a cooler medium. The stored heat is referred to Heat Capacity. The Specific Heat / Heat Capacity of building materials in an urban area can contribute to their role in influencing the temperature of the city in terms of excess heat stored in structures. The differences in Heat Capacity of materials could result in differences in when the air is heated over a day/night cycle. **Teacher Note:** You have two scheduled days for this topic.	
How does Earth's surface cool?	• **Opening Activity:** Engage student's prior experiences with heat waves by having them read a news article about heat advisories in Baltimore. ○ Students will read, annotate and answer the questions for the close reading activity News Excerpts: Heat advisory continues in Baltimore area, as temperatures surge and cooling centers stay packed ○ Use this reading activity to lead students to wonder how the materials in the urban environment effect the temperature on a hot (or cold) day. • **Investigation:** Students will investigate how common building materials react when heated. ○ Heat Energy and Urban Materials ▪ Pre-Lab Preparation-The teacher will need to have enough containers with boiling water for heating each of the 4 rock sample types. These will need to be boiling for at least 20 minutes prior to the activity to insure the rock samples have come to equilibrium with the boiling water. Be sure to have enough samples in each hot water bath for the groups to have 2 samples-one for each part of the activity. • It is suggested that each group only test 2 rock types and then share their findings with another group. • When you are finished with the rock samples, they can be reheated for each subsequent class. ▪ At the end of the activity, save the rocks to be reused in Unit 7. ▪ Have students share their Specific heat data on a class summary chart on the board so that the whole class can compare the heat capacities of all the materials. • Discuss the lab results with students. Possible discussion points:	**NGSS Dimensions:** • PS3.D HS1 • SEP2 HS3 • CCC4 HS3

	○ Which building materials hold the most heat? ○ Do all the rock types give off their heat at the same rate? ○ How might these properties effect the temperature in our neighborhoods? (Day? Night?) ○ What properties emerge from interaction of components in the system that can't be seen just by looking at the interactions?(CCC4) ○ **Teacher Notes: Key points:** ▪ The urban building materials in the environment are being heated and cooled throughout a daily cycle. ▪ Heating from absorption of radiation is a function of Albedo ▪ Surfaces lose energy by emitting long wave (heat) radiation ▪ Different materials store and lose heat differently depending on the chemistry of the materials. ▪ Chart of Specific Heat of Building Materials • **Updating Models:** Students will update/edit/modify their models based on today's lesson.(SEP2) ○ Have students edit their heat models to incorporate the concepts from today's lesson. ○ Discussion Prompt: How do the different components of the system interact? What feedback loops are affecting the system?(CCC4) ○ Add to the class model based on student input. • **Homework:** If more time is needed, allow student to complete the model as homework.	
20. Thermal Radiation – Part 2	The objective of this lesson is for students to understand that materials differ not only in how much energy they can reflect, but also in how much absorbed energy is needed to increase their temperature (Specific Heat). This property also influences the rate at which materials lose heat when exposed to a cooler medium. The stored heat is referred to Heat Capacity. The Specific Heat / Heat Capacity of building materials in an urban area can contribute to their role in influencing the temperature of the city in terms of excess heat stored in structures. The differences in Heat Capacity of materials could result in differences in when the air is heated over a day/night cycle. **Teacher Note:** This is your second scheduled day for this topic.	
How does Earth's surface cool?	• **Opening Activity:** Ask students to discuss the design of the lab activity from lesson 19 and what might have been caused inaccuracies in the model format. ○ Discussion Prompts: What are the key assumptions of the model? How do the assumptions affect the reliability of the model? (CCC4) ○ Possible responses: ▪ Wet rock will cool faster than dry as evaporation can affect the temperature. ▪ The surface the rock was sitting on could absorb the energy instead of radiative	**NGSS Dimensions:** • PS3.D HS1 • SEP2 HS3 • CCC4 HS3

	cooling.
	• **Further exploration:** Students will explore the effect of evaporative cooling on surfaces.
	  ○ Students return outside with the IR thermometers and spray bottles.
	  ○ At each location students will take the measurement of the dry surface, spray the surface, and measure the temperature of the wet surface.
	  ○ Thermal Exploration data table V2
	• **Updating Models:** Students will update/edit/modify their models based on today's lesson.(SEP2)
	  ○ Students will update and finalize their Baltimore heat model to incorporate the concepts from today's lesson.
	  ○ At this time, they should complete the explanation portion of the model sheet.
	  ○ Update the Class Model
	• **Homework:** Complete the model if extra time is needed.	

21. Baltimore's Energy Balance – Day 1	Over the next two lessons students will study the Urban Heat Island effect as it applies to Baltimore and its surrounding region and propose possible solutions for neighborhoods within Baltimore City.	

How does the temperature in Baltimore City compare to the temperature in Baltimore County?	• **Opening Activity:** Introduce the concept of Urban Heat Island.
	  ○ Choose one:
	    ▪ Show the Urban Heat Island Video (Science Museum of Virginia 2:11).
	    ▪ Show Why It's Usually Hotter in Cities (NPR 2:29)
	    ▪ Read Urban Heat Island Effect
	• **Compare Temperature Data:** Students will compare surface temperatures.(SEP4)
	  ○ The video we just watched was made about Richmond, VA, let's see if we can find evidence of the same effect happening in Baltimore.
	  ○ Students examine land surface temperature and land development maps of Baltimore looking for an urban heat island effect.
	    ▪ These are infrared and standard satellite images of Baltimore City.
	    ▪ Students should notice that the developed areas of Baltimore are warmer than the undeveloped areas.
	    ▪ These images can be printed out for individual comparison or projected for class discussion.
	    ▪ Discussion Prompt: What is happening to energy in this system? (CCC5)
	• **Measuring Heat Islands**
	  ○ Have students wet the back of their hand. The wet location should feel cooler because evaporation is occurring. The same process explains why wet surfaces are cooler than dry
		NGSS Dimensions:
		• PS3.D HS1
		• SEP4 HS1
		• CCC5 HS2

	surfaces. (Resource)
	  ○ Students refer to the data they collected in Lesson 1 to identify the warmest and coolest locations in the schoolyard.
	  ○ A Baltimore Heat Wave-Student activity
	• **Urban vs Rural Energy Balance (SEP4)**
	  ○ Provide students with blank copies of the modeling template.
	    ▪ Have student create a revised Baltimore (Urban) thermal model and then create a Baltimore County(Rural/suburban) version of the same model.
	    ▪ **Teacher Note:** Remind students of the difference between reflected heat and heat radiated from buildings and the symbols they created to differentiate these two on their models. Remind them that their models should also include descriptions of the process and mechanism represented in the model.
	  ○ Have students watch Baltimore neighborhood called a 'heat island' (WMAR-2 News 3:31)
	  ○ Students make a claim about how to reduce the Urban Heat Island Effect in Baltimore
	• **Homework:** Jigsaw part 1:
	  ○ Assign students to four groups. Each group reads one of four different articles for homework:
	    ▪ Trees EPA Trees reading
	    ▪ Cool Roofs EPA Cool Roofs reading
	    ▪ Cool Pavement EPA Cool Pavement reading
	    ▪ Green Roofs EPA Green Roofs reading	

22. Baltimore's Energy Balance – Day 2	This is day two of the lesson. Students will, in teams, develop their proposed solutions for neighborhoods within Baltimore City and present them to the class.	

What controls the temperature in Baltimore?	• **Opening Activity**
	  ○ Show a news clip or have students read an article on heat related deaths in Baltimore
	    ▪ Worst Heat Wave in Decades is Upon Us (WJZ-2:04) is a news report from June 2016
	    ▪ Heat Wave Affecting People Around Baltimore (YouTube 1:53) from July 2017.
	    ▪ Forecast through Monday calls for region's most intense heat wave in years, is a Baltimore Sun article from July 22.
	    ▪ Marylanders grapple with oppressive heat in Baltimore, this Baltimore Sun article, from July 23, 2016, also has a 18s clip of children splashing in a fountain near the Inner Harbor.
	• **Identify solutions to heat in Baltimore (SEP6)**
	  ○ Jigsaw Part 2: Form groups of four, with one person who has read each article (assigned for homework the previous night) present in each group.
	      • Additional Resource: Near record breaking and dangerous heat later this week. Including impacts on human health, car temperatures and surface
		NGSS Dimensions:
		• PS3.D HS1
		• SEP6 HS5
		• CCC6 HS1

	temperatures. ○ Students share the different options municipalities can use for reducing the Urban Heat Island Effect. ○ Design a Plan: How can Baltimore decrease the temperature in its neighborhoods? ▪ Students can use one or more of the options discussed. ▪ Students will create a sign showing their proposed plan for cooling Baltimore. • Include reasoning for design. • Include drawing/diagrams. ▪ Discussion Prompt: Be prepared to describe the structures in your solution. Describe the function of your solution. What is important about the relationship between structure and function in your solution that make it a successful design?(CCC6) ○ Gallery walk the finalized signs and have students use sticky-notes to give feedback. • **Urban vs Rural Model:** Students will update their models. ○ Students will update their models showing energy motion in each of the following: ▪ model of Baltimore City ▪ model of rural area (Baltimore County) • **Homework:** Complete models if extra time is needed.	
23. Review Earth's Energy Balance	Students will engage in teacher designed activities to review and prepare for the unit exam.	
What else do you need to know to understand global temperatures?	• **Opening Activity:** Invite students to share their Baltimore energy models and ask each other questions that they are still uncomfortable with. • **Concept Review Questions:** Students review with teacher designed activities. ○ Students use clickers, white boards, or cell phones to answer teacher-created/selected concept review questions (aka Clicker Questions). Further information on using clickers can be found here. ○ Questions should include all topics from the unit. ○ Some sample questions related to calorimetry can be found here. ▪ Do not use all the questions, as some of the questions are too advanced. ○ Some sample questions related to heat can be found here. ○ Some sample questions related to earth's interior can be found here. ▪ Lots of unnecessary recall questions, but some good questions are mixed in. • **Prepare a Note Card(Optional):** ○ Teachers may choose to allow students to prepare one hand-written 3x5 inch notecard for use on their unit assessment.	All standards covered in this unit should be reviewed.

	• **Homework:** Students review their notes, examine returned work, skim essential readings, and finish creating their notecard.	
24. Unit Assessment	Students will take a district created unit assessment that includes NGSS aligned item sets (multiple choice, data analyses and short response).	
What do you know?	• **Unit Assessment can be found on DataLink.**	All standards, from this unit and previous units, may be assessed.