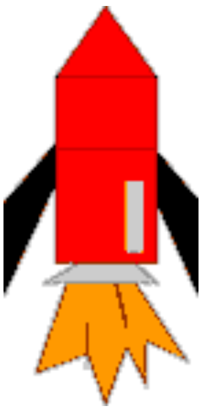
Heat: An Agent of Change

Heat Effects on Metals

STUDENT ACTIVITY

Design engineers who use metal components are always interested in the components' tendencies to expand when heated, and in the amount of heat they can hold and transmit to adjacent components. The metal structure of a building, for example, must not expand unevenly or the building would bend and topple. Likewise, metal bridge structures must not be allowed to expand in a way that would crumple the bridge. Have you ever noticed the felt pads acting as joints between sections of a metal bridge? They are called expansion joints. When the metal bridge sections expand in hot weather, they do not push directly against other metal sections and cause them to buckle. Instead, they compress the felt, which causes no harm to the overall structure.



The design engineers of the Genesis mission must anticipate problems caused by the intense heat of the Sun. Some examples of these problems involve thermal expansion and specific heat. Heat expansion is a property of a material that causes it to increase in volume as it is heated and shrink in volume as it is cooled. **Specific heat** is a property of matter that determines the rate at which it will heat up and cool down. It is a measure of the material's heat capacity divided by its mass. The faster a material gains heat, the faster it can also lose heat. In addition, the higher the value of specific heat of a substance (J/kg-C°), the more heat energy it will hold (**heat capacity**). The melting point of materials used on the Genesis spacecraft must be high enough to withstand the high temperatures that the spacecraft must endure.

PURPOSE

Which metals should engineers consider using in the Genesis spacecraft to minimize the problems associated with heat expansion and specific heat?

PROCEDURE (Read entirely before beginning.)

With your group, collect the following materials:

3-6 samples of solid metal cylinders
Safety goggles for all group members
Block of paraffin wax
Caliper (10 cm) for each cylinder
Set of tongs
2—500-1000 ml beakers full of water
Ice for one of the beakers
Ruler with mm increments
2—wood or plastic blocks
Clock or timer
Hot glove
Hotplate
Metric scale

Part A—Heat Expansion

1. Put on your goggles. Place the metal cylinders in a beaker of ice water. Label each caliper for one of the cylinders. After five minutes, take the cylinders out of the water, one at a time, and tightly set the correct caliper for the length of each.
2. Put all of the cylinders in the other beaker of water. Put on your goggles. Place the beaker on the hotplate and turn it on. Bring the water to a boil. Keep boiling for five minutes.
3. After the five minutes are up, use the tongs and take each cylinder out of the water one at a time. Quickly attempt to slip the cylinder back into its caliper **without readjusting the caliper!** Fill out in Table 1 based on your observations. Turn off the hot plate. You can take off your goggles now.

Table 1

Metal cylinder	How easily did the cylinder slip back into its caliper? √				
	Very easily	Easily	Barely	With difficulty	Would not

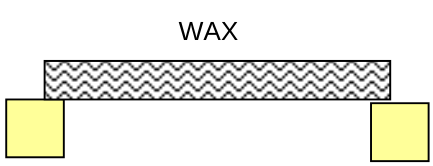
Part B—Specific Heat

1. Weigh each cylinder on the scale and fill in the mass in Table 2*.* Also, measure the length of each cylinder and fill in the value in Table 2*.*
2. Hypothesize which cylinders would melt through wax farthest if they all started at the same temperature. Rank the cylinders on Table 2 according to your hypothesis. Rank number one as the cylinder that would melt the farthest through wax.

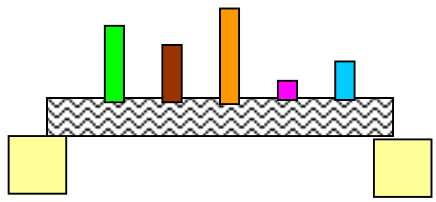
Table 2

Metal cylinder	Mass (g)	Length (mm)	Hypothetical rank in melting wax

3. Set up the wax and blocks in a bridge according to this diagram:



4. Put all of the cylinders back in the beaker. Put on your goggles. Using the hot glove, place the beaker on the hotplate and turn it on. Bring the water to a boil. Keep boiling for five minutes.
5. One at a time, use the tongs to remove each cylinder from the boiling water and quickly place them upright on the wax according to the following diagram:



6. Turn off the hot plate. Observe the cylinders as they melt through the wax. Make sure that none of them tip over by gently nudging them with the tongs it they start to tilt. Wait five minutes for the cylinders to finish melting through. You may take off your goggles now.
7. Using the ruler, measure the cylinder height left above the flat wax surface in mm. Fill in the values in Table 3***.***
8. Subtract the height above the wax, determined by step 7, from the cylinder lengths. Fill in the values in Table 3***.***
9. Using the information in Table 3, rank the cylinders according to which cylinders melted farthest into the wax in Table 3. Rank number one the cylinder that melted farthest into the wax.

Table 3

Metal cylinder	**Length (**from *Table 2)*	**Remaining above wax** (mm)	**Sunk into wax** (length – length remaining)	**Actual rank in melting wax**

CONCLUSION

Write a conclusion in paragraph format that addresses the following questions:

- Why are there differences in the observations recorded in Table 1?
- Do all metals expand when heated? Do they all expand at the same rate? Support your answers with the data.
- Why did the experiment begin with putting the cylinders in ice water?
- Did the cylinder rankings for melting through the wax in Table 2 match the experimental result rankings in Table 3? Why or why not?
- How does the specific heat of each metal effect the results in Table 3?
- If you were an aerospace engineer working on the design of the Genesis spacecraft, which metals from this experiment would you consider using in the design to minimize the adverse effects of the intense heat of the sun?