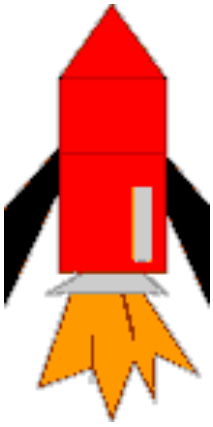
Heat: An Agent of Change

Heat Effects on Metals

TEACHER GUIDE

BACKGROUND INFORMATION



Spacecraft design engineers worry about the properties of the materials they choose for different components of a craft. Will they heat up too much during the mission or on reentry? Will they transmit their heat readily to sensitive detectors or other instruments mounted on the deck of the spacecraft? Will they expand or contract in the various environments to which the spacecraft will be subjected, causing the entire structure to warp and bend?

The **thermal coefficient of expansion** is the number, unique to each substance, which is multiplied by the temperature difference to determine how much the material will expand when heated a certain amount. It is measured in ppm/^{o}C. A larger value shows greater expansion with the same input of heat. Aluminum has a coefficient of 23.1, and lead's value is 28.9. These are typical values for metals, which tend to expand noticeably with the addition of heat. However, carbon, which does not expand very much at higher temperatures, has a coefficient of 7.1.

STANDARDS ADDRESSED

Grades 5–8

Abilities necessary to do scientific inquiry
Physical science: Properties and changes of properties in matter

Grades 9–12

Abilities necessary to do scientific inquiry
Physical science: Conservation of energy and the increase in disorder

MATERIALS NEEDED (amounts given per lab group)

3-6 samples of solid metal cylinders of equal diameter and varied mass. Brass, copper and aluminum are highly recommended. Other interesting samples are iron, zinc and lead. Density cylinders work well.
Safety goggles for all students
Block of paraffin wax for canning
Caliper (10 cm) for each cylinder
Set of forceps
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

Laboratory Materials Substitution

Referring to the materials list, the following materials can be substituted:

Recommended Material	Substitutable Material
• Metal cylinders of varied mass	• The activity can be modified to reach similar conclusions if cylinders of equal mass are used
• Calipers	• Large vise clamps • A crude clamp can be improvised from a ring stand and two ring stand clamps
• Beakers	• Any container with a volume large enough to fit the cylinders in and suitable for boiling
• Ice	• Refrigerator/freezer
• Propping blocks	• Any material that will bridge the wax according to the diagram
• Hot glove	• Hot pad
• Hotplate	• Any safe set-up to boil water (do not use a microwave)

If cylinder of various weights are used, many students will assume that the heaviest cylinders will sink the farthest into the wax. When the data does not match the distribution of mass, a discussion of specific heat and its effects may logically begin. If cylinders of equal weight are substituted, the students may similarly wonder why the cylinders sink to different depths.

PROCEDURE

Part A—Heat Expansion

Students are using heat sources and boiling water in this activity. Be sure they use appropriate safety precautions, such as wearing goggles. Consider ways to organize your room layout to minimize traffic near the hot plate.

If there are not enough metal cylinders for each lab group to have three to six different ones, it is possible to achieve the objectives of this activity by sharing data. Make sure that at least two lab groups measure the same metal, and arrange for collection of a classroom set of data. Compare and contrast results from different lab groups for the same metal, as well as between different metal samples.

Although the measurements being made are qualitative rather than quantitative, accuracy is important. Students should use the time during cooling or heating of the cylinders to label the calipers to match the types of metal they are testing. They should carefully check that the are using the correct caliper for each sample measured. The calipers must not be readjusted between the cold measurement and the hot one.

Part B—Specific Heat

Again, safety issues need to be dealt with, as in Part A above.

It is likely that the results will surprise your students. If there is time, encourage students to repeat their experiments. They may wish to change other variables, such as the size or mass of the cylinders.

ADDITIONAL LEARNING OPPORTUNITIES

Research the specific heat and conductivity of various metals. Prepare a report, based on your research, recommending the most suitable metals for a space probe sent into a high temperature environment.

Research the Genesis mission and prepare a presentation on the actual metals chosen for the spacecraft. Explain the reasons they were chosen.

RESOURCES

http://www.newspace.com/feature/thermal/home.html
"Thermal Pursuit" is a Trivial Pursuit-type game focused on spacecraft thermal engineering.