Lesson Title: A Cool Lesson on Thermal Expansion

Subject	Grade Level	Timeline
Physical Science, Earth & Space Science	4 - 8	30 minutes

Objectives

This lesson investigates the expansion and contraction of metal due to changes in temperature.

Standards

Next Generation Science Standards
Middle School Physical Sciences Storyline
https://www.nextgenscience.org/sites/default/files/MS%20PS%20DCI%20Combined%206.13.13.pdf

Students who demonstrate understanding can:

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.
5-PS1-3 Make observations and measurements to identify materials based on their properties.

Materials

Ring-and-ball apparatus
Heat source (heat gun or Bunsen burner)
Cold water (tap water will work)
Bimetallic strips

Vocabulary

- Thermal expansion: the property that causes metals to expand in size as the temperature goes up, and to shrink in size as the temperature goes down.
- Heat: The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.

Lesson Plan

Background for teachers:

Safety: Remember, dangerously hot metal looks exactly like cold metal! Burns can result from even very brief contact with a heat gun, open flame, or hot metal.

Note: Some ball-and-ring apparati are designed so the ball can fit through the ring when they are the same temperature, and some are designed so the ball cannot fit unless the ring is hotter. This lesson is written for the setup where the ball can fit at the same temperature, as in the video. If you have the apparatus where it cannot fit when both are at the same temperature, the principles are the same but the difference in equipment should be noted for the students.

Teacher Demonstration

1. Show students that the metal ball passes through the ring.
2. Turn on the heat gun or Bunsen burner and hold the metal ball in the heat source for one minute.
3. Try to put the heated ball through the ring. Allow students to see that it will not pass through.
4. Put the heated metal ball in the cold water and allow to cool.
5. Show students that the metal ball passes through the ring once again.

Explain

Most materials expand when heated, so the diameter of the ball is actually greater when the metal is hot than when the metal is cold. The expansion is very small, and the ball is dangerous to touch, so it is difficult to measure the change in size with classroom equipment. But the effect can be seen clearly.

Engineers build things with this expansion in mind. Railroad tracks, automobile parts, the metal support beams for bridges and buildings; all have space built in for parts to expand and contract at different temperatures. The International Space Station and other artificial satellites are built with this in mind, too. Without planning ahead for thermal expansion effects, bridges and railways would buckle in the heat, and pieces that fit together correctly on Earth would have cycles of expansion and contraction in space as they pass from sunlight to shadow time they each orbit.

Follow-up (Optional)

Ask students what will happen if the ring is heated. Will the diameter of the ring get bigger? Or smaller?

6. Turn on the heat gun or Bunsen burner and hold the metal ball in the heat source for one minute.
7. Try to put the heated ball through the ring. Allow students to see that it will not pass through.
8. *Without* cooling the ball in water, carefully put the *ring* in the heat source for one minute.
9. Show students that the metal ball passes through the ring when both are hot!

Explain

At first it may be unclear why the expanding metal ring does not expand both outward and inward, filling the hole. But consider the inside surface of the ring as a bent strip of metal. If we were to measure that inner circumference at a cool temperature, and then heat it and measure the inner circumference again at a higher temperature, we would find that the hotter circumference is larger because it is the same amount of metal, but expanded.

Student Activity:

Examine the bimetallic strips you have been given. Each bimetallic strip is actually two strips--two different metals that have been fused together, so the stip will look different on one side compared to the other.

- What will happen if the bimetallic strip is heated to above room temperature?
- What will happen if the bimetallic strip is cooled to below room temperature?

To find out if you are correct about what will happen, you will need to first heat the bimetallic strip to observe what it does, and then cool the bimetallic strip to see what it does.

Safety: Remember, dangerously hot metal looks exactly like cold metal! Burns can result from even very

brief contact with a heat gun, open flame, or hot metal. To heat and cool the bimetallic strips more safely, use warm water and ice water.

Questions:

- If metal expands when heated, why does the bimetallic strip behave the way it does?
- The outside of the International Space Station has thermal covers to protect hinges, bolts, and other equipment from the constant cycling of hot (from direct sunlight) and cold (from being in shade). Why does a cover work in that situation, but not on bridges, railroad tracks, and other items on Earth?
- How can objects on Earth get hotter or colder, other than direct sunlight and shade?

Resources

- **NASA Jet Propulsion Laboratory**
  https://genesismission.jpl.nasa.gov/educate/scimodule/heat/explorat_4TG.pdf

- **Mind Trekkers (at Michigan Technological University)**
  https://mindtrekkers.mtu.edu/lessons/143.pdf