Science through LEGO Engineering
Design a Model House: The Properties of Materials

Curriculum Resources
2008-2009 Edition

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# Science through LEGO Engineering

## Module Overview

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<td><strong>1</strong> How can we describe materials and objects?</td>
<td>Students will be introduced to the unit’s overall design challenge and will make predictions for their model house materials. Then, students will practice recognizing properties of materials and objects by sorting a set of objects into groups of similar items.</td>
<td>Students will be able to: Separate or sort a group of objects or materials based on their properties. Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.</td>
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<td><strong>2</strong> Can support columns be made of clay?</td>
<td>Students will construct model-house support columns out of modeling clay and test their strength and stability.</td>
<td>Describe objects by the properties of stability and strength. Measure the properties of materials and objects with manual tools such as test-weights. Identify the properties that are most important for a specific design task and select materials and objects that exhibit those properties.</td>
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<tr>
<td><strong>3</strong> Can support columns be made of LEGO beams?</td>
<td>Students will construct model-house support columns out of LEGO beams and test their strength and stability.</td>
<td>Describe objects by the properties of stability and strength. Measure the properties of materials and objects with manual tools such as test-weights. Identify the properties that are most important for a specific design task and select materials and objects that exhibit those properties.</td>
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<td><strong>4</strong> What shapes make good roofs?</td>
<td>Students will design and build roof frames out of LEGO pieces and determine the most stable roof frame shape.</td>
<td>Describe objects by the properties of shape and stability. Identify the properties that are most important for a specific design task and select materials and objects that exhibit those properties.</td>
</tr>
<tr>
<td><strong>5</strong> How can we make stable and strong house frames?</td>
<td>Students will use the LEGO columns and roof frames they previously designed to create the frame of their model house. The house frame should still be stable and strong.</td>
<td>Describe objects by the properties of stability and strength.</td>
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### Science through LEGO Engineering

**Module Overview**
Properties of Materials: Design a Model House

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| **6** Which wall material will help our houses stay quiet? | Using LEGO sound sensors, students will test the sound absorption (soundproofing) ability of cotton sheets and craft foam as possible inner-wall materials. | **Students will be able to:**
- Describe materials by the property of sound absorption ability.
- Measure the properties of materials and objects with electronic tools such as sound level sensors.
- Identify the properties that are most important for a specific design task and select materials and objects that exhibit those properties. |
| **7** Which wall material will help our houses stay warm? | Students will test the thermal insulation ability (using digital LEGO thermometers) of cotton sheets and craft foam as possible inner-wall materials. | **Students will be able to:**
- Describe materials by the property of thermal insulation ability.
- Measure the properties of materials and objects with electronic tools such as digital thermometers.
- Identify the properties that are most important for a specific design task and select materials and objects that exhibit those properties. |
| **8** Which wall materials will help keep out rain and bright light? | Students will test the waterproofing and reflectivity abilities of cardboard and transparency sheets as possible outer-wall materials. | **Students will be able to:**
- Describe materials by the properties of waterproofing, reflectivity, and color.
- Measure the properties of materials and objects with both manual and electronic tools, such as spring scales and thermometers.
- Identify the properties that are most important for a specific design task and select materials and objects that exhibit those properties. |
| **9** How can we make stable, quiet, and comfortable model houses? | Using the materials that performed best in the tests, students will finish their model houses by measuring, cutting, constructing, and assembling the columns, roofs, and wall surfaces. | **Students will be able to:**
- Identify the properties that are most important for a specific design task and select materials and objects that exhibit those properties.
- Measure the properties of materials and objects with manual tools such as rulers.
- Describe objects by the properties of weight, length, height, and shape. |
| **10** How do the properties of materials help us with engineering? | Students will create design posters that explain how specific properties are important to their houses. They will participate in a whole-class discussion to review how the houses meet the overarching engineering design requirements. | **Students will be able to:**
- Identify the properties of the materials from which objects are made.
- Recognize that selecting the best material is a process in which engineers often engage.
- Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.
- List and explain the steps of the engineering design process. |
Science through LEGO Engineering

Module Overview
Properties of Materials: Design a Model House

Learning Objectives for LEGO Engineering
Properties of Materials Module

By the end of this module, students will be able to:

1) Describe materials by the following properties: strength, flexibility, insulating ability, sound absorption ability, waterproofing, color, and reflectivity.
2) Describe objects by the following properties: weight, length, height, shape, strength, waterproofing, and stability.
3) Identify the materials from which objects are made.
4) Separate or sort a group of objects or materials based on their properties.
5) Measure the properties of materials and objects with both manual and electronic tools, such as rulers, weights, digital thermometers, and sound meters.
6) Identify the properties (e.g., strength, insulating ability, shape) that are most important for a specific design task.
7) Select materials and objects that exhibit the desired properties for a specific design task.
8) a) Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.
   b) List and explain the following steps of the engineering design process:
      i. Identifying a problem
      ii. Researching possible solutions
      iii. Picking the best solution
      iv. Building a prototype
      v. Testing the prototype
      vi. Repeating any steps needed to improve the design
### Properties of Materials: Design a Model House – Related National, State, and District Learning Standards

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<th>Design a Model House Learning Objectives</th>
<th>National AAAS Benchmarks</th>
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<tr>
<td>By the end of this module, students will be able to:</td>
<td>4.D. 2\textsuperscript{nd} Grade</td>
</tr>
<tr>
<td>1) Describe materials by the following properties: strength, flexibility, insulating ability, sound absorption ability, waterproofing, color, and reflectivity.</td>
<td>- Objects can be described in terms of the materials they are made of (clay, cloth, paper, etc.) and their physical properties (color, size, shape, weight, texture, flexibility)</td>
</tr>
<tr>
<td>2) Describe objects by the following properties: weight, length, height, shape, strength, waterproofing, and stability.</td>
<td>4.D.5\textsuperscript{th} Grade</td>
</tr>
<tr>
<td>3) Identify the materials from which objects are made.</td>
<td>- When a new material is made by combining two or more materials, it has properties that are different from the original materials. For that reason, a lot of different materials can be made from a small number of basic kinds of materials.</td>
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<tr>
<td>4) Separate or sort a group of objects or materials based on their properties.</td>
<td>4.E.5\textsuperscript{th} Grade</td>
</tr>
<tr>
<td>5) Measure the properties of materials and objects with both manual and electronic tools, such as rulers, weights, digital thermometers, and sound meters.</td>
<td>- When warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are all at the same temperature. A warmer object can warm a cooler one by contact or at a distance.</td>
</tr>
<tr>
<td>6) Identify the properties (e.g., strength, insulating ability, shape) that are most important for a specific design task.</td>
<td>- Some materials conduct heat much better than others. Poor conductors can reduce heat loss.</td>
</tr>
<tr>
<td>7) Select materials and objects that exhibit the desired properties for a specific design task.</td>
<td>4.F.5\textsuperscript{th} Grade</td>
</tr>
<tr>
<td>8) a) Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.</td>
<td>- Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.</td>
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<tr>
<td>b) List and explain the following steps of the engineering design process:</td>
<td></td>
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<tr>
<td>i. Identifying a problem</td>
<td></td>
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<td>iii. Picking the best solution</td>
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<td>iv. Building a prototype</td>
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<td>v. Testing the prototype</td>
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<td>vi. Repeating any steps needed to improve the design</td>
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### National Science Education Standards

- **Content Standard B: Properties of Objects and Materials (K-4)**
  - Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances, and thermometers.
  - Objects are made of one or more materials, such as paper, wood, and metal. Objects can be described by the properties of the materials from which they are made, and those properties can be used to separate or sort a group of objects or materials.

### Massachusetts Frameworks

- **Grades K-2, Strand 2: Physical Science**
  - Sort objects by observable properties such as size, shape, color, weight, and texture.

- **Grades 3-5, Strand 3: Physical Science**
  - Differentiate between properties of objects (e.g., size, shape, weight) and properties of materials (e.g., color, texture, hardness).
  - Recognize that light travels in a straight line until it strikes an object or travels from one medium to another, and that light can be reflected, refracted, and absorbed.

### Somerville Science Benchmarks

- **Materials & Tools Learning Standards, Grade 3**
  - Appropriate materials, tools, and machines extend our ability to solve problems and invent.
  - Identify materials used to accomplish a design task based on a specific property, i.e., weight, strength, hardness, and flexibility.

- **Materials & Tools Benchmarks, Grade 3**
  - Identify the properties (weight, strength, hardness, and flexibility) of different kinds of materials (natural materials, e.g., wood and stone; and human-made, e.g., plastic and glass).
  - Choose a suitable material to accomplish a particular job and explain your choice.
Lesson 1

How can we describe objects and materials?

One 60-minute session

First, students will be introduced to the overall design challenge for the unit and will make predictions for their model house materials. Next, students will practice recognizing properties of materials and objects by sorting a set of objects into groups of similar items.

- Introduction of the “Design a Model House” engineering challenge
- Reading from *The Three Little Pigs*
- Predicting materials for model house
- Object sorting activity
- Class discussion of different sorting methods

By the end of this lesson, students will be able to:

- Separate or sort a group of objects or materials based on their properties.
- Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.

Properties of Materials Introduction

People experience objects everywhere in their daily lives. Objects are anything that exists in a form that can be seen or touched. Most people do not examine the materials or substances used for constructing or making an object. Materials can be solids, liquids, or gases. Even fewer examine the properties or traits of a material or object that can be observed or measured. In everyday situations, people are usually only concerned with how they use an object. We can learn from material scientists and engineers how to examine objects further.

Material scientists make it their business to examine objects in order to determine the materials that make up an object. Material scientists also analyze objects and materials to determine their properties. In addition, they extract materials in order to transform them into useful forms.

The first step in gaining a deeper understanding of an object is to look at it as a material scientist would, by identifying the materials from which it is made. Then, the properties of both the object and the materials can be further examined or measured.
Lesson 1

How can we describe objects and materials?

Engineering Design

Engineers typically work together to solve the problems that face society. Engineering design is the process of creating solutions to human problems through creativity and the application of math and science knowledge. The basic steps within the design process include:

i. Identifying a problem –
Observing a problem and seeing a need for a solution.

ii. Researching possible solutions –
Coming up with ideas to address the problem.

iii. Picking the best solution –
Determining which idea best addresses the problem. This decision may involve monetary, practicality, material, and property concerns.

iv. Building a prototype –
Build a working model of the chosen solution.

v. Testing the prototype –
Be sure the working model solves the problem and holds up to any important material property tests.

vi. Repeating any steps needed to improve the design –
The engineering design process is not always a step-by-step process, as engineers often repeat steps or go back and forth between the other five steps.

Throughout the design process, students may want to revisit steps and add elements that were previously omitted, just as “real” engineers do. Students will continuously formulate and test hypotheses in order to solve their problem. As the students take on the role of an engineer, they will analyze their solutions, build models, and clarify concepts and explanations. Solutions may require further testing and experimentation to meet the criteria for success defined previously, and even the criteria for success may be amended as they progress. Students should conclude the engineering design challenge by providing a clear expression of their process that includes the questions, procedures, evidence, a proposed explanation, and a review of alternative explanations.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Material - Any substance used for constructing or making an object. A material can be a solid, liquid or a gas.

Object - Anything that exists in a form that can be seen or touched.

Property - A trait of a material or object that can be observed or measured.
Lesson 1

How can we describe objects and materials?

**Plastic** - A man-made substance that can be easily shaped and then hardened into a durable form.

**Paper** - A thin sheet made usually from wood, rags, straw, or bark that can be used for writing, wrapping, decorating walls, packaging, and similar tasks.

**Wood** - The hard substance that makes up the trunk and branches of a tree and can be used as a building material.

**Metal** - A substance that is often shaped and melted, a good conductor of electricity and heat, strong in its solid form, and usually shiny.

**Rubber** - A stretchable and flexible substance made from the juice of various tropical plants.

Materials

For each student

- Engineer’s Journal Part 1

For each student pair

- Sets of the following 10 items: (1) paper clip, (2) small piece of aluminum foil, (3) LEGO brick, (4) plastic spoon or bottle cap, (5) index card, (6) paper napkin or paper towel, (7) wooden pencil, (8) wooden twig, stick, piece of branch, or bark, (9) rubber band, (10) rubber eraser

For the class

- A version of the story *The Three Little Pigs* (for example, *The True Story of the Three Little Pigs*, by Jon Scieszka and Lane Smith)

Preparation

- Distribute Engineer’s Journals.
- Prepare bags of 10 items for sorting. (These may have been provided for you).

Instructions for Teachers

**GETTING STARTED**

PART I: Presentation of “Design a Model House” Engineering Challenge (20 min)

1) Explain to students that the engineering problem they need to solve for this science unit is creating a miniature model house that is as stable, quiet, waterproof, and comfortable in temperature as possible with the available materials. This is their design challenge, and by completing this challenge, they will learn about the science of
How can we describe objects and materials?

material properties.

2) Read to students a selection from your favorite version of *The Three Little Pigs*, in which the pigs build houses out of straw, sticks, and bricks, with varying degrees of success. The pigs are examples of other “engineers” who were trying to solve the problem of building a stable house. Point out that the pigs used straw, sticks, and bricks as types of materials, and the wolf “tested” their houses for the property of stability.

3) Ask students to brainstorm what parts of a house are important to make it stable, quiet, waterproof, and comfortable in temperature. They should discuss their ideas with their partner and then write their ideas in their Engineer’s Journal. After two to three minutes of brainstorming, explain that they will focus on just four main elements: the vertical support columns, the roof, the inside walls of the house, and the outside walls of the house.

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<tr>
<th>What Questions Might Students Ask During this Lesson?</th>
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<tr>
<td>▪ What do you mean by “column” and “beam”? What parts of the house are those? <em>Columns and beams are usually only visible while houses are still under construction.</em></td>
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<tr>
<td>▪ Why are we only building columns, roofs, and walls? Why can’t my house have a kitchen, dog house, basement, garage, etc.? <em>The frame and wall surfaces are the parts of a house that have the greatest impact on whether it is stable, quiet, waterproof, and thermally comfortable.</em></td>
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**PART II: Predicting Materials and Explaining Choices for “Design a Model House” Engineering Challenge (15 min)**

4) Ask the students to turn to page 1-2 in their Engineer’s Journal and predict one common craft or LEGO material to use for each of the four main parts of their model houses: the vertical support columns, the roof beams, the inside walls of the house, and the outside walls of the house.

5) Ask students to complete the chart by explaining how their predicted materials would help them complete the design challenge. Encourage them to simply try their best if they find this task difficult. In the upcoming unit, they will have many opportunities to learn what makes materials good choices for a model house.

6) Call on at least one student to explain his or her reasoning about the materials that would help meet the design requirements.

**PART III: Introduction to Properties of Materials (25 min)**

7) Explain that the students’ main task in completing this engineering design challenge is to choose what materials to use for each part of the house. They will now do a “warm-up” sorting activity to practice thinking about materials.

8) Distribute one set of the 10 sorting objects (see materials list) to each
student pair. Ask students to sort the objects into groups that contain objects that are similar in some way. Give some examples: the spoon and the foil might be grouped because they are usually found in the kitchen; the foil and the index card might be grouped because they are both flat.

9) While students are sorting, sort your own set of objects into five different groups according to their material type: metal (paper clip and aluminum), plastic (LEGO and spoon or cap), paper (card and napkin), wood (pencil and stick), and rubber (band and eraser).

10) Allow five to ten minutes for sorting by student pairs. Students should describe their sorting method in their Engineer’s Journal.

11) Gather students together and ask each pair to tell the class about one of their object groups. As they describe their groups, record on a class chart their method for sorting. Divide the chart into three areas, one for sorting by property, one for sorting by function (use), and one for sorting by material type (but do not label these areas yet). For example, if students make a group of objects that are all white, record the word “white” on the chart in the area that will be labeled “property.”

12) If no student pair describes a group that is sorted by material (e.g., these items are all wood), then display your five groups and ask students to guess your sorting method. Record the five different material types on your class chart.

13) After each pair has shared at least one group, explain that these methods for sorting can be categorized into three different sorting approaches. Label the areas as you explain the three sorting methods. One approach is to sort by material type (what the object is made of); another approach is to sort by property (words, usually adjectives, that describe how the object behaves, looks or feels); a third approach is to sort by function (words that describe the use of an object).

14) Conclude the lesson by reviewing the difference between objects and materials. Objects are always made of one or more materials. Even when two objects have different sizes, shapes, colors, and weights, they might still be made of the same basic material. We can describe a material by its properties, like strong, shiny, hard, flexible, easily torn, etc.
## Lesson 2

### Can support columns be made of clay?

**Lesson Overview**

One 60-minute session

Students will construct model-house support columns out of modeling clay and test their strength and stability.

- Class discussion of support column considerations, with visual aids on overhead transparencies
- Brief free-build with clay
- Teacher-led strength and stability testing of clay columns
- Recording results in Engineer’s Journal
- Class discussion of the appropriateness of clay for support columns

**Learning Objectives**

By the end of this lesson, students will be able to:

- Describe materials by the property of strength.
- Describe objects by the property of stability.
- Measure the properties of materials and objects with manual tools such as test weights.
- Identify the properties that are most important for a specific design task, and select materials and objects that exhibit those properties.

**Strength**

- **Strength** - The ability to hold something up or resist distortion when a force (push or pull) is applied.

  Strength can be used to describe both objects and materials.

When you push or pull on a strong material, it will not change shape. A weak material will change shape when it is pushed or pulled. Objects that are made of strong materials also exhibit the property of strength. When objects are made of both weak and strong materials, it is important to test the object in order to tell if the object as a whole exhibits the property of strength. It is also important to test the strength of the connections between different pieces or materials of an object.

  There are two common ways of testing for strength. One test involves applying a force to an object (or material) by pushing or pulling on it. If the object resists distortion (does not change shape), it is considered a strong object. The other test involves checking if a piece of the material or an object can hold up a different, relatively heavy object. The exact heaviness of this object being held up (the “test weight”) depends on how the material or object under question will be used. It is important that the “test weight” applies at least as much force as the material or object will feel during use. For example, if you are testing a piece of plastic material for possible use in a chair, the test weight applied to the plastic must be at least as heavy as a person. Using the...
word “strength” to describe objects can be compared to using the word “strength” to describe people. When people can hold up heavy boxes full of books, they are considered strong, just as an object is considered strong when it can hold up items that are relatively heavy compared to its own weight and size.

**Flexibility**
- **Flexibility** - The ability to bend easily without breaking.

  Flexibility can be used to describe both objects and materials. Flexible materials bend, but do not break, when you push or pull on them. Inflexible materials either do not bend when you push or pull them, or they bend but then break. Objects that are made of flexible materials also exhibit the property of flexibility. When objects are made of both flexible and inflexible materials, it is important to test the object in order to tell if it exhibits the property of flexibility.

  A good test for flexibility involves holding both sides of an object (or material) and trying to bend the object. If the object bends and does not break, it is considered flexible. An example of a flexible material is clay. If the object does not bend, it is considered inflexible, such as LEGO beams.

**Stability**
- **Stability** - The ability to remain in a steady position without shaking or bending.

  Stability is used to describe only objects. Even if an object is made of only one material, the stability of the object – rather than of the material – is considered. This is because materials can be made into objects of many different sizes and shapes, some of which will be stable and some of which will not be stable. An object is stable if it can stay in the same place without shaking or bending. Support columns for a house are included to make a house stable. You would not want your house shaking around you all the time! Objects that are usually stable (such as homes) sometimes become unstable when subjected to unusually large forces (such as earthquakes).

  A good test for stability is to push on the side of an object and see if it shakes or bends. If the object remains stationary, it is stable. Buildings are some of the most stable objects because we would not want them coming down on top of our heads! If the object instead moves or bends, it is unstable. Dominoes are examples of unstable objects. Dominoes are also examples of objects that we actually want to be unstable or else we would not be able to use them for certain games. Engineers must take into account the purpose of the object they are designing when deciding on the stability, or any other property, of the object.
Lesson 2

Can support columns be made of clay?

Vocabulary

**Support column** - A tall, thin, strong object that helps to hold the weight of a large building or structure. Several support columns are needed to hold a building’s weight.

**Strength** - The ability to hold something up or resist distortion when a force (push or pull) is applied.

**Flexibility** - The ability to bend easily without breaking.

**Stability** - The ability to remain in a steady position without shaking or bending.

Materials

*Note: Many kinds of clay turn hands and desks colors. Using white or yellow prevents some of the discoloration.*

For each student

- Engineer’s Journal Part 2
- 8 ½ x 11 paper (can be scrap paper) to protect surfaces from clay residue
- 2 oz. (57 grams) of Play-Doh modeling clay (About ¼ cup (60 mL) of Play-Doh, or 2 Play-Doh “Mini-Cans”)
- 5-inch plastic coffee straw

For each student pair

- Plastic bag
- 100-gram weight
- Ruler

For the class

- Transparencies or print-outs of photos of building frames and vertical support columns (i.e., struts)

Preparation

- Distribute Engineer’s Journals.
- Divide clay into a 2-oz. (1/4-cup) lump for each student
- For each student pair, put two lumps of clay and two straws in a bag

Instructions for Teachers

GETTING STARTED

PART I: Introduction and Preparation of Test Columns (20 min)

1) Explain that in this lesson students will begin to investigate materials for the vertical support columns of their model houses. Use the overhead projector to display photos of support columns, or distribute photocopies of photos to student groups. As you look at the photos of building frames, point out which beams are the *vertical* support columns, as some students will assume you are talking about both the horizontal and the vertical beams.

2) Give students two-to-three minutes to talk with their partners and then write or draw their ideas about today’s science exploration question: “What properties are important for a house’s support columns?” Students should record their ideas on page 2-1 of their
Lesson 2

Can support columns be made of clay?

Engineer’s Journal.

3) Explain that in this lesson students will test modeling clay as a possible material for the support columns. They will test two specific properties: stability (when formed into a column) and strength.

4) Discuss the definition of these two properties:

a. An object’s stability is its ability to remain standing in a steady position without shaking or bending, even when it is being pushed or pulled by outside forces. Often, stability is related to the flexibility of the material out of which the object is made. Flexibility refers to how easily a material changes shape without breaking. These properties are sometimes confused.

b. A material’s strength is its resistance to changing shape under a heavy load or weight.

5) Distribute two pieces of clay to each pair. Give students five minutes to experiment with the clay. You might challenge them to write their names with clay, or create miniature sculptures of themselves. Point out that they will not be able to keep what they make because they will have to use the clay for support columns.

6) Direct students to roll out 5-inch columns of clay. Students should widen the bottom and the top of the columns to create a base for standing and a flat top for holding test weights. These will be the “tester” columns. Each student should make one column.

What Questions Might Students Ask During this Lesson?

- How do I make the clay into a column? Roll it out on your paper or in between your hands.
- How thick or thin should the column be? As thick as your thumb, or as thin as it needs to be so that it is as long as the straw.
- Why is the middle of my column thinner than the edges? You’re only pressing on the middle.
- How do I put the straw in the clay? Line it up next to the clay; then press it into the clay and wrap the clay around it.
- How can I get the clay column to stand up? Make a “foot” for it by pressing down on the part touching the table.

Figure 1. Clay columns, with straw (top) and without straw (bottom).

PART II: Stability and Strength Tests (20 min)

7) Explain that the first test is a stability test to determine whether the clay-only column can stand upright on its own. Direct the students to:

a. Stand their column upright, give it a tap, and observe what
Can support columns be made of clay?

happens. (The column falls over.)

b. Stand the column upright again, place a 100-gram weight on top of it without letting go of the weight, give it a tap, and observe what happens. (The column falls over, faster than without the weight.)

8) Explain that the second test is a strength test to determine the ability of the tester columns to resist strong pushes (forces). Direct students to hold the column between two hands with the top touching one palm and the bottom touching the other palm (so palms are initially spread five inches apart). Then, press both palms toward each other in order to squeeze the column lengthwise, and observe what happens. (The column collapses, or “squishes.”)

9) Explain that sometimes engineers combine two materials to make an object that has the properties they are looking for. Ask students to do this by rolling out their column again, placing a coffee straw next to it, pressing the straw into the clay, and wrapping the column around the straw so that the straw ends up in the center of the column.

10) Direct students to repeat the two versions of the stability test (with and without weight) for this new clay-straw column. (Without the weight, the clay-straw column remains standing, thus passing the test. With the weight, the column stands for a few seconds and then slowly collapses.)

11) Direct students to repeat the strength test with the clay-straw column. (It bends in half.)

PART III: Class Discussion and Journal Work (20 min)

12) Ask students to turn to page 2-3 of their Engineer’s Journal. Review with students the section of the Journal designated for recording results from the stability and strength tests. Allot five minutes for students to complete this section.

13) Create a poster-size version of the following results chart and display it in a location where all students can see it.

CHOOSING THE MATERIAL FOR MODEL-HOUSE COLUMNS

<table>
<thead>
<tr>
<th></th>
<th>Stability Test w/out Weight</th>
<th>Stability Test w/ Weight</th>
<th>Strength Test</th>
<th>Total # Tests Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay with Straw</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14) Ask the students to discuss with their partner whether each version of
the clay column “passed” or “failed” each test.

15) Ask the students to come to the class chart and add a “P” or an “F” to each box of the chart, according to their own test results. The chart should now be filled with “P’s” and “F’s.”

16) Discuss with students how the results chart can help them decide whether clay columns are a good choice for model house support columns. Help them understand that the chart summarizes the results of today’s material property tests. Explain that engineers often use charts like this one to keep track of several design options, such as materials, that they are considering at the same time.

Stone:
http://www.stoneagedesigns.net/accents/images/Columns.jpg
http://images.worldofstock.com/slides/ADT2636.jpg
Lesson 3

Can support columns be made of LEGO beams?

Suggested Time

One 60-minute session

Lesson Overview

Students will construct model-house support columns out of LEGO beams and test their strength and stability.

- Teacher-led strength and stability testing of LEGO columns
- Adding bases to LEGO columns and conducting strength and stability tests again
- Recording results in Engineer’s Journal
- Class discussion of appropriateness of LEGO beams for support columns

Learning Objectives

By the end of this lesson, students will be able to:

- Describe materials by the properties of strength and flexibility.
- Describe objects by the property of stability.
- Measure the properties of materials and objects with manual tools such as test weights.
- Identify the properties that are most important for a specific design task, and select materials and objects that exhibit those properties.

Teacher Background

See background information for Lesson 2.

Vocabulary

Support column - A tall, thin, strong object that helps to hold the weight of a large building or structure. Several support columns are needed to hold a building’s weight.

Strength - The ability to hold something up or resist distortion when a force (push or pull) is applied.

Flexibility - The ability to bend easily without breaking.

Stability - The ability to remain in a steady position without shaking or bending.
### Lesson 3

#### Can support columns be made of LEGO beams?

**Materials**

- **For each student**
  - Engineer’s Journal Part 3

- **For each student pair**
  - LEGO Mindstorms Kit
  - 100-gram weight
  - One copy of either or both versions of LEGO column building instructions (optional)

- **For the class**
  - Transparencies or print-outs of LEGO support columns

- Distribute Engineer’s Journals.

---

**Preparation**

**Getting Started**

- **Note:** If students’ desks are not level, have them work on the floor.

**Instructions for Teachers**

**PART I: Stability and Strength Tests with LEGO Beam Only (10 min)**

1) Explain that in this lesson students will continue to investigate materials for the vertical support columns of their model houses. Give students two to three minutes to talk with their partners and then write or draw their ideas about today’s exploration question: “What materials might work better and worse than clay as support columns? Why?” Students should record their ideas in their Engineer’s Journal.

2) Explain that in this lesson, students will test LEGO beams as a possible material for the vertical support columns. They will test two specific properties: **stability** (when used as a column) and **strength**.

3) Review the definitions of these properties if necessary.

4) Distribute a LEGO Mindstorms kit to each pair. Direct students to find a 1x16 beam in their kit. This beam is the first “tester” column of this lesson.

5) Direct students to perform the two versions of the **stability** test with the LEGO beam.
   
   a. First, simply stand the beam upright and give it a slight tap. Observe what happens (The beam falls over.)
   
   b. Second, stand the beam upright again, and place a 100-gram weight on top of it. Observe what happens. (It falls over with any slight disturbance.)

---

### What Do Children Think About Structural Stability?

- Some students will already have a good sense for how to make structures stable. We have heard students describe the process of making LEGO columns stable as “combining one long and two short pieces.” They are referring to adding two short beams at a 90-degree angle to the bottom of one long beam.

- Some students conclude that a material passes a strength test when one’s hand starts to hurt from pushing on it. You might caution students that engineering tests should never be harmful to humans.

- Occasionally, students decide that clay would make better support columns because it is more fun to touch than LEGO columns.
Lesson 3

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>EXPLANATION</th>
</tr>
</thead>
</table>

**STUDENTS’ INDEPENDENT ACTIVITY**

**Note:** Two versions of building instructions are available for this activity (Figures 1 and 2). They provide step-by-step directions to build one type of LEGO column base. One version (Figure 3) provides images of four different completed LEGO columns. Depending on your students’ familiarity with LEGO building, you may choose to distribute one, both, or none of these instructions. Figures 1 and 3 are included on page 3-4 of the Engineering Journal.

Can support columns be made of LEGO beams?

6) Direct students to perform the **strength** test with the LEGO beam: hold the beam between two hands with one narrow end of the beam touching each palm (so palms are initially spread about 5 inches apart). Press both palms toward each other in order to squeeze the column longitudinally. Observe what happens. (It does not deform at all and thus passes the test.)

7) Ask students if anything can be done to the LEGO beam to help it pass the stability test (much like the coffee straw was added to the clay column). After hearing a few ideas, explain that a wider base may help it stand upright.

**PART II: Design of LEGO Beam Base**

(30 min)

8) Challenge students to build a stable base for the LEGO beam, so that it stands upright even when subjected to the stability test. They may use any pieces in their kits except for additional 1x16 beams. Each column should contain only one 1x16 beam. Point out axles and bushings as potentially helpful tools. Each pair should build at least two bases. (Students will use these LEGO beams with bases as two of the columns for their final model houses.)

9) Monitor students’ progress. If, after five minutes, they are not on track toward constructing successful bases for the beam, you might suggest that they look around the room for other stable structures. Hopefully they will notice that wider bases are important for stability.

10) You might also point out the building instructions on page 3-4 of their Engineer’s Journal to provide building instructions and example columns or give verbal tips for building.

11) After adding bases to the LEGO beams, students should perform the stability and strength tests again.

**What Questions Might Students Ask During This Lesson?**

- Should the column be vertical or horizontal? **Vertical.**
- Why won’t my column stay upright? **You only have one point of attachment to the base, so it can rotate around that point. Attach it to the base in two places.**
- When I put an axle through these three beams, why do they rotate around each other? **To prevent rotation, you must attach beams in at least two places.**
- How firmly does my column have to stay upright? **Your column should not wiggle back and forth.**
- What else can we use besides axles to connect two beams? **Try using connector pegs.**
- How will we use these columns in our actual model house? **They will be the four corners of your house. You will tape the walls to them.**
- How many 1x16 beams can we use in each column? **Only one. Be careful not to use too many pieces. You will need more pieces to build your roof frame.**

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Lesson 3

Can support columns be made of LEGO beams?

**Figure 1.** Step-by-step building instructions for simple LEGO column base.

**Figure 2.** More detailed, step-by-step building instructions for complex LEGO column base.

Note: Some students may want to do drop tests with their columns. This is not necessary, but is a good extension activity for students who are fast builders. You can also instruct students to build more columns if they finish two, since they will need four columns by the end of Lesson 5.
Lesson 3

Can support columns be made of LEGO beams?

4 Ideas for Building Sturdy LEGO Columns
If you have trouble inventing your own column design, here are some ideas that might help.

Figure 3. Less detailed building instructions for LEGO column bases.

PART III: Class Discussion and Journal Work (20 min)

12) Add two more rows to your results chart so that it looks like the chart below.

<table>
<thead>
<tr>
<th>Choosing the Material for Model-House Columns</th>
<th>Stability Test without Weight</th>
<th>Stability Test with Weight</th>
<th>Strength Test</th>
<th>Total # Tests Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay with Straw</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEGO Beam Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEGO Beam with Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13) Ask the students to add a “P” or “F” to each new box on the class chart, according to the results of tests with the LEGO beam columns. Presumably, each student pair will give the LEGO Beam Only a “P” for the Strength Test and “F”s” for the Stability Tests, and each pair will give the LEGO Beam with Base a “P” for each of the tests.
14) Discuss with students how the results chart can help them decide whether either version of the LEGO beam is a good choice for model house support columns. If the LEGO beams have behaved as usual, students will see “P’s” filling the row for “LEGO Beam with Base.” Help students understand that this row full of “P’s” is a visual summary of the large number of positive test results for the LEGO Beam with Base. This abundance of positive results suggests that the LEGO Beam with Base is the best choice for the model house columns. Students might say that they expected the Beam with Base to “win” all along. If so, explain that engineers cannot be certain about choosing a material until they use scientific tests to prove that it is a better choice than other materials.

15) Direct students to keep their columns intact. They will be used to build the frame of their model house in Lesson 5. Be sure that students do not use the 1x16 beams in any of their other roof and frame building. They will need one 1x16 beam for each of their support columns.
Lesson 4

What shapes make stable roofs?

One 60-minute session

Students will design and build roof frames out of LEGO pieces and determine the most stable roof frame shape.
- Class discussion of roof frames, shapes and surfaces with visual aids on overhead transparencies
- Building of two different LEGO roof frames
- Strength testing of roof frames with push test
- Recording results in Engineer’s Journal
- Discussion and demonstration of stable shapes

By the end of this lesson, students will be able to:
- Describe objects by the properties of shape and stability.
- Identify the properties that are most important for a specific design task, and select materials and objects that exhibit those properties.

Stability
- Stability - The ability to remain in a steady position without shaking or bending.

Stability is used to describe only objects. Even if an object is made of only one material, the stability of the object rather than the material is considered. This is because materials can be made into objects of many different sizes and shapes, some of which will be stable and some of which will not be stable. An object is stable if it can stay in the same place without shaking or bending. Support columns for a house are included to make a house stable. You would not want your house shaking around you all the time! Objects that are usually stable (such as homes) sometimes become unstable when subjected to unusually large forces (such as earthquakes).

A good test for stability is to push on the side of an object and see if it shakes or bends. If the object remains stationary, it is stable. Buildings are some of the most stable objects because we would not want them coming down on top of our heads! If the object instead moves or bends, it is unstable. Dominoes are examples of unstable objects. Dominoes are also examples of objects that we actually want to be unstable or else we would not be able to use them for certain games. Engineers must take into account the purpose of the object they are designing when deciding on the stability or any other property of the object.
## Lesson 4

### What shapes make stable roofs?

**Shape**
- **Shape** - The configuration or form of an object.
- **Triangle** - A shape with three straight sides that are connected at three different points.
- **Rectangle** - A shape with four straight sides with four corners that meet at 90 degree angles.

Shape is used to describe only objects. Even if an object is made of only one material, the shape of the *object* rather than the material is considered. The shape is the form or outline of an object. Triangles, squares, diamonds, hexagons, circles, spheres, prisms, and rectangles are examples of different shapes. The triangle is of particular note due to the inherent stability of its shape. Since each side of the triangle is connected to every other side of the triangle, it is able to support larger weights, since the entire shape goes about supporting the weight rather than only part of it. If a heavy weight were placed on a rectangular object and a triangle, the triangle would hold its shape, while the rectangle might become a parallelogram under the weight. When designing, engineers need to consider the shape of an object for aesthetic reasons, but also to be sure the object can serve its function.

**Shape** - The configuration or form of an object.

**Stability** - The ability to remain in a steady position without shaking or bending.

**Triangle** – A completely enclosed shape with three straight sides that are connected at three different points.

**Rectangle** - A completely enclosed shape with four straight sides with four corners that meet at 90 degree angles.

### Vocabulary

- **Shape**
- **Stability**
- **Triangle**
- **Rectangle**

### Materials

**For each student**
- Engineer’s Journal Part 4

**For each student pair**
- LEGO Mindstorms NXT kit

**For the class**
- Drinking straws and tape
- Several 100-gram weight
- Transparency or hand-outs of photos of roof frames

### Preparation

- Distribute Engineer’s Journals.
- Make drinking straw triangle and square by taping straws together.

### What Do Children Think About Sturdy Shapes?

- Some students assert that the best shape for a roof frame is the most interesting or intricate shape (e.g., octagonal dome, steeple).
- Many students think that the square is stronger than the triangle.
Lesson 4

Science through LEGO Engineering

PART I: Introduction to Roof Frames (15 min)
1) Explain that in this lesson students will begin to investigate choices for the roofs of their model houses.
2) Give students two-to-three minutes to talk with their partners and then write or draw their ideas about today’s science exploration question: “What properties of a roof would keep snow and ice from piling up?” You may need to review the definition of property. If you made a chart separating materials, properties, and functions in the first lesson you can use it now as a reminder. Students should record their ideas on page 4-1 of their Engineer’s Journal.
3) Explain that just as the base of the house has both columns and walls, the roof of the house similarly has a frame and a surface. Explain that this lesson will focus on the frame of the roof.
4) Use the overhead projector to display a photo of an exposed roof frame (or distribute photocopies of photo to student groups) so that students understand the difference between the roof frame and the completed roof. Some of the columns pictures could be useful here.
5) Students will think about the shape of the roof frame by designing and testing different shapes for their property of stability. Explain that in this case, stability should be considered a property of an object – the roof frame – rather than a property of a material. For this lesson, the material has already been chosen – students will build frames out of LEGO beams.
6) Review the definition of the property of stability:
   - An object’s stability is its ability to remain standing upright, without shaking or bending, even when it is being pushed or pulled by external forces.
7) Continue to display images of roof frames, and ask students to describe the roof shapes they see in the photos.
8) Ask students to think about the most stable shape for a roof, discuss this prediction with their partner, and then write their final prediction on page 4-2 of their Engineer’s Journal.

What Questions Might Students Ask During This Lesson?

- How big should the roof be? It should be at least big enough to span an index card. It might help to put an index card on your desk and pretend that you are building a roof for your index card.
- What pieces should I use? Any pieces that you have not already used for your LEGO columns. Straight beams, angled beams, axles, bushings, and connector pegs will all be useful.
- How can I make my roof sturdier? Connect pieces together in two places instead of one.
- How can I keep my roof frame from bending in? Connect pieces more rigidly by adding more attachment points.
- How can I make my roof bigger? Use axles to span across two identical frames.
Lesson 4  What shapes make stable roofs?

PART II: Building and Testing LEGO Roof Frames (30 min)

9) Explain that the main task for this lesson is to construct roof frames out of LEGO pieces and test their stability. Students should test the stability of each frame with the “one-finger push test.” To conduct this test, place the roof frame upright on a desk, table, or floor, and push with one finger on the highest point of the roof. If the roof does not change shape (i.e., collapse), then it passes the test.

10) Before students begin building, display at least two sample LEGO roof frame shapes.

11) Distribute LEGO Mindstorms kits to students and suggest that beams, connector pegs, axles, and bushings might be the most helpful pieces for this task.

12) Direct students NOT to use 1x16 beams in their roofs. They will need these beams to complete the columns of their houses in Lesson 5.

13) Each student pair should build and test at least two different LEGO roof frame shapes. They should describe each frame and record the results of each push test on page 4-2 of their Engineer’s Journal.

PART III: Class Discussion and Journal Work (15 min)

14) Facilitate class discussion about the most stable roof frame shapes.

15) Conclude this lesson on the stability of shapes by showing that the triangle is the most stable shape in general. Conduct the following demonstration:

   a. Tape three straight drinking straws together into a triangle shape.
   b. Tape four straight drinking straws together into a rectangle shape.
   c. Hang 100-gram weights from the triangle. The triangle should be able to hold at least 300 grams before deforming.
   d. Then, hang 100-gram weights from the rectangle. The rectangle should only be able to hold 200 grams before deforming into a diamond or collapsing completely.
Roof Shape Images
Sample LEGO Roof Frames
Lesson 5

How can we make stable and strong house frames?

Suggested Time

Lesson Overview

Learning Objectives

Teacher Background

One 60-minute session

Students will use the LEGO columns and roof frames they previously designed to create the frame of their model house. The house frame should still be stable and strong.
- Building of two additional columns
- Finishing roof frame
- Connecting columns and roof to create completed house frame
- Strength testing of house frames with push test
- Recording results and diagramming frame in Engineer’s Journal
- Discussion and demonstration of strong and stable frames

By the end of this lesson, students will be able to:
- Describe objects by the properties of strength and stability.

Strength
- Strength - The ability to hold something up or resist distortion when a force (push or pull) is applied.

Strength can be used to describe both objects and materials. When you push or pull on a strong material, it will not change shape. A weak material will change shape when it is pushed or pulled. Objects that are made of strong materials also exhibit the property of strength. When objects are made of both weak and strong materials, it is important to test the object, in order to tell if the object as a whole exhibits the property of strength. It is also important to test the strength of the connections between different pieces or materials of an object.

There are two common ways of testing for strength. One test involves applying a force to an object (or material) by pushing or pulling on it. If the object resists distortion (does not change shape), it is considered a strong object. The other test involves checking if a piece of the material or an object can hold up a different, relatively heavy object. The exact heaviness of this object being held up (the “test weight”) depends on how the material or object under question will be used. It is important that the “test weight” applies at least as much force as the material or object will feel during use. For example, if you are testing a piece of plastic material for possible use in a chair, the test weight applied to the plastic must be at least as heavy as a person. Using the word “strength” to describe objects can be compared to using the word “strength” to describe people. When people can hold up heavy boxes full of books, they are considered strong, just as an object is considered strong when it can hold up items that are relatively heavy compared to its own weight and size.
Lesson 5

How can we make stable and strong house frames?

**Stability**

- **Stability** - The ability to remain in a steady position without shaking or bending.

  Stability is used to describe only objects. Even if an object is made of only one material, the stability of the *object* rather than the material is considered. This is because materials can be made into objects of many different sizes and shapes, some of which will be stable and some of which will not be stable. An object is stable if it can stay in the same place without shaking or bending. Support columns for a house are included to make a house stable. You would not want your house shaking around you all the time! Objects that are usually stable (such as homes) sometimes become unstable when subjected to unusually large forces (such as earthquakes).

  A good test for stability is to push on the side of an object and see if it shakes or bends. If the object remains stationary, it is stable.

  Buildings are some of the most stable objects because we would not want them coming down on top of our heads! If the object instead moves or bends, it is unstable. Dominoes are examples of unstable objects. Dominoes are also examples of objects that we actually want to be unstable or else we would not be able to use them for certain games. Engineers must take into account the purpose of the object they are designing when deciding on the stability or any other property of the object.

---

**Vocabulary**

- **Support column** - A tall, thin, strong object that helps to hold the weight of a large building or structure. Several support columns are needed to hold a building’s weight.

- **Strength** - The ability to hold something up or resist distortion when a force (push or pull) is applied.

- **Shape** - The configuration or form of an object.

- **Stability** - The ability to remain in a steady position without shaking or bending.

---

**Materials**

- **For each student**
  - Engineer’s Journal Part 5

- **For each student pair**
  - LEGO Mindstorms NXT kit

- **For the class**
  - Transparency or hand-outs of entire house frames

- Distribute Engineer’s Journals.
### Lesson 5

#### Instructions for Teachers

**GETTING STARTED**

**How can we make stable and strong house frames?**

**PART I: Introduction to House Frames (15 min)**

1) Explain that in this lesson students will complete their model house frame. The completed frame needs four columns and a roof frame.

2) Give students two to three minutes to talk with their partners and then write or draw their ideas about today’s science exploration questions: “(1) How do you think roofs and columns of real houses are attached to each other? (2) How could you attach your LEGO roof and columns to each other?” Students should record their ideas on page 5-1 of their Engineer’s Journal.

3) Explain that when they are connected together, columns and a roof frame make up the frame of an entire house. Later, students will add the inner and outer walls (or surfaces) to both the column and roof portions of their model house frames.

4) Have a few students share their ideas about how real house columns and roofs are attached, and about how they might attach their own LEGO columns and roofs. Follow up on their ideas by asking students, “What properties should your attachment methods give your house? (Their connections should have stability and strength.)”

5) Use the overhead projector to display a photo of different frames (or distribute photocopies to student groups). Some of the columns pictures could also be useful here.

6) Explain to students that they will think about the stability and strength of the house frame. Explain that, in this case, stability and strength should be considered a property of an object – the house frame – rather than a property of a material.

7) Review the definition of the properties of stability and strength:

   - An object’s **stability** is its ability to remain standing upright, without shaking or bending, even when it is being pushed or pulled by external forces.
   - An object’s **strength** is its ability to hold something up or resist distortion when a force (push or pull) is applied.

**What Questions Might Students Ask During This Lesson?**

- I didn’t write about strength or stability. Does that mean the property I wrote about isn’t important? No, there are many important properties for houses. These are just the two we are centering on for our tests.
- I don’t have enough pieces to make the same columns again. You do not need to make identical columns. They should be the same height, but they do not need to be identical.
- How can I stop my support columns from rotating around the roof frame? Add a piece that connects them diagonally or use different pieces to connect the roof to the support columns that will not rotate.
- How can I make my house frame sturdier? Connect pieces together in two places instead of one.
- How can I make my house frame stronger? Connect the support columns together on the top and bottom.

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### Lesson 5

#### How can we make stable and strong house frames?

<table>
<thead>
<tr>
<th>PART II: Building and Testing LEGO House Frames (30 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8) Explain that the main task for this lesson is to construct model house frames out of LEGO pieces and test their stability and strength.</td>
</tr>
<tr>
<td>9) Students should first build two more support columns and then finish their roof frames if they are not complete. Then, students should connect the roof frames and support columns together to make a house frame.</td>
</tr>
<tr>
<td>10) Once the house frame is completed students should test the stability and strength of the frame.</td>
</tr>
<tr>
<td>11) Explain that they will once again use the “one-finger push test” for stability. To conduct this test, place the roof frame upright on a desk, table, or floor, and push with one finger on the highest point of the roof. If the roof does not change shape (i.e., collapse), then it passes the test.</td>
</tr>
<tr>
<td>12) Explain that they will also repeat the strength test they did with clay and LEGO beams when they tested the columns. They should put their house frame between their hands and press in on either side. If the house frame does not move or change shape, then it passes the test.</td>
</tr>
<tr>
<td>13) Before students begin building, display at least two sample LEGO house frames.</td>
</tr>
<tr>
<td>14) Explain that students’ house frames may not pass both tests on the first time. If their house frame does not pass one of the tests, then they will need to improve their design. Making improvements is an important part of the engineering design process.</td>
</tr>
<tr>
<td>15) Distribute LEGO Mindstorms kits to students and allow students to build for approximately 10 minutes. Then, stop students to address any common difficulties and allow them to give each other building suggestions.</td>
</tr>
<tr>
<td>16) After completing their house frames, students should diagram (draw and label) them on page 5-2 of their Engineer’s Journal.</td>
</tr>
</tbody>
</table>

#### PART III: Class Discussion of House Frames (15 min)

| 17) Facilitate class discussion about what makes a house frame strong and stable. |
| 18) Have student groups explain what helped make their house frame strong and stable and what did not work. |
Design a Model House
Sample House Frames
Lesson 6

Which wall material will help our houses stay quiet?

One 60-minute session

Using LEGO sound sensors, students will test the sound absorption (soundproofing) ability of cloth blanket (polyester quilt batting) and craft foam (“Foamie” sheets) as possible inner-wall materials.

- Introduction of sound absorption ability and discussion of methods for testing
- Learning how to use the NXT sound meter
- Student-conducted sound absorption tests of cloth blanket and craft foam
- Class discussion on appropriateness of cloth blanket and craft foam as inner-wall materials

By the end of this lesson, students will be able to:

- Describe materials by the property of sound absorption ability.
- Measure the properties of materials and objects with electronic tools such as sound level sensors.
- Identify the properties that are most important for a specific design task, and select materials and objects that exhibit those properties.

Sound Absorption

- **Sound absorption** - Blocking the passage of sound vibrations with a material in order to decrease the volume of a sound.
- **Soundproofing** - The ability to block the passage of sound. In a perfectly soundproof room, you do not hear sounds from outside, and people outside do not hear sounds made in the room.
- **Sound level** - The volume of a sound.
- **Decibel** - A unit for measuring the volume of sounds.

Good sound insulators are used as soundproofing materials. An object or material that can successfully provide soundproofing is a good sound absorber. Sound absorption occurs when a sound hits an object or material, goes through it, and comes out at a lower volume. Since the volume of a sound is directly related to the size of the vibrations that produce a sound, sound absorption is also the action of decreasing the size of sound vibrations.

A test for soundproofing determines the volume of a sound on either side of an object or material. The volume is often measured in decibels. To test soundproofing, first a sound is made on one side of an object or material. The volume of the sound is determined on both sides of the object or material through a microphone or sound detector. If an object or material is a good sound absorber, the volume will be lower once the sound passes through the object or material.
### Vocabulary

**Insulation**
- **Insulation** - The ability to prevent the passage of heat, electricity, or sound.
- **Insulator** - An object or material that provides insulation. A good thermal insulator maintains the temperature of whatever object it surrounds.

Both materials and objects can be considered insulators. Insulators serve the purpose of providing insulation, or preventing heat, electricity, or sound from passing. Different types of tests are needed for different types of insulation. Sound insulation prevents sound from passing through an object or material into another area. Sound insulation can be tested by comparing the volume of noises on each side of an object or material. The volume should decrease (and, ideally, be nonexistent) on the other side of a sound insulator.

**Sound absorption** - Blocking the passage of sound vibrations with a material in order to decrease the volume of a sound.

**Soundproof** - The ability to block the passage of sound. In a perfectly soundproof room, you do not hear sounds from outside, and people outside do not hear sounds made in the room.

**Sound level** - The volume of a sound.

**Decibel** - A unit for measuring the volume of sounds.

### Materials

**For each student**
- Engineer’s Journal Part 6

**For each group of four students**
- 9” x 12” piece of polyester quilt batting, about 1/8” thick
- 9” x 12” piece of craft foam, about 1/8” thick
- Stapler or masking tape
- One NXT programmed to be the “Noisemaker” NXT, as described in “Preparation” section
- One NXT with sound sensor and connector cable, to be used as the “Noise Detector” NXT
- Transparencies or print-outs of photos of different kinds of walls (e.g., brick, mud, drywall, wood)

**What Do Children Think About Sound Absorption?**

- When sounds pass through solids, it is because there are tiny holes in the solids. For example, there are tiny holes in the walls, desks, floors, and chairs.
- Foam is not good at soundproofing because it has lots of holes. (Actually, foam is often used for soundproofing because its holes trap air, which transmits sound much less effectively than solid materials do.)
- Sounds are emitted in straight paths and bounce off materials in straight lines. (Sounds are transmitted spherically outwards.)
- If there is a door in the wall and we can still hear, it is because sound travels through the lock and under the door.
- When a sound is stuck in a box, it fights at the sides to get out.
- If sound gets out of a box, it is because it is stronger than the box.

**Preparation**

- Cut 9” x 12” pieces of batting and foam for each student pair.
Lesson 6

Which wall material will help our houses stay quiet?

- Set out staplers or prepare masking tape for students (you might tear off strips of tape and attach to desks). Students will fold the batting and foam sheets in half and use staples or tape to seal two edges of these “pockets.” (Alternatively, you could pre-make the pockets for students.)
- Onto half of the NXTs in the classroom, download the NXT-G (or ROBOLAB) program that tells the NXT to play a sound repeatedly. These NXTs will be the “noisemaker” NXTs. Two sample programs are included on the module CD, and they are pictured at the end of this lesson plan. You could also write your own program.
- Distribute Engineer’s Journals.

---

**PART I: Introduction (20 min)**

1) Explain that in this lesson students will begin to investigate materials for the inside walls of their model houses. Use the overhead projector to display photos of different kinds of walls, or distribute photocopies of photos to student groups.

2) After viewing images of walls, give students two to three minutes to talk with their partners and then write or draw their ideas about properties that are important for wall materials. Students should record their ideas on page 6-1 of their Engineer’s Journal.

3) Explain that this lesson’s investigation will focus on the inside layer of walls (the wall surface that faces the inside of the house). They will test cloth blanket (polyester batting) and craft foam as possible materials for the inner-walls. Specifically, they will determine how good these materials are at sound absorption (soundproofing).

4) Ask students to brainstorm for two to three minutes about why it might be important for walls to be good at absorbing sounds. They should discuss their ideas with their partner and then write their ideas on page 6-1 of their Engineer’s Journal.

5) Ask some students to share their ideas with the class.

6) Explain the today’s test involves making a sound and measuring its volume, and then covering the sound-maker with cloth and foam and measuring the sound again to see how the covering changes it. Ask students to brainstorm for another two to three minutes about ideas for sound-making and sound-measuring: if they were conducting this test, what could they use to make the sound and what could they use to measure its volume? They should discuss their ideas with their partner and then write their ideas in their Engineer’s Journal.

7) Arrange students in groups of four (two student pairs working together).
Lesson 6

ACTIVITY EXPLANATION

8) Explain that students will test for sound absorption ability with the help of two LEGO NXT computers. They will use one NXT as a “noisemaker” and one NXT as a “noise detector.”

9) Explain that you will give each group one sheet of cloth and one sheet of foam. They should fold each sheet in half and tape or staple along one long edge and one short edge to make a “pocket.” Then, they will place the noisemaker NXT inside one pocket, and use the noise detector NXT to measure how much sound is absorbed. Finally, they will repeat with the other pocket. (Alternatively, you can do the stapling or taping ahead of time, and give each group a pre-made foam pocket and a pre-made cloth pocket.)

10) Distribute one “noisemaker” NXT and one “noise detector” (NXT plus sound sensor) to each group of four students.

11) Review the use of the NXT buttons.
   • Orange is for “on,” “select,” and “run.”
   • Dark gray is for “back” and “stop.”
   • Light gray arrows are for “right” and “left.”

12) Using a poster (such as the one shown in Figure 1) as a visual aid, walk students through the procedure for viewing sound sensor readings on the NXT. Figure 1 provides the specific instructions.

What Questions Might Students Ask During this Lesson?

- What does the number on the NXT screen tell me? A higher number means louder sound; a lower number means quieter sound and better soundproofing.
- The number on the NXT screen keeps changing. Which number should I record? Record the middle number, or the one that you see the most often.
- Our group is arguing because we all think we see different numbers. Which one should we write down? Each student should say what he or she saw; then they should pick the number in the middle.

Figure 1. Poster with instructions for viewing the sound sensor.

Which wall material will help our houses stay quiet?

What Questions Might Students Ask During this Lesson?
13) Explain that you will practice viewing sound sensor readings together as a class.
   a. Have students set their NXTs to display the sound level in dBA.
   b. Tell students to be as quiet as possible while watching the sound level on the NXT.
   c. Tell students to talk all at the same time while watching the sound level on the NXT.
   d. Ask students: “When was the sound level higher, when you were quiet or when you loud?” (Loud) “So, what kind of number means there is more sound, a higher number or a lower number?” (Higher)
   e. Tell students to talk at the same time again while watching the sound level on the NXT.
   f. Then, tell students to cover their mouths with their hands as they talk, and continue to watch the sound level.
   g. Ask students: “When was the sound level lower, when you had your hands over your mouth or when you didn’t?” (Hands over mouth) “So which kind of number means sound is being absorbed, a higher or lower number?” (Lower)

PART II: Sound Absorption Test (25 min)
14) Using a poster such as the one shown in Figure 2, direct students through the steps for running the “noisemaker” program.

![Noise Maker NXT Directions]

Figure 2. Poster with instructions for running the noisemaker program.

15) Review the instructions for the sound absorption test with students.
Lesson 6

Which wall material will help our houses stay quiet?

Students will:

a. Choose one pair to control the “noisemaker” NXT and one pair to control the “noise detector” NXT.

b. Use the “View” function on the “noise detector” NXT to view the sound level (in dBA units) detected by the sound sensor.

c. “Run” the noisemaker program, and “View” the sound level sensed by the noise detector NXT. Record in your Engineer’s Journal.

d. Insert the noisemaker NXT into the cloth blanket (batting) pocket, and place the pocket where the NXT alone had been located.

e. “View” the sound level now sensed by the noise detector NXT. Record in your Engineer’s Journal.

f. Remove the noisemaker NXT from the cloth pocket and insert it into the craft foam pocket. Place the foam pocket where the cloth pocket had been located.

g. “View” the sound level now sensed by the noise detector NXT. Record in your Engineer’s Journal.

h. Stop the noisemaker program.

i. Repeat steps (d) through (i) two more times.

Figure 3. (Left) Placing the “Noisemaker” NXT in a craft foam pocket, which will provide some soundproofing. (Right) Set-up for measuring the amount of sound absorbed when wrapped in craft foam.

16) Allot 15-20 minutes for students to conduct the sound absorption test.
PART III: Class Discussion and Journal Work (15 min)

17) Create a poster-size version of the following chart and display it in a location where all students can see it.

<table>
<thead>
<tr>
<th>CHOOSING THE MATERIAL FOR MODEL-HOUSE WALLS</th>
<th>Sound Absorption Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloth Blanket</td>
<td></td>
</tr>
<tr>
<td>Craft Foam</td>
<td></td>
</tr>
</tbody>
</table>

18) Ask students to decide in their groups whether one material absorbed more sound than the other, or whether they absorbed about the same amount of sound. If they decide that one material absorbed more sound than the other, they should write a “P” in the Sound Absorption Test box for that material and an “F” in the box for the other material. If they decide that the materials absorbed about the same amount, they should place “P’s” in the Sound Absorption Test boxes for both materials.

19) Ask a volunteer from each group to record their “P’s” and “F’s” on the class chart for wall materials. Typically, the cloth blanket (batting) will receive a “F,” while the craft foam will receive a “P.” In other words, the cloth blanket (batting) absorbs less sound than the craft foam.

20) Facilitate class discussion on whether the students know enough to conclude whether the cloth blanket (batting) or craft foam is a more suitable material for the model house’s inner-walls.

21) Explain that tomorrow students will test the inner-wall materials for the property of thermal insulation.

22) Ask students to complete their Engineer’s Journal if necessary.

Note: Sometimes the results are very close. In this case you may want to give the material that was slightly better at soundproofing a P+ and the other material a P−.
Noisemaker Programs

NXT-G

The program pictured below is provided on the module CD. It was created in NXT-G, with the “Loop Forever” icon, the “Sound” icon set to play “Blips 07,” and the “Wait For Time” icon set to 0.05 seconds.

ROBOLAB

The program pictured below is provided on the module CD. It was created in ROBOLAB Inventor Level 4, with the “Loop Forever” icons and the “Play a Sound” icon.
What materials are these inner walls made out of?


Lesson 7

Which wall materials will help our houses stay warm?

One 60-minute session

This lesson focuses on cloth blanket (polyester quilt batting) and craft foam as possible inner-wall materials. Students will assist as the teacher uses digital LEGO thermometers to test the thermal insulation ability of cloth blanket and craft foam.

- Class discussion of wall materials, with visual aids on overhead transparencies
- Discussion of the property of insulation
- Teacher-led insulation testing of wall materials
- Recording results in Engineer’s Journal
- Class discussion of appropriateness of cloth blanket and craft foam for inner walls
- Attaching inner walls to TWO sides of house frames

By the end of this lesson, students will be able to:

- Describe materials by the property of thermal insulation ability.
- Measure the properties of materials and objects with electronic tools such as digital thermometers.
- Identify the properties that are most important for a specific design task, and select materials and objects that exhibit those properties.

Temperature

- **Temperature** - A measurement of how hot or how cold something is.
- **Thermometer** - A tool used to measure temperature. Thermometers can be used to find the temperature of things such as the air, water, or an object. (JB)

The temperature of an object or a location is generally observed with a thermometer. Temperature is measured in degrees Fahrenheit or degrees Celsius. In the United States we commonly use the Fahrenheit system, while the Celsius system is more common abroad. Temperature gives us a means to compare the warmth of different places, objects, or materials.

The way a material acts at certain temperatures is also important to consider. Some materials will change from liquid to gas form when the temperature rises or from liquid to solid form when the temperature drops. When making design choices, it is important to know the temperatures at which a material changes state. One would not want to make a pot out of a material that would melt or evaporate when put on a stove!
Lesson 7

Which wall materials will help our houses stay warm?

**Insulation**
- **Insulation** - The ability to prevent the passage of heat, electricity, or sound.
- **Insulator** - An object or material that provides insulation. A good thermal insulator maintains the temperature of whatever object it surrounds.

Both materials and objects can be considered insulators. Insulators serve the purpose of providing insulation, or preventing heat, electricity, or sound from passing. Good insulators are always poor conductors. *Thermal* insulators are those that are poor conductors of heat. A good thermal insulator will maintain the temperature of the space or object inside the insulator. For example, on a hot day, insulating walls will help the inside of a house stay at the cooler night-time temperature. On a cold day, insulating walls will help the inside of a house stay at the temperature reached by heating. A good electric insulator will not allow any electricity to pass through it. Electric insulators are often plastic, or other non-conducting materials, which surround wires that carry power. A good sound insulator prevents noises that are outside an object from going inside the object, and vice versa. Many people appreciate having sound-insulating walls in their home so conversations do not travel throughout the house and so loud outside noises do not interrupt inside activity.

Different types of tests are needed for different types of insulation. Thermal insulation can be tested by comparing the temperature inside and outside an object or material that serves as an insulator. A good thermal insulator will keep the inside temperature from changing, no matter what happens to the outside temperature. If a cooling or heating system is in place, the cooler or heater will need to operate less frequently when a good insulator exists. Comparing how frequently a heating system needs to operate to maintain a certain temperature within two different materials would also serve as an insulation test.

---

**Vocabulary**

**Temperature** - A measurement of how hot or how cold something is.

**Thermometer** - A tool used to measure temperature. Thermometers can be used to find the temperature of things such as the air, water, or an object.

**Insulation** - The ability to prevent the passage of heat, electricity, or sound.

**Insulator** - An object or material that provides insulation. A good thermal insulator maintains the temperature of whatever object it surrounds.
Lesson 7

<table>
<thead>
<tr>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For each student</strong></td>
</tr>
<tr>
<td>Engineer’s Journal Part 7</td>
</tr>
<tr>
<td><strong>For the class</strong></td>
</tr>
<tr>
<td>LEGO NXT</td>
</tr>
<tr>
<td>LEGO thermometer</td>
</tr>
<tr>
<td>Watch or clock</td>
</tr>
<tr>
<td>Large bucket or bag of ice</td>
</tr>
<tr>
<td>0.5-Liter plastic bottle, with the top cut off so it is 5” tall</td>
</tr>
<tr>
<td>Serving bowl, bucket, or other plastic container measuring at least 8” across the top (e.g., large Gladware container)</td>
</tr>
<tr>
<td>5” x 7” piece of polyester quilt batting</td>
</tr>
<tr>
<td>5” x 7” piece of craft foam</td>
</tr>
<tr>
<td>Masking tape</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distribute Engineer’s Journals.</strong></td>
</tr>
<tr>
<td><strong>Set up thermometers, bowl or other container, ice, bottles, and insulation.</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructions for Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GETTING STARTED</strong></td>
</tr>
<tr>
<td><strong>PART I: Introduction (15 min)</strong></td>
</tr>
<tr>
<td>1) Explain that in this lesson students will continue to investigate materials for the inner walls of their model houses. Students will continue to test cloth blanket and craft foam as possible materials for the walls. In this lesson, they will test one property: <strong>insulation ability</strong>.</td>
</tr>
<tr>
<td>2) Discuss the definition of this property:</td>
</tr>
<tr>
<td>a. A material’s insulation ability is its ability to prevent heat from passing through it. In other words, it is the ability to keep things at the same temperature. Insulation helps both with keeping heat out (keeping something cold) and with keeping heat in (keeping something hot).</td>
</tr>
<tr>
<td>b. An insulator is an object or material that provides insulation. A good thermal insulator maintains the temperature of whatever object it surrounds.</td>
</tr>
<tr>
<td>3) Ask students to brainstorm for two to three minutes about ways to test for insulation ability (how good a material is at keeping things at the same temperature). You might ask students to think of one way to test how good a material is at keeping things hot and one way to test</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What Do Children Think about Thermal Insulation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students’ ideas include:</td>
</tr>
<tr>
<td>Insulation is either the ability to keep something cold, or the ability to keep something hot, but not both.</td>
</tr>
<tr>
<td>A material’s insulation ability is not as important as its strength.</td>
</tr>
<tr>
<td>The thicker the material, no matter what it is, the better it will be at insulating.</td>
</tr>
<tr>
<td>The more layers of material, no matter what they are, the better it will be at insulating.</td>
</tr>
<tr>
<td>For a hot chocolate mug, color is a more important property than insulation. Black and brown are the best for tasting the chocolate flavor. Hardness is also an important property for a hot chocolate mug. A mug’s insulation ability is not very important.</td>
</tr>
</tbody>
</table>
how good a material is at keeping things cold. They should discuss their ideas with their partner and then write their ideas on page 7-1 of their Engineer’s Journal.

PART II: Thermal Insulation Test (20 min)

4) Explain that although there are many ways to test for insulation ability, in this lesson you will conduct one test as an entire class. You will find out which material is better at keeping the air inside of a container warm when the container is surrounded by ice. (In other words, you will find out which wall material would be better at keeping cold weather from from cooling the air inside a house.)

5) Before beginning the test, explain that students will work independently in their Engineer’s Journals as the test is running. They will complete today’s exploration questions on page 7-2 of their Journals. Since they will have more time for this question today, they should work to make their answer as convincing as possible, as well as write and draw their answer to the questions.

6) After assigning the Journal question, set up the insulation test, and explain the testing method as you go. You will conduct the insulation test first with the craft foam and then with the cloth blanket (batting). Each test will run for six minutes.

Figure 1. Set-up for testing insulation ability. The material to be tested lines the bottom of a plastic bottle, which is placed in an ice-filled bowl. A LEGO thermometer hangs down into the bottle but does not touch the lining material.
Lesson 7

Which wall materials will help our houses stay warm?

a. Roll the 5” x 7” piece of craft foam into a 5”-tall cylinder shape. Insert this cylinder into the shortened ½-liter bottle. Make sure the foam covers the entire inside wall of the bottle.

b. Place the now “insulated” bottle in the middle of a larger container. Do NOT add ice yet.

c. Tape the thermometer wire so that the thermometer hangs in the middle of the bottle WITHOUT touching the foam material or the bottom of the bottle.

d. Plug the thermometer into the NXT. You will need the adapter wire (which has a phone-cord plug on one end, and a 2x2-LEGO-stud plug on the other end).

e. Demonstrate to students how you can use the NXT “view” function to view the thermometer reading. Ask for a volunteer student pair to read off the current value of the thermometer.

f. Ask another volunteer pair to record this value in the “0-minute” row on a poster-size data table. Your table might look like this:

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Temp Inside Craft Foam (°F)</th>
<th>Temp Inside Cloth Blanket (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

g. After recording the initial temperature, fill in the rest of the larger container with ice. Begin keeping track of time.

h. After three minutes, ask a new student pair to read the temperature value and another pair to record it on the data table.

i. After three more minutes, ask two more pairs to read and record the temperature value.

(Alternatively, you might use NXT software to program the NXT to record temperature values at repeated intervals over a six-minute period, and then view the data using Investigator’s automatic graphing function.)

j. You have completed the test for the cloth’s insulation ability.

k. Before running the test for the craft foam, pour out any water from the larger container and add more ice to refill the container.

l. Allow the thermometer’s temperature to return to room temperature.

m. Repeat steps (a) through (i) for the cloth blanket (batting) material.

Note: If you and students are interested, you could run the tests for a longer duration. This would enable you to include more students in temperature reading and recording; however, this is optional.
Lesson 7

Which wall materials will help our houses stay warm?

7) Remind students that while the insulation test is occurring, they should work on the “Exploration Question” section of their Engineer’s Journal.

PART III: Class Discussion (10 min)

8) After both tests are complete, ask students to record the initial (0-minute) and final (6-minute) temperatures in their Engineer’s Journal. Explain again that because the LEGO thermometers are not as accurate as other thermometers, you cannot rely on the final temperature reading. Instead, you must look at the CHANGE in temperature for each material.

9) Ask students to compute the change in temperature for each of the three thermometers, by subtracting the initial value from the final value. They should do this computation in their Engineer’s Journal.

10) Come to an agreement as a class on the material that allowed the SMALLEST change in temperature.

11) Add an Insulation Test column to your results chart for wall materials.

Choosing the Material For Model House Walls

<table>
<thead>
<tr>
<th>Cloth Blanket</th>
<th>Soundproof Test</th>
<th>Insulation Test</th>
<th>Total # of Tests Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12) Ask the students to add a “P” or an “F” to each box on the class chart, according to the insulation test results. They should give a “P” to the wall material that performed better on the insulation test, and an “F” to the material that performed worse. To pass the test “better” means to allow the smaller change in temperature. If the two materials allowed the same temperature change, students may write a “P” in both boxes.

13) Facilitate further class discussion about whether one material is a better choice for the model house walls. For example, if the craft foam has earned a P for both tests, you have evidence that the craft foam is the better choice. On the other hand, if the craft foam earned an F on the insulation test while the cloth batting earned a P, then both materials will have passed one test (assuming the craft foam was a better sound absorber). In this case, students will need to decide which property is more important and justify their decision.

14) Ask students to complete their Engineer’s Journal if necessary.
Which wall materials will help our houses stay warm?

PART IV: Cutting and Attaching Inner-Wall Material (10 min)

15) After students choose the best inner-wall material and provide scientific reasoning for their choice, they are ready to add the material to their model house frame.

16) Instruct students to cover just TWO walls of their model house with their chosen inner-wall material. Two walls should be left uncovered so that the house frame remains visible for sharing the house with others.

17) Have students show you their completed Engineer’s Journal and then give them scissors and cloth or foam material. Have students cut cloth or foam pieces to fit two walls of their model house frames.

18) Remind students that they will only cover half of their house and that these are the inner walls of the house. If there is not enough time for this step, students can complete the inner walls at a later time.
Design a Model House

Completely framed house with partial walls
(Notice that the frame is still visible.)
Lesson 8

Suggested Time

Lesson Overview

Learning Objectives

Teacher Background

Which wall materials will help keep out rain and bright light?

One 60-minute session

In this lesson, students will test cardboard and transparent plastic as two possible outer-wall materials for their model houses. First, they will assist with a teacher-led reflectivity test that models the effect of bright sunlight shining on the outer surface of a house. Then, they will conduct a waterproofing test that models the effect of rain hitting the outer surface of a house.

- Introduction to outer-wall materials
- Teacher-led reflectivity testing
- Student journal work and waterproof testing
- Teacher-led waterproof testing
- Recording results in Engineer’s Journal
- Class discussion on choosing the outer-wall materials

By the end of this lesson, students will be able to:

- Describe materials by the properties of waterproofing, reflectivity, and color.
- Measure the properties of materials and objects with both manual and electronic tools, such as spring scales and thermometers.
- Identify the properties that are most important for a specific design task, and select materials and objects that exhibit those properties.

Waterproof

- **Waterproof** - Able to prevent water from passing through a material or to prevent a material from absorbing water.

  The term *waterproof* can be used to describe both objects and materials. When you place a *waterproof* material in water, it will not absorb, or take up, any of the water. A *non-waterproof* material will absorb the water. A *water-resistant* material will avoid absorbing water for a limited amount of time. *Objects* that are made of waterproof materials also exhibit the property of being waterproof. If an object is made of more than one piece of waterproof material, the seams between the pieces must be securely covered with waterproof materials to create an entire object that is waterproof. When objects are made of both waterproof and non-waterproof materials, it is important to conduct tests to determine whether the object as a whole exhibits waterproofing abilities.

Reflectivity, Color, & Transparency

- **Reflectivity** - The ability of a surface to bounce back light.
- **Color** - The shade reflected by a surface to the eye.
- **Transparent** – Clear or see-through, and having the property that all light...
Lesson 8

Which wall materials will help keep out rain and bright light?

passes through

The term *reflectivity* is used to describe both materials and objects. Any material or object with a *color* has some degree of reflectivity, since an object’s color is determined by the color of light reflected away from the surface of the object. Some colors indicate that an object is capable of more reflectivity or more absorption. A white or light-colored surface is more reflective, while a dark or black surface is more absorbent. White is a reflection of every color in the color spectrum, while black is the absorption of every color in the color spectrum. Reflectivity and color also influence temperature of objects. A white object or one that reflects much light will not heat up as much as a black object or one that absorbs much light.

*Transparent* materials allow all the light that hits them to pass through. Because transparent materials do not reflect, or bounce back, any light, they appear to be colorless, or *clear*.

---

**Vocabulary**

Waterproof - Able to prevent water from passing through a material or to prevent a material from absorbing water.

Reflectivity - The ability of a surface to bounce back light, heat, or sound.

Temperature - A measurement of how hot or how cold something is.

Transparent – Clear or see-through, and having the property that all light passes through

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**Materials**

*Note: Use chipboard (non-corrugated, cereal-box cardboard) so that it is similar in thickness and consistency to transparency plastic.*

For each student
- Engineer’s Journal Part 8

For each student pair
- 5” x 7” piece of transparency plastic
- 5” x 7” piece of non-corrugated cardboard (cereal-box cardboard, called “chipboard”)
- Small cup of water
- Eyedropper/pipette (optional)
- Paper towel

For the class
- 5” x 7” piece of transparency plastic
- 5” x 7” piece of non-corrugated cardboard
- Masking tape
- LEGO NXT
- Watch or clock

---

**What Do Children Think About Reflectivity?**

Students’ ideas about the relationship between color and insulation include:
- White or light material lets heat through and thus causes a room to become warmer.
- Black or dark material traps heat and thus prevents it from making a room warmer.
- White makes things cooler simply because it is “brighter.”
- White surfaces reflect sunlight back to the sun.
- Black “attracts” heat from the sun, so it will make a space warmer.
- Something with two layers will be a better thermal insulator because there is an extra pocket of air that “prevents the heat from going through.”
- A roof’s ability to insulate has more to do with its material type than its color.
**Lesson 8**

<table>
<thead>
<tr>
<th><strong>Which wall materials will help keep out rain and bright light?</strong></th>
</tr>
</thead>
</table>
| - Desk lamp  
- 1-Newton spring scale (force meter)  
- Pre-built LEGO stand for the reflectivity test |

**Preparation**

- Build a LEGO stand for the reflectivity test (instructions at end of lesson plan).
- For each student pair, pour about ¼ cup (2 oz.) water into a cup.
- Distribute Engineer’s Journals

<table>
<thead>
<tr>
<th><strong>Instructions for Teachers</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GETTING STARTED</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>ACTIVITY EXPLANATION</strong></th>
</tr>
</thead>
</table>
| 1) Explain that in this lesson students will investigate materials for the outer walls of their model houses. They will test clear plastic and cardboard for their properties of reflectivity and waterproofing.

2) Discuss the definitions of reflectivity and waterproofing:

   a) A material’s **waterproofing ability** is its ability to prevent water from passing through or to prevent itself from absorbing water.

   b) A material’s **reflectivity** is its ability to bounce back light, heat, or sound. A material’s reflective ability can be related to the material’s color.

3) Explain that while the reflectivity test is running, the students’ task will be to work on the exploration questions in their Engineer’s Journals. After you explain the test set-up and start the test, they should begin work on this Journal section.

4) Set up the reflectivity test as described below, and explain as you go. You will need to construct the LEGO stand prior to the class discussion.

5) Before beginning the first reflectivity test (with cardboard), remind students to work on their exploration questions while the test runs.

6) Follow the reflectivity test set-up instructions below.
   a. Place the LEGO stand on the desk or table surface.
   b. Attach a LEGO thermometer to the stand, as shown in the diagram below. Be sure the thermometer tip does not the desk or table surface.
   c. Place the 5” x 7” piece of cardboard on top of the LEGO stand.

**STUDENTS’ INDEPENDENT ACTIVITY #1**

**What Questions Might Students Ask During This Lesson?**

- Why are we running the reflectivity experiments at different times? *So that the lamp can shine in the same place in the same experiment otherwise you could not compare the results.*

- Are reflectivity and insulation the same property? *They are related properties. A material that is very reflective is also a good insulator. Reflective materials bounce back light, which helps keep an object at the same temperature.*

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Lesson 8

Which wall materials will help keep out rain and bright light?

d. Arrange a lamp so that its bottom is roughly one inch above the cardboard test piece. It should shine on the center of the test piece. Do not turn the lamp on yet.

e. Plug the thermometer into the NXT.

f. Demonstrate to students how you can use the NXT “view” function to view the thermometer value. Ask for a volunteer student pair to read off the current value of the thermometer.

g. Ask another volunteer pair to record this value in the 0-minute row on a class data table. Your table might look like this:

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Cardboard (°F)</th>
<th>Clear Plastic (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

h. After recording the initial temperatures, turn on the lamp and begin keeping track of time.

i. Every two minutes for the next 10 minutes ask a new student pair to read temperature values and another pair to round and record the values on the data table.

Figure 1. Set-up for reflectivity test. A LEGO thermometer is attached to the base of a LEGO stand, and the testing material rests on the top surface of the stand. A 60-Watt desk lamp shines on the testing material.
Lesson 8

Which wall materials will help keep out rain and bright light?

7) Before beginning the second reflectivity test (with transparency plastic), review the instructions and distribute the materials for the waterproofing test (see instructions below).
8) During the second test, have students work on the waterproofing test.
9) Repeat steps (b) through (i) for the transparency plastic material.

PART II: Waterproofing Tests (15 min)
10) Students will first perform a simple waterproofing test at their desk. Then, students can assist as you run a more precise teacher-led test.
11) Each student pair will need a piece of transparency plastic, a piece of cardboard, a small cup of water, a paper towel, and an eyedropper (optional) to complete this test.
12) Explain the steps for the waterproofing test:
   a. Take a small amount of water in an eyedropper or in your fingers and sprinkle it on the transparency plastic. Then repeat on the cardboard.
   b. Tip the piece of material onto the paper towel.
   c. Repeat this four more times and observe what happens to each material.

Figure 2. Simple waterproofing test with material sample, drops of water, and paper towel.

13) Allot five to ten minutes for students to conduct the waterproofing test.
14) Elicit student ideas about the waterproofing ability of each material.
15) To prepare for the teacher-led waterproofing test, create a data table to record “dry weight” and “wet weight” results.

<table>
<thead>
<tr>
<th></th>
<th>Wet Weight</th>
<th>Dry Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Plastic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardboard</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Which wall materials will help keep out rain and bright light?

16) Then lead a second waterproofing test for a class:
   a. Hang a piece of cardboard on a spring scale and record its “dry” weight. Note that this is the second column in the table in the students’ Engineering Journal.
   b. Spray or drip water onto the cardboard. After ten drops or sprays, record the “wet” weight of the cardboard in the table.
   c. Repeat this process for the transparency plastic.

PART III: Class Discussion and Journal Work (10 min)

17) Once you have completed both the reflectivity and waterproofing tests, have the students’ return their attention to the reflectivity test. Have the students use Journal page 8-2 to compute the temperature changes that occurred during that test.

18) Facilitate a class discussion about which material is the most reflective. Which allowed the smallest temperature increase for the air underneath it? Which kept out the most light?

19) Revisit the definitions of reflectivity, color, and transparency.
Lesson 8

Which wall materials will help keep out rain and bright light?

20) Create a poster-sized version of the following chart.

<table>
<thead>
<tr>
<th>CHOOSING THE MATERIAL FOR MODEL-HOUSE OUTER-WALL SURFACES</th>
<th>Reflectivity Test</th>
<th>Waterproofing Test</th>
<th>Total # Tests Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Plastic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardboard</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

21) Have students decide with their partners which material best passed the reflectivity test. The material that best passed the test is the one that allowed the smallest change in temperature. Students should write a “P” in the box for the material that best passed the test, and an “F” in the box for the other material. Or, if the materials “tied” for best performance, students may give both of those materials a “P.”

22) Have students decide with their partners whether each material passed or failed the waterproofing test and record their decisions in their own journals.

23) Have students record their “P’s” and “F’s” on the class chart.

24) Facilitate class discussion about whether one material is a better choice for the model house walls than the other material. Typically, each of the materials passes one test. Consequently, students will need to decide which property is more important and justify their decision with scientific reasoning. You may want to review the overarching design challenge of the unit at this time, since this is the material choice that will determine whether the model houses are waterproof.

PART IV: Cutting and Attaching Outer-Wall Material (10 min)

25) After students choose the best outer-wall material and provide scientific reasoning for their choice, they are ready to add the material to their model house frame.

26) Have students show you their completed Engineer’s Journal and then give them scissors and cardboard or clear plastic material. Have students cut cardboard or plastic pieces to fit two walls of their model house frames. These pieces should be sized to cover the two sections of inner wall materials (which were chosen in Lesson 7).

27) Remind students that they are only covering half of their house, and that these are the outer walls of the house. If there is not enough time for this step, students can complete the outer walls in the next lesson.
Building Instructions for Reflectivity Test Stand:

Parts Needed for Reflectivity Test Stand:
What materials are these outer walls made out of?


Lesson 9

How can we make stable, quiet, and comfortable model houses?

One 60-minute session

Using the materials that performed best in the tests, students will build model houses by finishing measuring, cutting, constructing, and assembling the columns, roof frames, and wall surfaces. Students who complete their houses can move onto reflecting on their model houses and creating posters.

- Reviewing overall design challenge to make the most stable, quiet, waterproof, and comfortable in temperature house possible
- Building house frames, if not already completed
- Choosing wall surface materials and attaching them, if not already completed
- Reflecting on houses and completing posters

By the end of this lesson, students will be able to:

- Identify the properties that are most important for a specific design task, and select materials and objects that exhibit those properties.
- Measure the properties of materials and objects with manual tools such as rulers.
- Describe objects by the properties of weight, length, height, strength, waterproofing, and shape.

Properties of Materials/Objects Overview

Objects Are made of Materials

Describe

Properties Are observed with Tools

See Lessons 1 through 8 for background information on the specific properties of materials.
### Lesson 9

<table>
<thead>
<tr>
<th><strong>How can we make stable, quiet, and comfortable model houses?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
</tr>
<tr>
<td><strong>Preparation</strong></td>
</tr>
<tr>
<td><strong>Instructions for Teachers</strong></td>
</tr>
</tbody>
</table>

#### For each student
- Engineer’s Journal Part 9

#### For each student pair
- LEGO Mindstorm NXT kits
- Scissors
- Masking tape
- House frame from Lesson 5

#### For the class
- Building materials laid out on a central materials table
  - Manila folders (to use as floor of house)
  - Cloth “blanket” (polyester quilt batting) (approx. 24”x24” per pair)
  - Craft foam (approx. 24”x24” per pair)
  - Cardboard (approx. 24”x24” per pair)
  - Transparency plastic (approx. 24”x24” per pair)
  - Construction paper
  - Colored pencils, markers, crayons

---

**Prepare a central materials table with the building materials listed above.**

**Display all results charts (for columns, walls, and roofs) in one area of the classroom.**

**Prepare index cards for Lesson 10 so that some students can begin the poster design if desired.**

**Distribute Engineer’s Journals.**

---

**PART I. Introduction and Building Instructions (10 min)**

1) Review with students the overall engineering challenge for the module. Their task is to build a small model house that is as **stable, quiet, waterproof and comfortable in temperature** as possible with the available materials.

2) Explain that in this lesson, students will take all that they have learned about the possible materials for their model houses, and use the best materials to build the columns, walls, and roofs of their houses so that they meet the four requirements of

---

**What Do Students Think About Model House Building?**

Students’ initial ideas about how to choose their house materials include:

- Because cardboard is the best for the walls, it also must be the best for the roof (generalizing the appropriateness of a material to all tasks).
- The more materials I use, the stronger my house will be so I should use craft foam, cardboard, clear plastic, and cloth blanket.
- Cardboard (or any other material) is best because it’s easier to work with than the others.
- Cardboard is stronger than foam because it fails by bending or creasing, while foam snaps entirely.
- Strength/stability is the most important property. We should simply pick the strongest materials, no matter how they did on the insulation and sound absorption tests.
- The way my house looks is very important to me, so I should choose the materials that look nicest.
Lesson 9

How can we make stable, quiet, and comfortable model houses?

- stable, quiet, waterproof, and comfortable in temperature.
- Display in one area all of the results charts from the module: one for columns, one for inner walls, and one for outer walls. As a class, review the results of each test.

PART II. Student Building (20 min)

- Direct students to review their wall material choices with their partner. If they did not complete their choices they should revisit the last page in their Engineers’ Journals for Lesson 7 and Lesson 8.
- Allot some LEGO building time for students who have not finished their house frames.

PART III. Student Reflection/Posters (30 min)

- When students have completed the frames and walls of their model house, they should begin the reflection/design poster found on Journal page 10-1.
- You might consider having students create large posters to present their ideas and design decisions to a larger audience.

What Questions Might Students Ask During This Lesson?

- What is the goal of our house building? How will we know if our house is “good” enough? Our engineering design challenge is to build a model house that is quiet, stable, waterproof, and able to keep a comfortable temperature. A “good” house is one that meets those four requirements.
- Isn’t my roof too small? You can make your house small, too. Just match the size of your walls to the size of your roof.
# Lesson 10

## Suggested Time

One 60-minute session

## Lesson Overview

Students will create design posters that explain how specific properties are important to their houses. Then, they will participate in a whole-class discussion to review how the houses meet the overarching engineering design requirements.

- Design poster creation
- Final class discussion on overall design requirements

## Learning Objectives

**By the end of this lesson, students will be able to:**

- Identify the properties of the materials from which objects are made.
- Recognize that selecting the best material is a process in which engineers often engage.
- Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.
- List and explain the following steps of the engineering design process:
  - Identifying a problem
  - Researching possible solutions
  - Picking the best solution
  - Building a prototype
  - Testing the prototype
  - Repeating any steps needed to improve the design

See Lessons 1 through 8 for background information on the specific properties of materials.

## Teacher Background

## Materials

- Engineer’s Journal Part 10

## Preparation

- Prepare an index card for each student with one of the following properties written on it: **strength, stability, insulation, sound absorption, reflectivity, waterproofing, shape**.
- Prepare a poster-sized chart modeled after the one shown in the instructional sequence below.
- Distribute Engineer’s Journals.
- Distribute the property index cards so that students in a pair have different properties.
Lesson 10

How do the properties of materials help us with engineering?

PART I. Design Posters (20 min)
1) Explain that the first task is to create design posters for the model houses. Engineers always document their work so that fellow engineers can learn from their designs and possibly re-create the prototypes at a later date.
2) Instruct students to read their index cards and write its property on their Engineer’s Journal page on the blanks in the two questions.
3) Review with students the three main sections of the posters. They should write about the hardest part of designing a house, complete the sentences about their property, and then draw and label a diagram of their house. Remind them that their diagram should be detailed enough that someone else could use it to re-build their house.
4) Allot 20 minutes for work on posters.

PART II. Final Review Discussion (25 min)
5) Gather the students for a final class discussion about the process of designing and building model houses. The goal of the discussion should be to summarize the students’ engineering design process, review how they met the model house design challenge, and record this information on a class chart.
6) First, ask students to help you answer the question: How did we do the engineering design process? How did we complete each step?

Hear students’ ideas, and clarify with the following information:
- **Find a problem:** Our problem was our design challenge: build a model house that is quiet, stable, waterproof and comfortable in temperature.
- **Research possible solutions:** We researched solutions by testing different materials and objects for columns, roofs, inner walls, and outer walls.
- **Pick the best solution:** We picked the best solution by looking at the test results and deciding which material best met the goals.
- **Build a prototype:** We built a prototype by constructing our model houses.

7) After reviewing the steps of your model house design process, ask students to help you answer a series of questions about how you met each goal (i.e., “requirement”) of the design challenge: How do we know that we built good prototypes? Let’s talk about how we met each goal. Our houses had to be quiet, stable, waterproof, and comfortable in temperature.

As you discuss these questions, fill in a class chart like the one shown.

Note: For this discussion, you might want to gather all the houses in one place and use them as props for your review of properties.
Lesson 10

How do the properties of materials help us with engineering?

below.

a.) How we met the “quiet” requirement:
   - What property did we look for in our materials? (sound absorption)
   - How did we test for that property? (see below)

b.) How we met the “waterproof” requirement:
   - What properties did we look for in our materials? (waterproofing)
   - How did we test for those properties? (see below)

c.) How we met the “comfortable” requirement:
   - What properties did we look for in our materials? (insulation, reflectivity)
   - How did we test for those properties? (see below)

d.) How we met the “stable” requirement:
   - What properties did we look for in our materials? (strength, stability, shape)
   - How did we test for those properties? (see below)

<table>
<thead>
<tr>
<th>Engineering Design Goal</th>
<th>Properties We Looked For</th>
<th>How We Tested Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiet</td>
<td>- Sound absorption</td>
<td>- Soundproofing test with NXT sound sensor</td>
</tr>
<tr>
<td>Waterproof</td>
<td>- Waterproofing</td>
<td>- Sprinkle with water and weigh and observe</td>
</tr>
<tr>
<td>Comfortable</td>
<td>- Insulation</td>
<td>- Insulation test with ice and LEGO thermometers</td>
</tr>
<tr>
<td></td>
<td>- Reflectivity</td>
<td>- Reflectivity test with lamp and LEGO thermometers</td>
</tr>
<tr>
<td></td>
<td>- Transparency</td>
<td></td>
</tr>
<tr>
<td>Stable</td>
<td>- Strength</td>
<td>- Column stability test with test weight</td>
</tr>
<tr>
<td></td>
<td>- Stability</td>
<td>- Column strength test by squeezing columns</td>
</tr>
<tr>
<td></td>
<td>- Shape</td>
<td>- Roof stability test with one-finger push</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Frame stability test with one-finger push</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Frame strength test with hand-palm test</td>
</tr>
</tbody>
</table>
YOUR GRAND ENGINEERING DESIGN CHALLENGE:
Design and build a miniature model of a house using craft materials and LEGO pieces. Your model house should be stable, quiet, waterproof, and comfortable in temperature.
TODAY’S EXPLORATION QUESTION: Today you will learn that your engineering challenge is to build a small model house that is stable, quiet, waterproof, and comfortable in temperature.

What parts of a house are important to make it stable, quiet, waterproof, and comfortable in temperature? List at least four ideas for parts of a house.

(Example) WINDOWS – They help make a house comfortable in temperature.

(1) ____________________________________________________________

(2) ____________________________________________________________

(3) ____________________________________________________________

(4) ____________________________________________________________
Name: How can we describe materials and objects?

ENGINEERING PREDICTIONS: (A) For each house part in the list below, predict a craft material or LEGO material that would help the house be stable, quiet, waterproof, or comfortable in temperature.

- Material for Support Columns:
- Material for Roof Beams:
- Material for Inner Walls:
- Material for Outer Walls:

(B) Explain why your predicted materials would be good choices for the design challenge:

<table>
<thead>
<tr>
<th>How would these materials help keep a model house <strong>stable</strong>?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How would these materials help keep a model house <strong>quiet</strong>?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How would these materials help keep a model house <strong>waterproof</strong>?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How would these materials help keep a model house <strong>comfortable in temperature</strong>?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

TODAY’S EXPLORATION: You will begin to think about the properties of materials by sorting objects into different groups.

**STEP 1.** Your teacher will give you a set of objects. Sort your objects into groups that contain objects that are **alike**.

**STEP 2.** Use the boxes on the next page to show how you have sorted your objects. In each box, list all the objects in one group. Explain how the objects are alike. You do not need to use all the boxes.
How can we describe materials and objects?

Objects in group:

How they are alike:

Objects in group:

How they are alike:

Objects in group:

How they are alike:

Objects in group:

How they are alike:

Objects in group:

How they are alike:
TODAY’S EXPLORATION QUESTION: Imagine you have a friend who lived in New Orleans when a hurricane hit and damaged many houses. Luckily, your friend’s house was okay because it had good support columns. What properties were important for its support columns?

In the space below, write AND draw your answer to this question. If you don’t know, take a guess.
**TODAY'S INVESTIGATION:** Today you will test clay support columns for their properties of stability and strength.

---

**Clay-Only Column**

**STEP 1.** Roll out 2 oz. of clay to make a clay column that is 5 inches tall.

**STEP 2.** Stand the column upright and give it a tap. What happens?

**STEP 3.** Stand the column upright again. Put a weight on top of it and give it a tap. What happens?

**STEP 4.** Hold the column between your hands, so that the top of the column is touching one palm and the bottom is touching the other palm. Press your hands together to squeeze the column lengthwise. What happens?

---

**Clay-with-Straw Column**

**STEP 1.** Roll out your column again. Press a small straw into it and roll the clay over the straw to make a clay-with-straw column.

**STEP 2.** Stand the clay-with-straw column upright and give it a tap. What happens?

**STEP 3.** Stand the clay-with-straw column upright again. Put a weight on top of it and give it a tap. What happens?

**STEP 4.** Hold the clay-with-straw column between your hands. Press your hands together to squeeze the column lengthwise. What happens?

---

On the next page, draw and label the results of your stability and strength tests.
Can support columns be made of clay?

## Stability Test WITHOUT Weight

<table>
<thead>
<tr>
<th>Clay Column</th>
<th>Clay Column WITH Straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labeled drawing of what happened:</td>
<td>Labeled drawing of what happened:</td>
</tr>
</tbody>
</table>

## Stability Test WITH Weight on Top of Column

<table>
<thead>
<tr>
<th>Clay Column</th>
<th>Clay Column WITH Straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labeled drawing of what happened:</td>
<td>Labeled drawing of what happened:</td>
</tr>
</tbody>
</table>

## Strength Test

<table>
<thead>
<tr>
<th>Clay Column</th>
<th>Clay Column WITH Straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labeled drawing of what happened:</td>
<td>Labeled drawing of what happened:</td>
</tr>
</tbody>
</table>
TODAY’S EXPLORATION QUESTION: You tested clay support columns for strength and stability. What materials or objects might work better than clay as support columns? What materials or objects might work worse than clay? Give a reason why each material would be better or worse.

In the space below, write AND draw your answer to this question. If you don’t know, take a guess.

<table>
<thead>
<tr>
<th>Better Materials or Objects and Why</th>
<th>Worse Materials or Objects and Why</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Can support columns be made of LEGO beams?

**TODAY'S INVESTIGATION:** Today you will test LEGO support columns for their properties of **stability** and **strength**.

**LEGO-Beam Column**

**STEP 1.** Get a 1x16 beam from your LEGO kit.

**STEP 2.** Stand the beam upright and give it a tap from the side. What happens?

**STEP 3.** Stand the beam upright. Put a weight on top of it, and then give it a tap from the side. What happens?

**STEP 4.** Hold the beam lengthwise between the palms of your hands and press your hands together. What happens?

**LEGO-Beam-with-Base Column**

**STEP 1.** Build a LEGO base for your 1x16 beam. There are directions on page 3-4.

**STEP 2.** Stand the beam with base upright and give it a tap from the side. What happens?

**STEP 3.** Stand the beam with base upright. Put a weight on top of it, and give it a tap from the side. What happens?

**STEP 4.** Hold the beam with the base lengthwise between the palms of your hands and press your hands together. What happens?

On the next page, fill in the results for all of your stability and strength tests.
**RECAP:** You tested clay and LEGO support columns for their properties of **strength** and **stability**.

Record whether each material passed or failed the tests.

<table>
<thead>
<tr>
<th></th>
<th>Stability Test without Weight</th>
<th>Stability Test with Weight</th>
<th>Strength Test</th>
<th>Total # Tests Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay with Straw</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEGO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEGO with Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Think about the ways you tested the support column materials. Answer the questions below.

(1) Which material best passed the **strength** test?

- Clay Alone
- Clay with Straw
- LEGO Beam Alone
- LEGO Beam with Base

(2) Which material best passed the **stability** test?

- Clay Alone
- Clay with Straw
- LEGO Beam Alone
- LEGO Beam with Base

(3) Which material is the **best material** for your model house support beams?

- Clay Alone
- Clay with Straw
- LEGO Beam Alone
- LEGO Beam with Base

(4) **Why** is this the best material for your support beams?

__________________________________________________________________

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Can support columns be made of LEGO beams?

**EXAMPLE LEGO BEAM BASE:** These directions show how to build a LEGO column with a base. You can come up with your own ideas, too.

1) Take these pieces out of your kit:

2) Push two long connector pegs into the 1x16 beam.

3) Add an L-beam to one side of the 1x16 beam.
   Make sure that the short part of the L-beam goes **below** the 1x16 beam.

4) Add an L-beam to the other side of the 1x16 beam.
   Make sure its short part points in the **opposite** direction of the other L-beam.

Other Examples:
TODAY'S EXPLORATION QUESTION: Snow and ice can be very heavy. If they pile up on a roof, they can damage the home. What properties of a roof would keep the snow and ice from piling up?

In the space below, **write AND draw** your answer to this question. If you don’t know, take a guess.
**TODAY’S INVESTIGATION:** You will build and test two roof frames for their property of stability.

**STEP 1.** Predict the most stable shape for a roof. Write your prediction below.

I think the most stable shape will be ____________________________________________________________________________________.

**STEP 2.** Build at least TWO different roof frame shapes. **Draw** each shape and **label** the LEGO materials used to build it. **Write** down the shape of the frame.

**STEP 3.** Test the stability of each frame. Use the “**one-finger push test**.” A roof frame passes this stability test if it does not change shape when you push on it with one finger.

**STEP 4.** Record the results of the test for each frame.

<table>
<thead>
<tr>
<th>Frame #1</th>
<th>Frame #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="#" alt="Frame #1" /></td>
<td><img src="#" alt="Frame #2" /></td>
</tr>
<tr>
<td>This frame is shaped like a ______________________________.</td>
<td>This frame is shaped like a ______________________________.</td>
</tr>
<tr>
<td>Did this frame pass the one-finger stability test?</td>
<td>Did this frame pass the one-finger stability test?</td>
</tr>
<tr>
<td>__________________________________________.</td>
<td>__________________________________________.</td>
</tr>
</tbody>
</table>
**DESIGN A MODEL HOUSE - PART 5**

**TODAY'S EXPLORATION QUESTIONS:** Today you will combine your support columns and roofs to make complete house frames.

In the space below, **draw AND write** your answers to the two questions. If you don’t know, take a guess.

<table>
<thead>
<tr>
<th>(1) How do you think roofs and columns of <strong>real</strong> houses are attached to each other?</th>
<th>(2) How could you attach your <strong>LEGO</strong> roof and columns to each other?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Name: How can we make stable and strong house frames?

**TODAY’S DESIGN CHALLENGE:** Build a house frame that is **stable** and **strong**.

**STEP 1.** Build two more support columns for your house frame.

**STEP 2.** Finish building your roof frame if you need to.

**STEP 3.** Attach the support columns and roof frame together.

**STEP 4.** Test the stability and strength of your house frame.

**STABILITY TEST:** Use the “**one-finger push test**.” A house frame passes this stability test if it does not change shape when you push on it with one finger.

**STRENGTH TEST:** Use the “**hand-palm test**.” A house frame passes the test if it does not move or change shape when you put the frame between your hands and press your hands together.

**STEP 5.** Improve your house frame until it passes both tests. It might not pass the first time. If not, make some changes and try again.

**STEP 6.** Draw and label a diagram of your house frame.

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**TODAY'S EXPLORATION QUESTIONS:** Today you will begin to test materials for the walls of your model house. As you begin to think about walls, write answers to the questions below.

**(1) Think about what makes a good wall.**

What are three properties that are important for the walls of a house?

(1) _____________________________________________________________________

(2) _____________________________________________________________________

(3) _____________________________________________________________________

**(2) Think about why it is good to have soundproof walls.**

What are two reasons for making walls soundproof?

(1) ________________________________________________________________________________

(2) _________________________

(3) Before you begin, think about how you might do this test.

**(3) What is one thing you could use to make a test sound?**

I could make a sound with ____________________________________________________________

**(4) What is one thing you could use to measure the volume of the test sound?**

I could measure the volume with ________________________________________________________
**Name:** Which wall material will help our houses stay quiet?

**TODAY’S INVESTIGATION:** Follow your teacher’s directions to perform the soundproof test for cloth blanket and craft foam. Record the results in the tables below.

<table>
<thead>
<tr>
<th></th>
<th>Noise Level from NXT Alone (dBA)</th>
<th>Noise Level from NXT in Cloth Blanket (dBA)</th>
<th>Noise Level from NXT in Craft Foam (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
</tr>
<tr>
<td>Test 2</td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
</tr>
<tr>
<td>Test 3</td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
</tr>
</tbody>
</table>

Repeat the soundproof test a **2nd** time.

<table>
<thead>
<tr>
<th></th>
<th>Noise Level from NXT Alone (dBA)</th>
<th>Noise Level from NXT in Cloth Blanket (dBA)</th>
<th>Noise Level from NXT in Craft Foam (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 2</td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
</tr>
<tr>
<td>Test 3</td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
</tr>
</tbody>
</table>

Repeat the soundproof test a **3rd** time.

<table>
<thead>
<tr>
<th></th>
<th>Noise Level from NXT Alone (dBA)</th>
<th>Noise Level from NXT in Cloth Blanket (dBA)</th>
<th>Noise Level from NXT in Craft Foam (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 3</td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
</tr>
<tr>
<td>Test 4</td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
<td><img src="#" alt="Table Row" /></td>
</tr>
</tbody>
</table>

**Think about the sound proof test results. Answer the questions below.**

(1) When did the “noise detector” NXT sense the **lowest** noise level?

- NXT Alone
- NXT in Cloth Blanket
- NXT in Craft Foam

(2) Which material was the **most soundproof**?

- Air
- Cloth Blanket
- Craft Foam
TODAY’S INVESTIGATION: Today you will keep testing materials for the inner walls of your model house. Today’s test is the insulation test.

Before you begin, think about how you know when something is a good insulator (good at keeping things at the same temperature). Write answers to the questions below.

What is one way you could test how good a material is at keeping things hot?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

What is one way you could test how good a material is at keeping things cold?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

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Which wall material will help our houses stay warm?

**TODAY’S EXPLORATION QUESTIONS:** Your teacher will run the insulation test. While the test is running, answer the following questions:

1) How do sweatshirts and winter jackets keep us warm?

2) How do coolers keep drinks cold?

3) School #1 is old, big, and made of stone. School #2 is new, small, and made of wood. When it is hot outside, it is much cooler inside School #1 than inside School #2. Why do you think School #1 stays cooler than School #2?
**TEST RESULTS:** Use the class temperature chart to fill in the chart below. Then, subtract the final (6-minute) temperature from the beginning (0-minute) temperature. The answer is the change in temperature. Write this number in the third column of the chart.

<table>
<thead>
<tr>
<th></th>
<th>Beginning Temperature (F)</th>
<th>Final Temperature (F)</th>
<th>CHANGE in Temperature (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craft Foam</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cloth Blanket</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Name: Which wall material will help our houses stay warm?

**RECAP:** Think about all the test results for the inner-wall materials. Record whether each material passed or failed the tests.

<table>
<thead>
<tr>
<th></th>
<th>Soundproof Test</th>
<th>Insulation Test</th>
<th>Total # Tests Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloth Blanket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craft Foam</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Use your own test results and the class chart to help you answer the questions below.

1. Which material best passed the **insulation test**? (Answer: Cloth Blanket)
2. Which material best passed the **soundproof test**? (Answer: Cloth Blanket)
3. Which material is the **best material** for your model house inner walls? (Answer: Cloth Blanket)
4. **Why** is this the best material for your inner walls? (If two materials seem just as good, think about which property or test is the most important.)

   ______________________  ______________________  ______________________  ______________________  ______________________  ______________________

   ______________________  ______________________  ______________________  ______________________

   ______________________  ______________________  ______________________

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**TODAY’S EXPLORATION QUESTIONS:** Today, you will test wall materials for their properties of **reflectivity** and **waterproofing**.

**STEP 1.** Your teacher will run the reflectivity test for the whole class. While the test is running, answer the questions below.

1. If the outer wall of a house is see-through, will that make a difference to the temperature inside the house?  
2. Which material will be more waterproof: clear plastic or cardboard?

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td></td>
</tr>
</tbody>
</table>

**Why?**

---

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STEP 2. Reflectivity Tests. Use the class temperature chart to fill in the chart below. Then, subtract the beginning temperature from the final temperature. The answer is the change in temperature. Write this number in the third column of the chart.

<table>
<thead>
<tr>
<th>Material</th>
<th>Final Temp. (°F)</th>
<th>Beginning Temp. (°F)</th>
<th>CHANGE in Temp. (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardboard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear Plastic</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Use this space for your subtraction work.)

Which material allowed the smallest change in temperature? (Circle your answer)

Clear Plastic  Cardboard

STEP 3. Waterproofing Tests. Follow your teacher’s directions for the waterproofing tests. Use the table below to record the results.

<table>
<thead>
<tr>
<th>Material</th>
<th>Observations from Waterproofing Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Plastic</td>
<td></td>
</tr>
<tr>
<td>Cardboard</td>
<td></td>
</tr>
</tbody>
</table>

Which material took up the least amount of water? (Circle your answer)

Clear Plastic  Cardboard
Which wall materials will help keep out rain and bright light?

RECAP: Your tested cardboard and clear plastic for their properties of reflectivity and waterproofing.

Record whether each material passed or failed the tests.

<table>
<thead>
<tr>
<th>Material</th>
<th>Reflectivity Test</th>
<th>Waterproofing Test</th>
<th>Total # Tests Passed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Plastic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardboard</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Think about the ways you tested the outer wall materials. Answer the questions below. You may circle more than one material for questions 1 and 2.

(1) Which material best passed the reflectivity test?
- Clear Plastic
- Cardboard

(2) Which material best passed the waterproofing test?
- Clear Plastic
- Cardboard

(3) Which material is the best material for your model house outer walls?
- Clear Plastic
- Cardboard

(4) Why is this the best material for your outer walls?

_________________________________________________________________________________
_________________________________________________________________________________
_________________________________________________________________________________
How can we make stable, quiet, and comfortable model houses?

DESIGN A MODEL HOUSE - PART 9

TODAY'S CHALLENGE: Review the design decisions that you made to build a model house that is stable, quiet, waterproof, and comfortable in temperature. Today you will use everything you have learned about properties of materials to finish your model house.

STEP 1. Collect the house frame you built in Lesson 5. Add pieces if you have not completed your house frame. If you have already completed it, move on to the next step.

STEP 2. With your partner, review what materials you chose for your inner- and outer-walls.

For the inner-wall, you chose between cloth blanket and craft foam. Write your choice here:

We chose ___________________ for our inner wall material

because ____________________________.

For the outer-wall, you chose between clear plastic and cardboard. Write your choice here:

We chose ___________________ for our outer wall material

because ____________________________.

STEP 3. Gather the materials for your walls if you have not already made them.

STEP 4. Cut wall pieces to the correct size so that they will cover half of your house frame. Tape your wall pieces to your frame. Make sure you can still see the inside of the house!

STEP 5. If your teacher says you have extra time, decorate your house.

STEP 6. Start your design poster for your model house presentation (next page).
What was the hardest part of designing and building a model house? **Why** was it hard?

________________________________________________________________________________________

**How** did you test for the property of _____________________________________________________?

________________________________________________________________________________________

________________________________________________________________________________________

**Why** is the property of ____________________________________________________________ important to your house?

________________________________________________________________________________________

Draw a design diagram of your model house. Label the **parts** of the house and the **materials** you used to build them.

(Be sure to label all the parts.)
Section 3: 
Supplemental Teacher Resources
Background Information for Properties of Materials: Design a Model House

An Introduction to the Properties of Materials

People experience objects everywhere in their daily lives. Objects are anything that exists in a form that can be seen or touched. Most people do not examine the materials or substances used for constructing or making an object. Materials can be solids, liquids, or gases. Even fewer examine the properties or traits of a material or object that can be observed or measured. In everyday situations, people are usually only concerned with how they use an object. We can learn from materials scientists and engineers how to examine objects further.

Material scientists make it their business to examine objects in order to determine the materials which make up an object. Material scientists also analyze objects and materials to determine their properties. In addition, they extract materials in order to turn them into useful forms.

The first step in gaining a deeper understanding of an object is to look at it as a material scientist would, by identifying the materials from which it is made. Then the properties of both the object and the materials can be further examined or measured.

Properties of Objects and Materials

Objects and materials can be described by some of the same properties. Properties can be measured with tools. Properties can also be observed through tests. We will focus on some of the important properties and how they can be observed or measured.

Strength

- **Strength**: The ability to hold something up or resist distortion when a force (push or pull) is applied.

Strength can be used to describe both objects and materials. When you push or pull on a strong material, it will not change shape. A weak material will change shape when it is pushed or pulled. Objects that are made of strong materials also exhibit the property of strength. When objects are made of both weak and strong materials, it is important to test the object, in order to tell if the object as a whole exhibits the property of strength. It is also important to test the strength of the connections between different pieces or materials of an object.

There are two common ways of testing for strength. One test involves applying a
force to an object (or material) by pushing or pulling on it. If the object resists distortion (does not change shape), it is considered a strong object. The other test involves checking if a piece of the material or an object can hold up a different, relatively heavy object. The exact heaviness of this object being held up (the “test weight”) depends on how the material or object under question will be used. It is important that the “test weight” applies at least as much force as the material or object will feel during use. For example, if you are testing a piece of plastic material for possible use in a chair, the test weight applied to the plastic must be at least as heavy as a person. Using the word “strength” to describe objects can be compared to using the word “strength” to describe people. When people can hold up heavy boxes full of books, they are considered strong, just as an object is considered strong when it can hold up items that are relatively heavy compared to its own weight and size.

**Flexibility**

- **Flexibility**- The ability to bend easily without breaking.

Flexibility can be used to describe both objects and materials. Flexible materials bend, but do not break, when you push or pull on them. Inflexible materials either do not bend when you push or pull them, or they bend but then break. Objects that are made of flexible materials also exhibit the property of flexibility. When objects are made of both flexible and inflexible materials, it is important to test the object in order to tell if it exhibits the property of flexibility.

A good test for flexibility involves holding both sides of an object (or material) and trying to bend the object. If the object bends and does not break, it is considered flexible. An example of a flexible material is clay. If the object does not bend, it is considered inflexible, such as LEGO beams.

**Stability**

- **Stability**- The ability to remain in a steady position without shaking or bending.

Stability is used to describe only objects. Even if an object is made of only one material, the stability of the object rather than of the material is considered. This is because materials can be made into objects of many different sizes and shapes, some of which will be stable and some of which will not be stable. An object is stable if it can stay in the same place without shaking or bending. Support columns for a house are included to make a house stable. You would not want your house shaking around you all the time! Objects that are usually stable, such as homes, sometimes become unstable when subjected to unusually large forces, such as earthquakes.

A good test for stability is to push on the side of an object and see if it shakes or bends. If the object remains stationary, it is stable. Buildings are some of the most stable objects because we would not want them coming down on top of our heads! If the object instead moves or bends, it is unstable. Dominoes are an example of unstable objects. Dominoes are also an example of an object that we actually want to be unstable or else we would not be able to use them for certain games. Engineers must take into account the purpose of the object they are designing when deciding on the stability, or any other property, of the object.
**Temperature**

- **Temperature** - A measurement of how hot or how cold something is.
- **Thermometer** - A tool used to measure temperature. Thermometers can be used to find the temperature of things such as the air, water, or an object. (JB)

The temperature of an *object* or a location is generally observed with a thermometer. Temperature is measured in degrees Fahrenheit or degrees Celsius. In the United States we commonly use the Fahrenheit system, while the Celsius system is more common abroad. Temperature gives us a means to compare the warmth of different places, objects, or materials.

The way a *material* acts at certain temperatures is also important to consider. Some materials will change from liquid to gas form when the temperature rises or from liquid to solid form when the temperature drops. When making design choices, it is important to know the temperatures at which a material changes state. One would not want to make a pot out of a material that would melt or evaporate when put on a stove!

**Insulation**

- **Insulation** - The ability to prevent the passage of heat, electricity, or sound.
- **Insulator** - An object or material that provides insulation. A good thermal insulator maintains the temperature of whatever object it surrounds.

Both materials and objects can be considered insulators. Insulators serve the purpose of providing insulation, or preventing heat, electricity, or sound from passing. Good insulators are always poor conductors. *Thermal* insulators are those that are poor conductors of *heat*. A good thermal insulator will maintain the temperature of the space or object inside the insulator. For example, on a hot day, insulating walls will help the inside of a house stay at the cooler night-time temperature. On a cold day, insulating walls will help the inside of a house stay at the temperature reached by heating. A good electric insulator will not allow any electricity to pass through it. Electric insulators are often plastic, or other non-conducting materials, which surround wires that carry power. A good sound insulator prevents noises that are outside an object from going inside the object, and vice versa. Many people appreciate having sound-insulating walls in their home so conversations do not travel throughout the house and so loud outside noises do not interrupt inside activity.

Different types of tests are needed for different types of insulation. Thermal insulation can be tested by comparing the temperature inside and outside an object or material that serves as an insulator. A good thermal insulator will keep the inside temperature from changing, no matter what happens to the outside temperature. If a cooling or heating system is in place, the cooler or heater will need to operate less frequently when a good insulator exists. Comparing how frequently a heating system needs to operate to maintain a certain temperature within two different materials would also serve as an insulation test.

Electric insulators are tested by comparing the power inside and outside the insulator. To ensure safety, electric insulators must be tested with proper electric equipment.

Sound insulation prevents sound from passing through an object or material into another area. Sound insulation can be tested by comparing the volume of noises on each side of an object or material. The volume should decrease (and ideally be non-existent) on the other side of a sound insulator.
Sound Absorption
- **Sound absorption** - Blocking the passage of sound vibrations with a material in order to decrease the volume of a sound.
- **Soundproofing** - The ability to block the passage of sound. In a perfectly soundproof room, you do not hear sounds from outside, and people outside do not hear sounds made in the room.
- **Sound level** - The loudness of a sound.
- **Decibel** - A unit for measuring the loudness of sounds.

Good sound insulators are used as soundproofing materials. An object or material that can successfully provide soundproofing is a good sound absorber. Sound absorption occurs when a sound hits an object or material, goes through it, and comes out at a lower volume. Since the volume of a sound is directly related to the size of the vibrations that produce a sound, sound absorption is also the action of decreasing the size of sound vibrations.

A test for soundproofing determines the volume of a sound on either side of an object or material. The volume is often measured in decibels. To test soundproofing, first a sound is made on one side of an object or material. The volume of the sound is determined on both sides of the object or material through a microphone or sound detector. If an object or material is a good sound absorber, the volume will be lower once the sound passes through the object or material.

Shape
- **Shape** - The configuration or form of an object.
- **Triangle** - A shape with three straight sides that are connected at three different points.
- **Rectangle** - A shape with four straight sides with four corners that meet at 90 degree angles.

Shape is used to describe only objects. Even if an object is made of only one material, the shape of the object rather than the material is considered. The shape is the form or outline of an object. Triangles, squares, diamonds, hexagons, circles, spheres, prisms, and rectangles are examples of different shapes. The triangle is of particular note due to the inherent stability of its shape. Since each side of the triangle is connected to every other side of the triangle, it is able to support larger weights, since the entire shape goes about supporting the weight rather than only part of it. If a heavy weight were put on a rectangular object and a triangle, the triangle would hold its shape, while the rectangle might become a parallelogram under the weight. When designing, engineers need to consider the shape of an object for aesthetic reasons, but also to be sure the object can serve its function.

Reflectivity & Color
- **Reflectivity** - The ability of a surface to bounce back light.
- **Color** - The shade reflected by a surface to the eye.

Reflectivity is used to describe materials and objects. Any material or object with a color has some degree of reflectivity, since an object’s color is determined by what color light is reflected away from the surface of the object. Some colors indicate that an object is capable of more reflectivity or more absorption. A white or light colored surface is more reflective, while a dark or black surface is more absorbent. White is a reflection of every color in the color spectrum, while black is the absorption of every color in the color spectrum. Reflectivity and color also influence temperature of objects.
A white object or one that reflects much light will not heat up as much as a black object or one that absorbs much light.

**Waterproof**
- **Waterproof** - Able to prevent water from passing through a material or to prevent a material from absorbing water.

The term *waterproof* can be used to describe both objects and materials. When you place a *waterproof material* in water, it will not absorb, or take up, any of the water. A *non-waterproof* material will absorb the water. A *water-resistant* material will avoid absorbing water for a limited amount of time. *Objects* that are made of waterproof materials also exhibit the property of being waterproof. If an object is made of more than one piece of waterproof material, the seams between the pieces must be securely covered with waterproof materials to create an entire object that is waterproof. When objects are made of both waterproof and non-waterproof materials, it is important to conduct tests to determine whether the object as a whole exhibits waterproofing abilities.

**Materials**

Materials may occur naturally or be man-made. Not all materials have the same properties and some properties are not even relevant for a material. We will focus on some of the common materials and their properties.

**Plastic**

Plastic is a man-made substance that can be easily shaped when heat or pressure are exerted on it. Plastic is then hardened into a non-breakable form. Most plastic is flexible when heat or extensive pressure is applied to it, but once the heat and pressure are removed it retains its shape and exhibits strength. Plastic is known for its ability to serve as an electric insulator. Plastic can come in all colors of the spectrum and be made into all sorts of shapes.

**Paper**

Paper is a thin sheet made usually from wood, rags, straw, or bark that can be used for writing, wrapping, decorating walls, packaging, and similar tasks. Paper is flexible, but it can be ripped if too much force is applied to it. Paper is not generally considered strong, although thicker sheets of paper are stronger than thinner sheets of paper. Paper can come in all colors and shapes.

**Wood**

Wood is the hard substance which makes up the trunk and branches of a tree and can be used as a building material. Wood is known for its strength. Thinner pieces of wood are flexible, while thick pieces of wood are inflexible. Wood can be cut to the size and shape needed for the desired application. Wood can be used for sound absorption or as a sound insulator.

**Metal**

Metal is a substance that is often shaped and melted, a good conductor of electricity and heat, strong in its solid form, and usually shiny. Thin pieces of metal,
particularly sheets, are flexible while thick pieces of metal, particularly rods, are inflexible. Since metal is a conductor, it is the opposite of an electric insulator. Sound vibrations also tend to vibrate metal, making it a poor sound insulator. In addition, metal heats up easily, making it a poor thermal insulator.

**Rubber**

Rubber is a stretchable and flexible substance made from the juice of various tropical plants. Some forms of rubber can be squished. Rubber, like plastic, does serve as a good electric insulator. Rubber can come in all colors and shapes, though it is most commonly black.

**An Introduction to Engineering Design**

Engineers typically work together to solve the problems that face society. Engineering design is the process of creating solutions to human problems through creativity and the application of math and science knowledge. The basic steps within the design process include:

1. **Identifying a problem** – Observing a problem and seeing a need for a solution
2. **Researching possible solutions** – Coming up with ideas to address the problem
3. **Picking the best solution** – Determining which idea best addresses the problem. This decision may involve monetary, practicality, material, and property concerns.
4. **Building a prototype** – Build a working model of the picked solution
5. **Testing the prototype** – Be sure the working model solves the problem and holds up to any important material property tests
6. **Repeating any steps needed to improve the design** – The engineering design process is not always a step-by-step process, as engineers often repeat steps or go back and forth between the other five steps.

Throughout the design process, students may want to revisit steps and add elements that were previously omitted, just as “real” engineers do. Students will continuously formulate and test hypotheses in order to solve their problem. As the students take on the role of an engineer, they will analyze their solutions, build models, and clarify concepts and explanations. Solutions may require further testing and experimentation to meet the criteria for success defined previously, and even the criteria for success may be amended as they progress. Students should conclude the engineering design challenge by providing a clear expression of their process that includes the questions, procedures, evidence, a proposed explanation, and a review of alternative explanations.