Demonstrate thermal expansion with a bimetal strip

This activity can be used when teaching these Illinois Leading Standards (see accompanying demonstration):

Elementary– 11.A.1a, 11.A.1b,11.A.1c, 11.A.1d, 11,A.1e, 11.A.1f

Late Elementary– 11.A.2a, 11.A.2b, 11.A.2c, 11.A.2d, 11.A.2e

Middle/Junior High School– 11.A.3a, 11.A.3b, 11.A.3c, 11.A.3d, 11.A.3e, 11.A.3f, 11.A.3g

Due to the young ages of the target audience, this demonstration is intended to be conducted by teachers, only.

Materials Needed:

Bimetal strip (See Sheet 1.) • Hair dryer • Two bulldog office clips • Paper • Ruler • Marker • Level, carpenter's square or other device for scribing a perpendicular line • Metal tray for protecting counter surface (optional)

Demonstration:

Set up this dem-onstration in front of a wall . Tape a piece of paper onto the wall and draw a perpendicular line. Horizontally tape a ruler on the wall nine inches above the surface where you place the strip (table, counter, etc.)

Clamp two large bulldog office clips on a short edge of the strip to make a base.

With a permanent marker, label each side of the strip with the metal type, i.e. "aluminum" and "galvanized."

Stand the strip upright so that it is perpendicular. Make sure the thin edge of the strip is facing your students. Align the strip with the perpendicular mark on the wall.

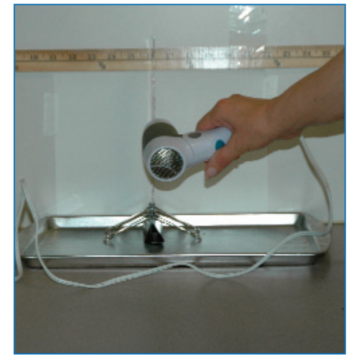
Slowly heat the strip with a hair dryer, keeping the dryer at a fixed distance from the strip. Point the dryer at the thin side of the strip so that it does not move.

Observe that the bimetal strip will slowly deflect to one side as it heats.

Take measurements of the amount of deflection with the ruler. Record the strip's movements at regular intervals as it moves until it stops deflecting. (The amount and speed of deflection will depend on the types of metals that compose the strip and how quickly the temperature rises.)

After the bimetal strip has stopped moving, remove the heat. The strip will slowly straighten to its original shape. (You can speed the straightening process by applying a cube of ice to the strip. Continued cooling with ice may actually cause the strip to bend away from perpendicular in the opposite direction.)

Turn the strip around and repeat the demonstration. The strip will bend in the opposite direction.

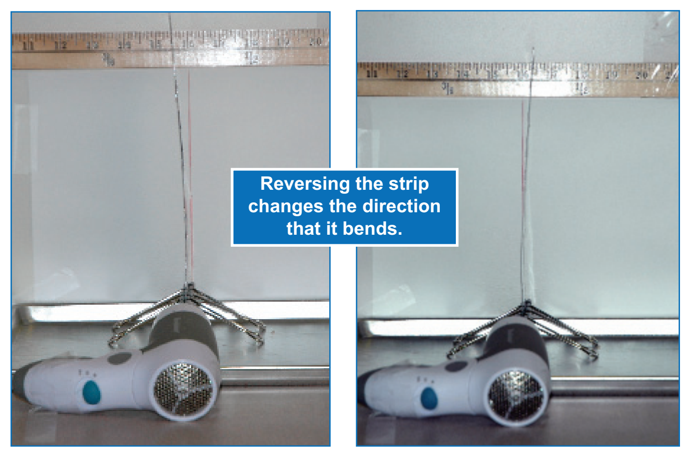


Ask your students to identify which layer of metal the strip bent toward.

Which type of metal expanded the fastest? the least?

Alternative: A flame can be used to heat the strip, but this is not the recommended practice because it takes longer. If you intend to heat with a small flame, support the strip horizontally with two non-flammable objects at each end. Place a small candle below the strip. When heated, the strip will bend up or down in its middle. Take measurements at the mid-point.

Continued . . .



Reversing the strip changes the direction that it bends.

Elementary Lesson

All substances (matter) are made of **atoms**. Atoms are tiny particles that contain moving parts. Atoms combine in different ways to form larger—but still incredibly small— particles called **molecules**. All the molecules in every type of substance are the same, but different from the molecules of other substances.That is because each type of molecule is made of different combinations of atoms.

For example, the molecules in the wood of your pencil are different from the molecules that make up the graphite in the middle. These are different from the molecules in the eraser and the paper you write on.

We stated that the atoms that make up molecules have moving parts. Therefore, molecules must have moving parts, too.

In general, the atoms in the molecules of substances move faster when they are heated and move slower when cooled. When the molecules of a substance move faster, they push apart from each other slightly. This causes the substance to grow larger.

Have you ever found you couldn't twist the metal cap off of a jar? To open it, have you ever held the cap under a stream of hot water? After heating, the lid twisted off quite easily.

When you heated the lid with the hot water, you caused the atoms in the molecules of the metal to move faster. This caused the molecules in the metal to push apart and the lid to become slightly larger. That is why it was easy to twist the lid off after the lid was heated.

Why didn't the glass part of the jar get bigger, too? If this had happened, wouldn't the lid have been just as tight? Yet, you were able to easily remove the lid. The answer it that the glass did grow, but just not as much as the metal.

This example shows that different substances (different kind of molecules) get larger, or **expand**, differently when they are heated. Why would this be? The molecules of one substance move at different speeds than the molecules of a different substance when heated the same amount.

There is a name for when a substance normally grows larger when it is heated. It's called **thermal expansion**.

This demonstration shows the different rates of thermal expansion of two different materials. It uses two different kinds of metals, aluminum and galvanized steel—a thin sheet of steel coated with a layer of another metal, zinc. (Builders often use zinc coated steel on the roofs of buildings because the zinc coating prevents the steel from rusting). Strips of these two metals have been glued together. We call this a **bimetal strip**.

[Conduct the classroom demonstration as described above. When recording the amount of deflection, it might be helpful for group of students measure the movement of the strip as another group times the intervals for taking the readings. A third group could record the distances as they are called out. Be sure to allow students or groups of students to observe the direction the strip moves. Repeat the demonstration by holding the hair dryer a different distance from the metal strip and record the distance the strip bends away from perpendicular. Ask students to describe what they observed.]

Topics for discussion

- After watching the demonstration, what questions do you have about the reasons the strip bent the way it did?
- Toward which type of metal did the strip bend?
  The galvanized strip
- Did this change when we turned the strip around?
  No
- Why do you think the strip always bent toward the galvanized side?
  The aluminum side expanded faster, bending the strip in the opposite direction.
- What were the distances you recorded at each time interval (30 seconds, one minute, one and one-half minutes or one, two three minutes)? Compare for each change in direction and distance from heat source?
- Do you see a pattern in your results?
  There is a linear relationship between the rise in temperature and the expansion of solids. You are applying heat at a constant rate over time, so we assume an equal, but different, increase in temperature for each metal. Results should be something like $^1/_4$, $^1/_2$, $^3/_4$ inch. Deviations could be caused by inconsistencies in measuring, timing or the application of heat.
- Make a simple chart listing your observations each time the strip bent to the right and left, and when the dryer was held at different distances from the metal. Compare the results with others, or other groups.

Challenge Level 2

Conduct the lesson as described above, plus teach these addition lessons.

- What is the name of an instrument that measures temperature?

A Thermometer. It is an instrument that has a part which changes as the thermometer heats or cools. We can observe this changing display to tell us that the temperature changes (Mercury or colored alcohol rising or lowering in a glass tube, digital display, etc.)

- Is the bimetal strip a thermometer? Why?

Yes. The strip bends as it heats and cools. With observation, we could determine how far the metal bends for each degree on an accepted temperature scale (Fahrenheit, Celsius).

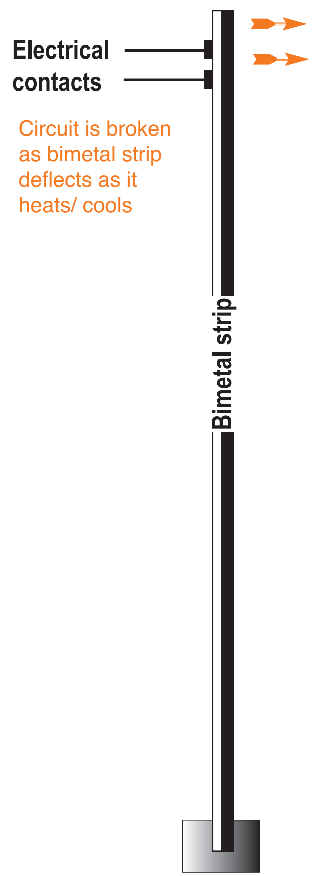
- Can you think of another use for a bimetal strip?

- Do you think a bimetal strip can be used as an electrical switch?

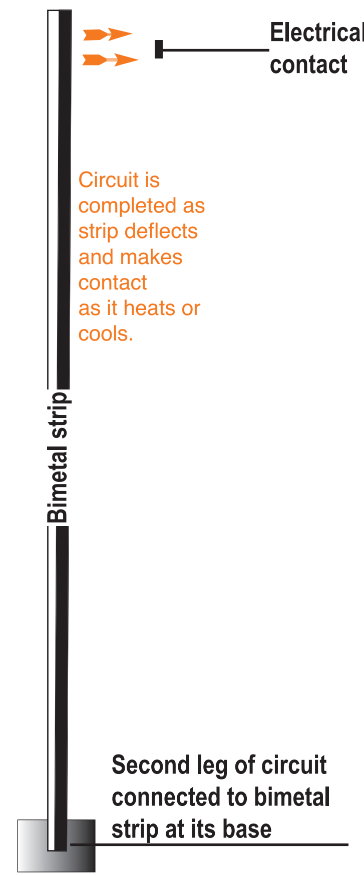
Switches that turn electrical appliances on or off as the temperature changes are called thermostats. The most popular design of a thermostat incorporates a bimetal strip.

Activity:

Based on our classroom demonstration, draw a simple diagram of how a bimetal strip thermostat would work? Ask students to share and explain their drawings. Display their drawings in the classroom.



Possible Thermostat Designs



Challenge Level Three

Discuss Challenge Level One as described above, plus teach these additional lessons.

The bimetal strip experiment taught us that all solids expand, and that different materials expand more than others.

- Can you think of problems that expansions would cause for designers of large structures like roads, bridges and buildings?

Concrete and steel, to name a few, are common building materials. If these materials were installed in long, continuous pieces, they would buckle when heated by hot summer conditions. For this reason builders leave gaps in these materials at regular intervals. These gaps allow sections to expand and fill the gaps when they become hot. Engineers and builders call these gaps **expansion joints**. Look for expansion joints in roads, buildings and sidewalks. Hint: sometimes expansion joints are filled with a flexible material, like tar, to keep water out.

Each type of solid material expands at a constant, or linear, rate. However, each type of material expands at its own, but different, rate. Because the expansion rates of different solids are predictable, engineers can calculate how much any amount of a solid material will expand by observing how much smaller amounts of the material expand. They can do this by creating a mathematical formula.

Scientists have measured expansion lengths of various materials. These numbers are written as fractions. The numerator (or top number) is the change in length of each material for one degree of temperature change. The bottom number, or denominator, is the original length of the material.

For example, if 100,000 millimeters of a material grew by one millimeter when heated one degree Celsius, the fraction would be written as follows:

$$\frac{1}{100{,}000}$$

These fractions are called **linear coefficients of thermal expansion**. Most materials have different expansion rates and are written as different coefficients. Using known coefficients of thermal expansion, an engineer can predict how much any length of the material will expand over any temperature change.

The answer is solved by multiplying the linear coefficient of thermal expansion by the length of a substance by the change in temperature in degrees.

Because linear coefficients of thermal expansion are very small number, they are expressed in **scientific notation**. This is a way of writing very large or very small numbers without a lot of zeros. As commonly written, there is a small number to the upper right of 10. The small number means that you multiply the number 10 by that many times. 10^4 means 10x10x10x10 or 100,000. A minus (-) before the small number indicates a tiny number, like 10^{-6}.

- Look at this table of linear coefficients of thermal expansion for various solid materials. By looking at these numbers can you tell which materials will expand the most? Least? Why?

Linear Coefficients Of Thermal Expansion

Material	Coefficient per °C (10^{-6})*
Aluminum	25×10^{-6}
Brass	18×10^{-6}
Copper	17×10^{-6}
Glass (soda)	17×10^{-6}
Glass (pyrex	3×10^{-6}
Gold	14×10^{-6}
Iron	11×10^{-6}
Platinum	9×10^{-6}
Pine (with grain)	5×10^{-6}
Pine (across grain)	5×10^{-6}
Quartz	0.4×10^{-6}

* As commonly written, there is a number written as a superscript on the right side of 10. This smaller number denotes the number of times that the larger number changes by the power of 10, which essentially means the decimal place is moved to the right or left of the larger number, depending on whether the smaller one (in superscript) is positive or negative.