Curie Heat Engine

Overview: We're going to heat a magnet so that it temporarily loses its magnetic poles, and watch what happens as it cycles through cooling.

What to Learn: Magnetic material loses its ability to stick to a magnet when heated to a certain temperature called the *Curie temperature*. The Curie temperature for nickel is 380 °F, iron is 1,420°F, cobalt is 2,070 °F, and for ceramic ferrite magnets it starts at 860°F.

Materials

- Large ceramic magnet
- Tiny bead magnet
- Thin copper wire
- Smooth pen or straw
- Candle (with adult help)
- Framework to hold the setup

Lab Time <u>Please be very careful with this lab! You will need adult help with the fire.</u>

1. The video will show you how to create your frame. If you're using the two water bottle design, make sure they are full of water and space them approximately six inches apart and lay a smooth pen or straw across the caps. Tape the pen into place.
2. Insert the wire into your bead magnet and twist the wire end back on itself so the bead doesn't come off. I use a wire that doesn't have insulation so it won't burn when in the flame.
3. Straighten out your wire.
4. Place a votive candle on the table between the two water bottles. I like to do this on a cookie sheet to protect the desks.
5. Wrap your wire around the pen loosely several times so that it can still swing like a pendulum easily while hanging at a height at the top of the wick of the candle. You want the bead magnet to be just touching the top of the flame when you light the candle. Make sure the pen is supported well.
6. Lay the ceramic magnet on its side across one side of the votive candle so that the bead magnet is attracted to it and sticks. Move the large magnet so that the bead magnet is just touching the top of the flame while it's sticking to it.
7. You'll be adjusting it while the candle is lit, so **please be careful**! The ceramic magnet retains heat for a long time and will be hot to the touch, as will the wire and the bead magnet.
8. Have an adult light your candle and help you make the proper adjustments. Watching the video again may help.

Reading

We're going to use the idea that magnetic material loses its ability to stick to a magnet when heated to a certain temperature called the *Curie temperature*. At the end of the swinging wire, there's a tiny bead magnet, which is quite strong for its size. The magnet is attracted to the large ceramic magnet and moves toward it, almost touching it.

The candle heats up the tiny bead magnet, causing it to temporarily lose its magnetism by adding energy into the atoms and randomizing their orientation within the magnet. You'll notice that the magnet quickly regains its magnetism after it cools. While you can permanently destroy the magnetic field in the bead magnet, you'd need something hotter than a propane torch to do it.

The Curie temperature for the ceramic magnet is much higher than a candle can produce, which is why the permanent magnet isn't affected by the flame. The Curie temperature for the tiny bead magnet is about 600°F, which is easily obtainable by your candle.

If you can't find a bead magnet, the Curie temperature for the Radio Shack rare earth magnets is just under 600°F, which also within reach of your candle's heat. The magnets are also on the small size, so they tend to heat up faster. You can break a magnet if you need a smaller piece for this experiment.

Exercises

1. Why does the tiny magnet lose its attraction to the large magnet?

2. How long does it take for the attraction-repulsion cycle to repeat?

3. Draw out your experiment, explaining how it works and labeling each part:

Answers to Exercises : Curie Heat Engine

1. Why does the tiny magnet lose its attraction to the large magnet? (Curie temperature is the temperature at which a ferromagnetic material becomes paramagnetic on heating and the effect is reversible. A magnet will lose its magnetism if heated above the Curie temperature.)
2. How long does it take for the attraction-repulsion cycle to repeat? (It depends on the size of your bead magnet and the temperature of your flame. Larger magnets take longer to heat up.)
3. Draw out your experiment, explaining how it works and labeling each part: