Module 2: Thermal Energy Transfer

Driving Question: How can we as architects and engineers design and construct a model house to minimize thermal heat transfer?

Storyline:

This module is centered around the driving question: How can we as architects and engineers design and construct a model house to minimize thermal heat transfer? The investigations in the module prepare students to answer this question through a culminating engineering performance task. Leading up to the performance task, students complete investigations that answer the questions, What is thermal energy? How can thermal energy be transferred from one object or system to another?

In Concept 1: Introduction to Thermal Energy, students begin by considering sources of thermal energy in their everyday lives and explore a variety of ways that thermal energy can be generated. Students are introduced to the engineering design cycle as they apply this knowledge to a design challenge which requires them to design a device that generates thermal energy through chemical reactions.

Then in Concept 2: Thermal Energy Transfer, students develop their understanding of thermal energy and make connections between the kinetic energy of particles, temperature, and thermal energy. Students distinguish between heat and temperature. Students also develop important qualitative ideas about energy including that the interactions of objects can be explained and predicted using the concept of transfer of energy from one object or system of objects to another. Students conduct investigations to learn more about how the mass and material of an object affect the transfer of thermal energy. Students also clarify the various way that thermal energy can be transferred (radiation, convection, and conduction) and apply this knowledge to real world situations.

In Concept 3: Flow of Energy, students investigate the flow of energy in order to develop the concept that energy is transferred out of hotter regions or objects and into colder ones. They further develop the idea that the total change of energy in any system is always equal to the total energy transferred into or out of the system.

In Concept 4: Minimizing Thermal Energy Transfer, students consider ways to minimize thermal energy transfer. Students investigate a variety of materials in order to see which materials would be best for maintaining temperature. Students will use the results of this investigation to inform their design decisions in the performance task.

In the culminating performance task, students apply their knowledge of thermal energy transfer and use the engineering design process to design a house that minimizes thermal energy transfer. Students create their prototypes, test them, and then complete a redesigned house based on what they learn from testing their own design and those of their classmates.
Module Standards:

The [Next Generation Science Standards](https://www.nextgenscience.org) also have assessment boundaries and clarification statements that can be accessed for more explanations about each performance expectation. [NGSS Evidence Statements](https://www.nextgenscience.org) provide educators with additional detail on what students should know and be able to do. These are statements of observable and measureable components that, if met, will satisfy NGSS performance expectations.

<table>
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<tr>
<th>NGSS Performance Expectations</th>
<th>NGSS Disciplinary Core Ideas (DCIs)</th>
<th>NEW Missouri Learning Standards</th>
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| NGSS MS-PS1-6 Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.* | PS1.B Chemical Reactions  
- Some chemical reactions release energy, others store energy. (MS-PS1-6) | 6-8-PS1-6  
Construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. |
| NGSS MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* | PS3.A: Definitions of Energy  
- 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. (MS-PS3-3),(MS-PS3-4)  
- 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. | 6-8-PS3-3  
Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. |
| NGSS MS-PS3-4 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. | PS3.B: Conservation of Energy and Energy Transfer  
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)  
- 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. (MS-PS3-4) | 6-8-PS3-4  
Plan and conduct an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the temperature of the sample. |
| NGSS MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object | | ETS1.A.1  
Define the criteria and constraints of a design problem with sufficient precision to ensure a |
changes, energy is transferred to or from the object.

NGSS MS-ETS1-1
Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

NGSS MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

NGSS MS-ETS1-3
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.

NGSS MS-ETS1-4
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.

• Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)

ETS1.A: Defining and Delimiting Engineering Problems
• The more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions. (MS-ETS1-1)

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. (MS-ETS1-1)
• There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2) (MS-ETS1-3)
• Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3)
• Models of all kinds are important for testing solutions. (MS-ETS1-4)

ETS1.C: Optimizing the Design Solution
• Although one design may not perform the best across all tests, identifying the characteristics 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. (MS-ETS1-3)
• 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. (MS-ETS1-4)

successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

ETS1.B.1
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

ETS1.B.2
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.

ETS1.B.3
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.
### Module 2: Thermal Energy Transfer Big Idea Chart

**Driving Question:** How can we as architects and engineers design and construct a model house to minimize thermal heat transfer?

<table>
<thead>
<tr>
<th>Big Idea:</th>
<th>Concept 1 Introduction to Thermal Energy</th>
<th>Concept 2 Thermal Energy Transfer</th>
<th>Concept 3 Flow of Thermal Energy</th>
<th>Concept 4 Minimizing Thermal Energy Transfer</th>
<th>Performance Task</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>Energy refers to the ability to change matter or make something happen. Thermal energy can be generated in a variety of ways. Chemical reactions can be a source of thermal energy.</td>
<td>Thermal energy is the energy related to the temperature of a substance due to its kinetic energy of moving particles. There is a relationship 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. Heat is an amount of energy transferred from one system to another through conduction, radiation or convection because of temperature differences.</td>
<td>Energy is transferred out of hotter regions or objects and into colder ones. The total change of energy in any system is always equal to the total energy transferred into or out of the system.</td>
<td>Some materials absorb more thermal energy than others. Design decisions can be made to minimize thermal energy transfer.</td>
<td>Students will apply their knowledge of energy and energy transfer to construct a house that minimizes thermal energy transfer.</td>
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| Time Estimate | 3 sessions + 1 extend | 9 sessions + 2 extends | 2 sessions + 1 extend | 3 sessions + 1 extend | 6 sessions + 1 extend |

| Vocab | Energy, energy source, thermal energy, chemical energy, chemical reaction, exothermic, endothermic, engineering design cycle, criteria, constraints, prototype | Thermal energy, kinetic energy, heat, temperature, conduction, radiation, convection, conductor, insulator, thermal conductivity, energy transfer, energy transformation, mass | Conservation of energy, energy flow | Minimize, absorb, reflect, variables, radiation, properties | Thermal energy transfer, criteria, constraints, prototype, engineering design cycle, design solution |