ENERGY LESSON

Make a model of a PASSIVE SOLAR HOUSE

Background

The sun’s energy gives us light energy, and heat energy. We can use that energy to heat water, air, or solids. It is a renewable source of energy that supports life on our planet.

- Create a model of a passive solar house to investigate how energy from the sun can heat our homes and warm the materials inside.
- Discover what makes a good solar house by designing different models or adding different materials to your model and testing them in the sun.

Concepts

- Passive solar design features
- Heat capacity or thermal mass
- Insulation, reflection, and radiation
- Experiment with variables

Materials

Gather as many of these kinds of materials as you can find in your home.

- Medium sized cardboard box.
- Any clear plastic, for the windows.
- A variety of materials that have high heat capacity like bricks, small or large stones, ceramic tiles, cement, or water (in a container).
- A variety of materials that have high insulating value, like Styrofoam insulation or Styrofoam packing, straw, quilt batting, corrugated cardboard, newspapers, etc.
- Light and dark coloured paper, or black paint.
- A thermometer – the kind you use for cooking or telling the temperature outside, not the kind you use when you are sick.
- Tape, glue, scissors, etc.
- Chart paper/pencil to record the temperature in the model house over time.

**Step 1. What is a passive solar house?**

A passive solar house is heated by the sun’s energy. It is specially designed to absorb the sun’s heat and insulate against heat loss when the sun isn’t shining.

The sections at the end of this lesson called *Design Features of Passive Solar Houses* and *Extra Information that might be helpful*, will help you design your passive solar house model.

**Step 2. Design your model house**

- Your model house will be heated by solar power. What will it need to look like? How will it absorb heat and hold onto that heat?
- List or sketch your ideas on paper.
  - **Orientation:** What direction should the house face in order to capture the sun’s heat?
  - **Building Materials:** How will the floor, walls and roof help to absorb the sun’s heat and hold onto that heat when the sun isn’t shining?
    - Colours – dark colours will absorb more heat, light colours will reflect heat,
    - Heat capacity – use materials that will absorb the sun’s heat. These are normally hard and/or heavy materials,
    - Insulation – use materials that will keep the heat from moving.
  - **Windows:** How big will your windows be and where will you place them to collect the most heat energy from the sun?
  - **Roof Overhangs:** How will the roof design and overhangs both allow the sun’s energy into the home, and protect it from overheating?
Step 3. Build your model house

- Build the model house using the box and construction materials you have.
- Be safe! Get help to cut out windows or cut other materials if you need it.
- Note: your house probably won’t look like a “normal” house, especially if you have rocks in it, or pieces of Styrofoam, or cement. Don’t worry, you are trying to test out how it heats up and holds onto heat, not whether a TV will fit.

<table>
<thead>
<tr>
<th>In Sun</th>
<th>Results – April 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:30pm</td>
<td>inside model</td>
</tr>
<tr>
<td>17°C</td>
<td>outside</td>
</tr>
<tr>
<td>21°C</td>
<td></td>
</tr>
<tr>
<td>4:35</td>
<td></td>
</tr>
<tr>
<td>20°C</td>
<td>“</td>
</tr>
<tr>
<td>4:45</td>
<td></td>
</tr>
<tr>
<td>24°C</td>
<td>“</td>
</tr>
</tbody>
</table>

Step 4. Add the thermometer to your model house

- Before you put the roof on, or close up the windows, place a thermometer inside the house where you will be able to read it without opening up the house. The thermometer lets you see how the temperature of the inside of your house changes over time.

**Thermometer placement:** A thermometer placed directly in the sun will not read a correct temperature. Place the thermometer in a spot inside the model house where it will be in shade at all times. If needed, build a little “tent” out of a piece of paper to provide shade for the thermometer.
Step 5. Test how well your passive solar house works

- Place the model in the sun. Outside is best, or in a sunny window.
  - **Test 1** – Right away, record the temperature of your model house on your piece of paper.
  - **Outdoor Temperature Comparison**: Each time you record the temperature inside the house, **record the temperature outside your model house**. If the model is outdoors, record the outdoor temperature from an outside thermometer, or from a weather source like a phone or tablet. If the model is inside your home in a sunny window, record the temperature that it says on the thermostat in your home. Knowing the outdoor temperature will let you compare how your model is absorbing and holding onto heat, compared to the temperature outside the model.
  - **Test 2** – After 10 - 20 minutes in the sun, record the model house temperature again.
  - **Test 3** – After another 10-20 minutes in the sun, measure and record the model home’s temperature again.

Step 6. Do you want to make changes to your design? (optional 🎉)

- Experiment with different materials in the house that you think will make the house absorb and hang onto the sun’s energy better than your first design. Retest the new design, recording the temperature right away, and after 10-20 minutes.

Step 7. Simulate nighttime

- Simulate nighttime by placing your home model in the shade. (At night, the sun has set, but a passive solar house still retains heat gathered from the daytime sun. It will cool down slowly through the night. The longer it retains or holds onto this heat, the warmer you will be.)
  - **Test 4** – Record the temperature of your model house as soon as you place it in the shade.
  - **Test 5** – After 5 minutes record the temperature of your model house.
  - **Test 6** – After being in the shade for a longer period of time, like 10 – 20 minutes, record the temperature again.

Step 8. Share your results

- Take a picture of your model house to share, or share your test results with friends, a teacher, or your parents. Did anyone else make a model house? If so, what did they find out? Which common features of the designs successfully captured the sun’s heat, and retained it?
**Temperature Chart**: print this chart or just use a piece of paper to keep track of temperatures inside and outside your passive house model.

<table>
<thead>
<tr>
<th>Daytime testing</th>
<th>Time</th>
<th>Model home temperature</th>
<th>Outside temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Simulated) Nighttime testing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Test 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test 6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Design features that may have contributed to temperature changes (list your ideas here)**
Discussion Questions:

- What happened to your house when it was in the sun?

  - What was the temperature range inside the house from the 1\textsuperscript{st} to the 3\textsuperscript{rd} temperature check?

  - What was the difference in temperature from outside to inside in each of the first three tests?

- What happened to your house when it was in the shade?

  - What was the temperature range inside the house from the 4\textsuperscript{th} to the 6\textsuperscript{th} temperature check?

  - What was the difference in temperature from outside to inside in each of the last three tests?

- If you made more than one model house, or were able to compare with someone else’s model, what differences did you notice in how they each reacted in the sun, and in the shade?

- What materials do you think contributed to the model absorbing the most heat?

- What materials do you think contributed to the model insulating against heat loss?
Design features of passive solar houses

A passive solar house is heated by the sun’s energy

- **Active solar** – means the house uses equipment with moving parts (like pumps) to capture the sun’s heat. For example: solar thermal panels, that heat water for radiant heating.

- **Passive solar** – means the house uses structure and design to capture heat and light for the home and hang onto it when the sun isn’t shining.

- 4 key design features of a passive solar house:
  - Orientation
  - Building materials
  - Energy efficient windows
  - Roof overhangs

- **Orientation**
  - South facing windows to capture the sun’s warmth
  - Trees on the north side of the house help to cut the wind
  - Shade trees on the west side can help to avoid too much heat gain.

- **Building materials**
  - Colour - light colours reflect the sun’s heat, dark colours absorb the sun’s heat
  - Thermal mass or **heat capacity** – is the ability of a material to store heat. Concrete, brick and water have high heat capacity.
  - **Insulation** – keeps heat from moving through the walls and roof. Styrofoam, straw, and fiberglass are good insulators.

### Average Annual Hours of Sunshine:

<table>
<thead>
<tr>
<th>Location</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moose Jaw</td>
<td>2376 hours</td>
</tr>
<tr>
<td>Yorkton</td>
<td>2330 hours</td>
</tr>
<tr>
<td>Saskatoon</td>
<td>2329 hours</td>
</tr>
<tr>
<td>Meadow Lake</td>
<td>2164 hours</td>
</tr>
<tr>
<td>Vancouver, BC</td>
<td>1928 hours</td>
</tr>
<tr>
<td>London, ON</td>
<td>1800 hours</td>
</tr>
</tbody>
</table>

### Saskatoon Average Hours of Sunshine

Source: Current Results

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tbody>
<tr>
<td></td>
<td>10</td>
<td>30</td>
<td>93</td>
<td>127</td>
<td>170</td>
<td>218</td>
<td>264</td>
<td>321</td>
<td>366</td>
<td>103</td>
<td>101</td>
<td>91</td>
</tr>
</tbody>
</table>

Source: Current Results
This drawing shows sun being absorbed into the house during the day. Materials with high heat capacity like tile floors or concrete countertops store the daytime heat and release it slowly at night. Materials with high insulation value keep the heat from moving.

- **Energy efficient windows**
  - While the windows in your model house may be made from plastic wrap or just cut out of the cardboard, windows in a real house should have airtight panes of glass.
  - Multiple panes of glass that are sealed to each other are more energy efficient.
  - Special coatings reflect light, reflecting heat inside in winter and keep the heat outside in summer.
  - Blinds or drapes help to reduce heat loss or heat gain, because they prevent heat from radiating through the window.

- **Roof overhang**
  - In winter, the right amount of overhang allows the low winter sun to reach far back into the house to warm surfaces that help heat the building.
  - In summer, the right amount of overhang will also keep the heat of the high, hot summer sun out of the house, helping to keep it cool.
Extra information that might be helpful

Understanding Thermal Mass or Heat Capacity

**Heat capacity** (thermal mass) is the ability of a material to store heat.

- Materials that have high thermal mass take a long time to heat up, and then release their heat slowly, taking a long time to cool down.

- In a building, something with high heat capacity like a concrete floor, or stone fireplace helps to regulate the home’s temperature.
  - As the house is heating up, some of that heat is absorbed by the concrete or stone, so the house heats more slowly.
  - As the house is cooling down, the concrete or stone releases the heat back into the house, so the house cools down more slowly.

Understanding Radiation

Energy comes from the sun as radiation. We can use this radiation to heat a passive solar house.

- When the sun shines, or radiates on a surface, it warms that surface. This includes walls, furniture and us.

- Surfaces with high heat capacity, like a concrete floor, or tiled counter will radiate that heat into the room slowly. This helps to keep the room warm after the sun is no longer shining in.
Understanding Insulation

Insulation is material that slows down the movement of heat. It is the material that keeps heat from moving through the walls, attics, and the foundations of our homes.

- In winter, a well-insulated house will keep the heat in, and stay warm and comfortable.
- In summer, a well-insulated house will keep the heat out, and stay cool and comfortable.
- Not all insulation materials are equal. R value represents how well the insulation material keeps heat from being lost. Materials with higher R values resist heat movement better than insulation materials with lower R values.