ENERGY

Make a SOLAR WATER HEATER

Background

The sun 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 solar water heater to investigate how energy from the sun can heat water.
- Test a few variations to discover which factors affect how quickly the water heats.

Concepts

- **Heat capacity, radiation**, **conduction**, and **convection** (see page 6)
- Use solar energy to heat water
- Experiment with variables, and chart results

Time

- 30 minutes to make the solar water heaters
- 5 minutes for each temperature check and charting

Materials

- 2 metal pop cans
- Black or dark paint. (For example, poster paint or spray paint.)
- 2 shoeboxes, or other similar sized boxes
- 1 or more thermometers with temperature range from 10^{o}C to 100^{o}C, such as a meat thermometer
- Plastic wrap, tape, water
- Paper/pencil to record the water temperature over time

Step 1. Make the solar water heaters

Make 2 solar water heaters.

1. Paint 1 can black on the outside. Set aside to dry.
2. Paint 1 box black on the inside. Set aside to dry.
3. Assemble the solar water heaters.
   - Fill both cans ¾ full of water,
   - Set each can inside a box (see photo above),
   - Cover each box with plastic wrap and tape it tight,
   - Put a piece of tape in the centre of the plastic to strengthen it. Make a hole in the plastic for the thermometer and place the thermometer into the opening of the can. (Make the hole in the plastic as small as possible, to reduce air moving in and out of the box.)

Step 2. Record the water temperature

Complete the temperature readings. ***Note*:** Do the trials at the same time; cloud cover, outdoor temperature and angle of the sun will influence the results. If you only have one thermometer, switch it back and forth between the solar water heaters, waiting until the temperature stabilizes in the new water heater before reading the temperature.

1. Make a hypothesis and write it on the chart on page 5: Which solar water heater will heat the water faster, and why do you think this is the case?
2. Record the temperature of the water in the solar water heaters.
3. Place the water heaters in full sun. Outside is best, or in a sunny window.
4. **Outdoor temperature comparison:** Each time you record the water temperature of your solar water heater, record the air temperature. If the models are outdoors, record the outdoor temperature from an outside thermometer placed as close to the water heaters as possible. If the solar water heaters are inside your home in a sunny window, record the temperature from a second thermometer near your solar water heaters, or the temperature that it says on the thermostat in your home. Knowing the air temperature will let you compare how your solar water heaters are absorbing and holding onto heat, compared to the temperature of the air.
5. After 15 minutes: Read the water temperature in each of the solar water heaters and record the readings on your chart.
6. Repeat the temperature readings at 30 minutes and 45 minutes. Record the readings on the chart.

Step 3. Testing other variables

You have already tested these variables:

- Black can in a black box, versus
- Unpainted can in an unpainted box.

Compare the temperatures on your chart.

1. What was the change in water temperature from test 1 to test 4 of the black painted water heater?

2. What was the change in water temperature from test 1 to test 4 of the unpainted water heater?

3. Which of the two solar water heaters showed the greatest change in temperature, from test 1 to test 4?

Now try other variables and make a hypothesis about which solar heater will show the greatest change in water temperature. Compare your hypothesis to the actual temperature results from the water heaters.

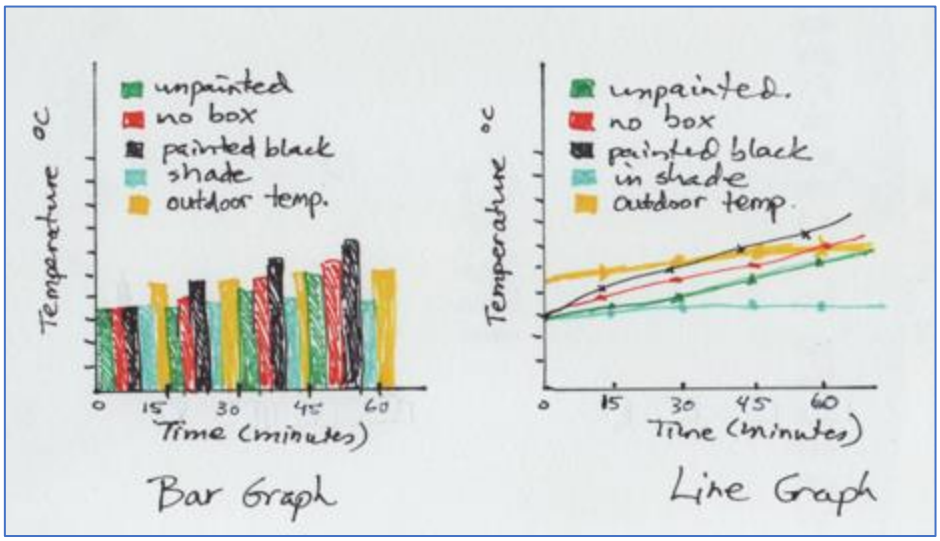
- Place one solar water heater in part sun/part shade,
- Place one solar water heater completely in the shade,
- Place one can in full sun without a surrounding box and plastic wrap,
- What else do you think might affect your results? Try it.

Mark all the variables you tried on the chart, and record temperatures as in step 2.

Charting and Discussion

1. Read the information on page 6:
    - understanding **heat capacity**,
    - understanding **radiation**,
    - understanding **conduction**,
    - understanding **convection**, and
    - understanding colour.

2. Make bar or line graphs of the temperature results of the solar water heater tests.



3. Compare the temperature results and answer the following questions:
   - What do you think caused the differences in temperature between heaters?
   - Rank the various solar water heater tests in order from slowest to heat water, to quickest to heat water.
   - What could you change in this experiment to make the water heat faster?
   - How do you think today's weather affected your experiment?

4. **Going further:** read the information on page 7.
   Heating water with solar energy: How solar evacuated tubes heat water.

5. If you were going to design a solar water heater to provide heat for your house, what factors would you need to consider? What are some things you would include in your design?

This experiment was adapted from: Energy Investigate: Why we need power and how we get it, by Kathleen M. Reilly, Nomad Press, 2009.

Solar Water Heater Temperature Chart

Painted can in painted box

My hypothesis:

Time	Water temperature (oC)	Outside temperature (oC)
Test 1		
Test 2		
Test 3		
Test 4		

Unpainted can in unpainted box

My hypothesis:

Time	Water temperature (oC)	Outside temperature (oC)
Test 1		
Test 2		
Test 3		
Test 4		

Other variables: e.g. place water heater in shade, can only – no box, etc.

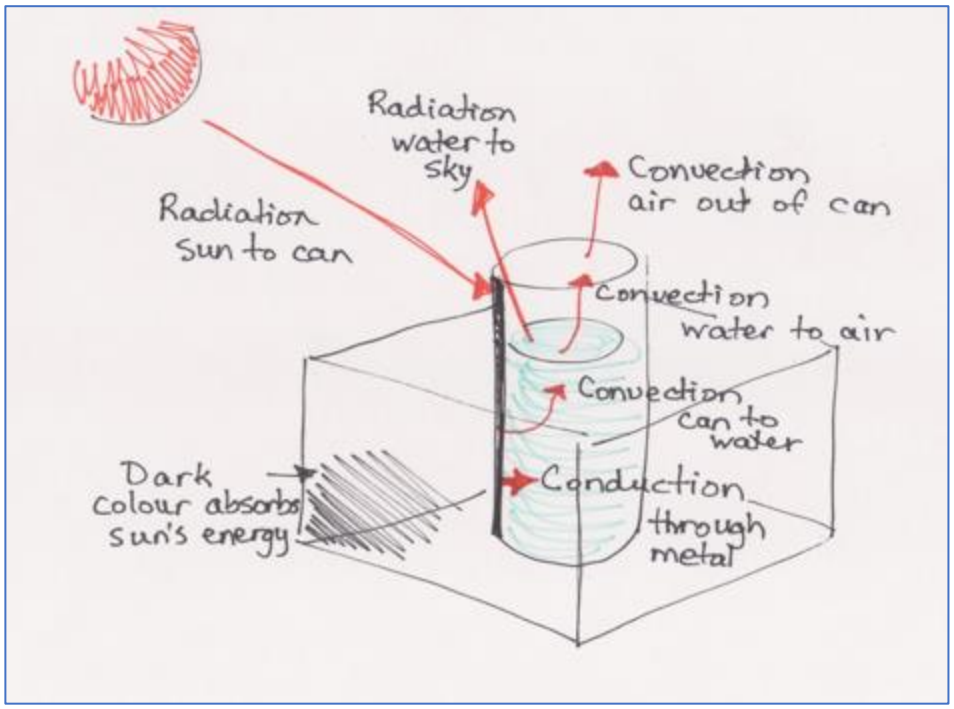
My hypothesis:

Time	Water temperature (oC)	Outside temperature (oC)
Test 1		
Test 2		
Test 3		
Test 4		

Understanding heat capacity
Thermal mass or heat capacity is the ability of a material to store heat. The water in the solar water heater has high heat capacity so it heats slowly and will hold a lot of the sun's heat energy. It will also cool slowly as it gradually releases that heat.

Understanding radiation
Energy comes from the sun as radiation. We can use this radiant energy to heat water. When the sun shines on, or radiates to a surface, it warms that surface. In the solar water heater, the sun will radiate heat to the can and the box. The box and can will radiate heat to cooler surfaces around.

Understanding conduction
Conduction refers to heat moving though a material. Metals are good conductors, meaning heat can move through them easily. In the solar water heater, the metal can conducts the sun's heat to the water.

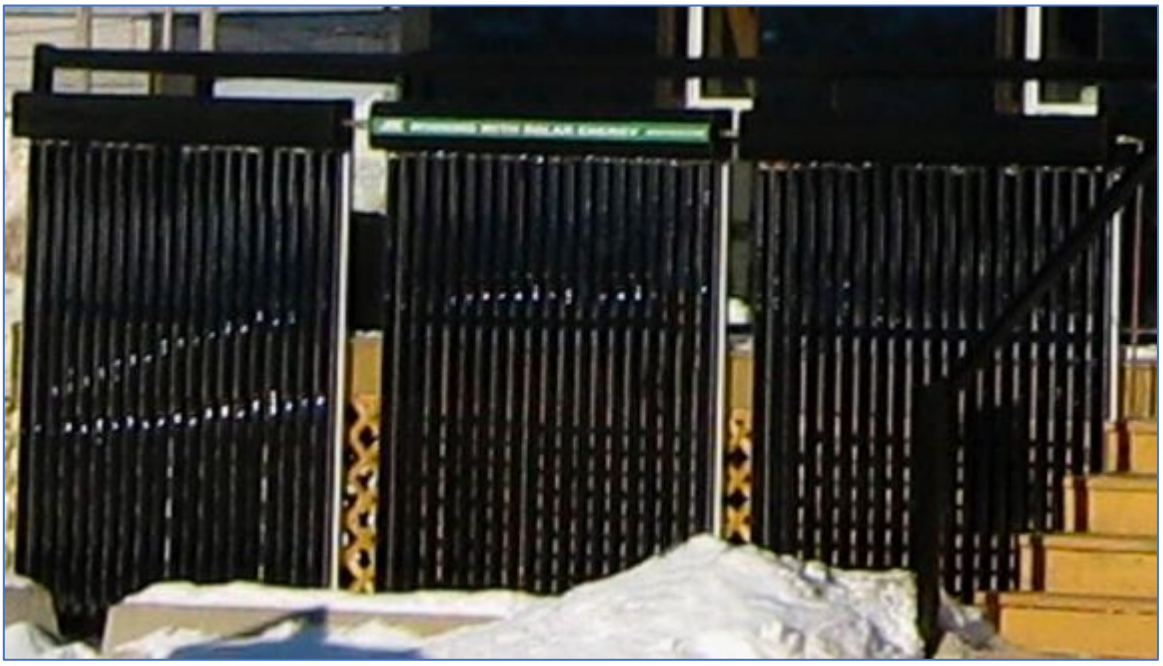


Understanding convection
Heat energy is transferred when heated air or liquid particles move from one location to another. As the inside of the can becomes warmer, it heats the water touching the can. That heated water rises, and cooler water flows to the side of the can, where it is heated.

Understanding colour
Dark coloured surfaces absorb more heat than they reflect. Light coloured surfaces reflect more heat than they absorb.

Going further: Heating water with solar energy

How solar evacuated tubes heat water



This is a photograph of solar evacuated tubes, placed on the south side of a home, and used to heat water. They convert the energy of sunlight into heat, which is used to heat water or a home.

Evacuated tubes do not have any air between two layers of glass, eliminating heat loss by **convection** or **conduction**. (Convection needs a gas or liquid to move, and conduction needs a material to travel through.)

- The sun's heat **radiates** through the glass tube and is trapped and absorbed by a dark painted copper tube inside the glass tube.
- Heat moves up the copper tube (**conduction**), where it is transferred to water being pumped through the system into a tank.
- A heat exchanger in that tank captures the heat through **conduction** and **convection**. The heat is then taken to a water heater, or to an in-floor radiant heating system.

Curriculum Connections

Grade 4 Mathematics P4.1 Demonstrate an understanding of patterns and relations by: identifying and describing patterns and relation in a chart, table or diagram, reproducing patterns and relation in a chart, table, or diagram using manipulatives, creating charts, tables, or diagrams to represent patterns and relations, solving problems involving patterns and relations. **Science LI4.1** Investigate the characteristics and physical properties of natural and artificial sources of light in the environment. **Social Studies RW4.1** Analyze the strategies Saskatchewan people have developed to meet the challenges presented by the natural environment.
Grade 5 Mathematics SP5.1 differentiate between first-hand and second-hand data. **SP5.2** Construct and interpret double bar graphs to draw conclusions. **SP5.3** Describe, compare, predict, and test the likelihood of outcomes in probability situations. **Science WE5.2** Investigate local, national, and global weather conditions, including the role of air movement and solar energy transfer. **Social Studies RW5.1** Explain the importance of sustainable management of the environment to Canada's future.
Grade 6 Mathematics SP6.1 Extend understanding of data analysis to include: line graphs, graphs of discrete data, data collection through questionnaires, experiments, databases, and electronic media, interpolation and extrapolation. **SP6.2** Demonstrate understanding of probability by: determining sample space, differentiating between experimental and theoretical probability, determining the theoretical probability, determining the experimental probability, comparing experimental and theoretical probabilities. **Science EL6.1** Assess personal, societal, economic, and environmental impacts of electricity use in Saskatchewan and propose actions to reduce those impacts. **Social Studies RW6.2** Contribute to initiating and guiding change in local and global communities regarding environmental, social, and economic sustainability.
Grade 7 Mathematics P7.1 Demonstrate an understanding of the relationships between oral and written patterns, graphs and linear relations. **SP7.3** Demonstrate an understanding of theoretical and experimental probabilities for two independent events where the combined sample space has 36 or fewer elements. **Science HT7.1** Assess the impact of past and current heating and cooling technologies related to food, clothing, and shelter on self, society, and the environment. **HT7.2** Explain how understanding differences between states of matter and the effect of heat on changes in state provide evidence for the particle theory. **HT7.3** Investigate principles and applications of heat transfer via the processes of conduction, convection, and radiation. **Social Studies RW7.3** Assess the ecological stewardship of economies of Canada and the circumpolar and Pacific Rim countries.
Grade 8 Health Education USC8.6 Examine and assess the concept of sustainability from many perspectives, and develop an understanding of its implications for the well- being of self, others, and the environment. **AP8.10** Design, implement, and evaluate three seven-day action plans that establish multiple supports for responsible health action related to family roles and responsibilities, non-curable infections/diseases, violence and abuse, body image, sustainability, and sexual health. **Mathematics SS8.2** Demonstrate understanding of the surface area of 3-D objects limited to right prisms and cylinders (concretely, pictorially, and symbolically) by: analyzing views, sketching and constructing 3-D objects, nets, and top, side, and front views, generalizing strategies and formulae, analyzing the effect of orientation, solving problems. **SP8.1** Analyze the modes of displaying data and the reasonableness of conclusions. **SP8.2** Demonstrate understanding of the probability of independent events concretely, pictorially, orally, and symbolically. **Social Studies RW8.3** Critique the approaches of Canada and Canadians to environmental stewardship and sustainability.