Ring and Ball Lesson Plan  
(Thermal Expansion)

Amount of time demo takes: 5 mins.
Don’t try this at home!

Materials
- Brass ring and ball apparatus
- Set of four bimetallic strips
- Butane canister
- Butane stove
- Optionally: a small container of liquid nitrogen

Set-up Instructions
1. Assemble and test butane burner, using all appropriate fire precautions.
2. Optionally: dispense a small amount of liquid nitrogen into a container for later use.
3. Set out ring and ball.
4. Lay out the bimetallic strips; these can be used to expand the content of this demo.

SAFETY!
- This demo uses a butane stove and, if expanded to cover more concepts, can use liquid nitrogen. Students should not handle either. Both the ring/ball and all the bimetallic strips will be extremely hot after being held over the stove, and many take a while to cool down (10+ minutes). A fire extinguisher should be kept within sight when using butane. Eye protection, insulated gloves, and closed-toed shoes are required when handling LN2.

Lesson’s Big Idea/Background Information
- In short: At room temperature, the brass ball will fit through the hoop without difficulty. When the ball is heated the molecules move further apart. Although you might not be able to see the ball expand, you will find that it no longer fits through the hoop. Alternately: When the hoop is immersed in liquid nitrogen, it will shrink subtly -- the ball will not fit through the hoop in this instance, either.
- The bimetallic strips have one metal on each side, and bend when heated or cooled. Because various metals have different responses to
temperature change, heating a given compound bar will cause it to bend one way, while cooling it will cause it to bend the other way.

- **In more depth**: When you heat the metals, they undergo **thermal expansion**. This expansion is proportional to the original length, area, or volume of the given material. Every material has a coefficient of linear expansion, which is handy for determining how much it will expand when heated. The equation dictating this process is: \( \Delta L = \alpha L_0 \Delta T \). All this means is:
  - \( \Delta L = \) change in length is equal to the product of...
  - \( \alpha \) = the coefficient of linear expansion for a the material.
  - \( L_0 = \) the original length
  - \( \Delta T = \) the change in temperature

- The metals in the bimetallic strips expand following the linear expansion laws. Our compound bars are made of four combinations: Brass/Aluminum, Brass/Iron, Copper/Iron, and Brass/Copper. At 20 °C, aluminum’s linear coefficient is ~24, brass is ~19, copper is ~17, and iron is ~12.

- When we heat the sphere, we are dealing more with volume than length. To account for this, the calculation is done in all three dimensions, and we get: \( \Delta V = \beta V_0 \Delta T \). \( \beta \), beta, is the volumetric coefficient (it’s actually just \( 3\alpha \) for solids).

**Instructional Procedure**

1. Show the students the ball and ring apparatus and demonstrate that the ball fits through the hoop with ease.
2. Either heat the ball using a butane burner or cool the ring with liquid nitrogen. Ask students whether they think this will cause a change in the size/shape of the ball and hoop, and have them explain why they think so.
3. Demonstrate that the ball can no longer pass through the ring.
4. **For more depth**: Show students one of the bimetallic bars and ask them what they think will happen if you heat/cool it. Do so, and explain why the bar bends -- if metals expand when heated, like the brass ball, why does the strip only bend one way? Why don’t both metals expand enough to keep the bar straight? Discuss these ideas with students.

**Assessment/sample questions you can ask**

1. Why were we able to pass the ball through the hoop at room temperature, but not when we heated it?
2. Which strip do you think will expand the most? Why?
3. Do different metals react differently under temperature changes?
4. What are some real-world applications of expansion and contraction of metals?
   
   Hint: Safety shutoff valves might be one. A component heated too much may expand too greatly to pass through another component, causing the system to shut down.

**Clean Up**

- Allow all materials to warm up (from liquid nitrogen) or cool down (from the butane torch, and including the stove) thoroughly before repackaging. This may mean shutting down the demo early -- we cannot package exceedingly hot or freezing cold items. Ensure that everything is clean, disassembled, and put away neatly in the kit. Inform someone if the butane is running low! Dispose of excess liquid nitrogen, if applicable.

**References**

- Hyper Physics: [http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/thexp.html#c2](http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/thexp.html#c2)

**Next Generation Science Standards**

- K-5
  - 2-PS1-1/4
  - 5-PS1-1/3
- 6-8
  - MS-PS3-3/4
- 9-12
  - HS-PS2-6
  - HS-PS3