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Educational Resources: Curie Point Engine

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Curie Point Engine

The Curie point of a metal is the temperature at which it loses its magnetic characteristics. Heat can cause magnets to stop being magnetic, which is why heating up magnets is not advised. This engine works because the Curie point of nickel is 354 degrees Celsius, a temperature that can be reached with a simple candle flame. Below are instructions about how to build your own engine and how to extend this activity for an entire classroom to experiment and build.

Relevant Indiana State Standards

There aren't any specific standards as of 2018 for grades 5-8 addressing magnetism/electromagnetic waves, but it is still an important subject. This activity also covers basic engineering principles and is relatively hands-on.

- 3-5.E.3 Construct and perform fair investigations in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved
- 6.PS.4 Investigate the properties of light, sound, and other energy waves and how they are reflected, absorbed, and transmitted through materials and space.
- 6-8.E.2 Evaluate competing design solutions using a systematic process to identify how well they meet the criteria and constraints of the problem.
- 6-8.E.3 Analyze data from investigations to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Supplies

For each engine

- 1 block of wood at least 2 inches wide at one end and 3.5 inches long
 - If you don't want an adjustable Curie engine, the piece can be only 2 inches long.
- 1 tea light candle
- 1 bent piece of wire as the frame
 - We used around 6 inches of a wire coat hanger. Normally 2-4 pieces can be cut from each coat hanger, depending on the size and shape of it.
 - If using rubber-coated hangers, strip the coating first. Painted ones work.
- 1-2 inches of nickel wire formed into a small loop
- 3 lengths of copper wire ranging from 2-4 inches
 - This forms the hanging piece for the nickel loop
 - Other non-magnetic wire with a reasonable melting point would also work
 - For our dimensions/wire shape, 3 inches worked the best. Having multiple different lengths allows students to experiment with which one works.
- 3-4 additional 1-1.5 inch pieces of copper wire
 - These are to act as spacers on the frame. They will be wrapped around the notches. These can technically be replaced with very thin tape strips, but the wire wraps seem to work better.
- 1 medium-sized rare earth magnet or 2-3 smaller ones stuck together.
 - Test the magnets you use before setting it up for a class.
 - Be careful, especially if each student is using 2 magnets. It's easy to pinch fingers with small, powerful magnets.
 - We found that two ½ inch diameter, ¼ inch tall magnets worked well.
- 2 1" iron nails
 - The nails are there to extend the reach magnet, making it so the magnet can be farther from the heat.
- Optional: thin blocks to raise the candle (to add another variable)

- 1 ruler
 - To measure magnet height

Other supplies (These can be given to each group or held by supervising adults)

- A lighter/matches
- A disposable cup with water
- Needle nosed pliers/tweezers
 - The cup and pliers are to quickly cool the nickel and wire hangers so students can adjust them immediately. They are optional.
- Paper towel for cleaning the sooty pendulum and nails

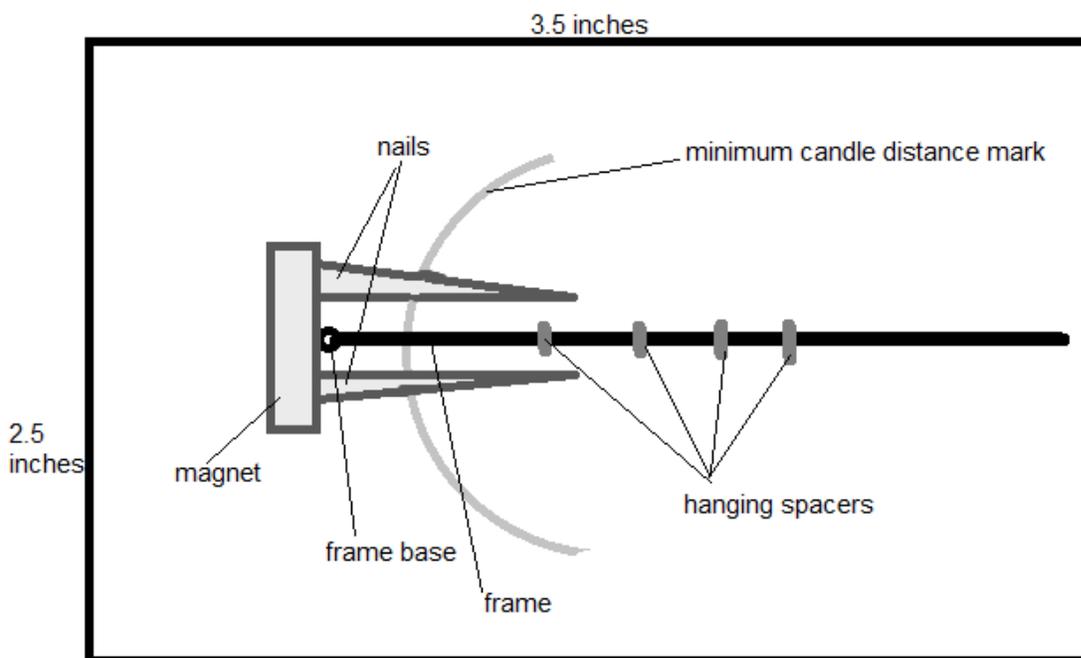
Tools required to build an engine

- A drill or hammer and a small nail (approximately the same diameter as the hanger wire) to put a hole in the wood block
 - The hole will end up being the base for the frame, so be careful not to make it too wide
- A good pair of wire cutters
 - They will need to cut the nickel wire, the hanger wire, and the frame made out of a wire hanger
- Needle nose pliers
 - For bending the hangers and nickel wire into shape.
- A metal file
 - Used to wear notches into the frame for wire spacing wraps
- A pencil for marking

Building Instructions

Curie Point Engine Diagram

Dimensions are approximate



Wooden base

1. Start by getting the proper sized block of wood. (A 2 by 4 board can be cut into quite a few 2 inch pieces to create around 2 by 2 by 4 blocks)
2. Mark a point somewhere between half and inch to an inch up from the center of the short side for the base of the frame.
3. Using a drill or a hammer and nail, make a hole around a half an inch deep.
 - a. If you're having problems with the wire frame wobbling, try making a shorter hole. Then, using a spare wire frame, hammer the frame in a little. This creates a hole that's the diameter of the frame. Sometimes this can bend the frame, so it's not a great idea to use the nice frames. This may also make the wire frame stick in the block.

Wire frame

1. Take the 6 inches of straight wire from the cut apart wire hanger.
2. Bend it at a right angle 3 inches from one end.
3. Place it in the block, long end facing the longest direction in the block
4. Put the candle on the wooden block, centered under the frame and a little over a quarter inch away from the base of the frame. Trace the side of the candle closer to the frame.
 - a. This is the minimum distance from the candle to the frame. If you move the candle any closer, the magnets start getting warm and possibly getting heat damage.
5. To find good locations for spacers, leave the candle at the minimum distance and go ahead and set up the magnet.
 - a. Place the magnet on the back of the frame, then put the two nails so they are parallel with the ground and the bent frame.
 - b. The nails are meant to extend the range of the magnet, making it so the magnet doesn't get damaged by heat.
6. Distance-wise, the 4 spacers on our sample engine were around evenly spaced between 1 and 2 inches away from the frame base.
 - a. Depending on time and other variables, putting 3 or 5+ spacers would also work over a larger or smaller area.
7. In relation to the other components, the first spacer was marked between the ends of the nails, one was almost directly above the candle wick, the third was so that the hanger would hang just inside the diameter of the tea light, and the fourth hung just outside the diameter of the tea light.
 - a. Spacers 1 and 2 are both intended to never let the nickel cool, spacer 3 normally works, and spacer 4 can work depending on candle height, hanger length, and magnet height.
8. Once your spacer locations are marked, take the frame piece off of the wooden block. Using the metal file, create grooves at the locations.
9. Wrap the spacer wire around the grooves and pinch it into the groove with the pliers.

Hangers/nickel loops

1. Take your length of nickel wire and bend it into a few tight loops with needle nosed pliers.
 - a. Make sure the loops are close. Your end piece should be the approximate diameter of a pencil eraser.
 - b. This is just meant to create a small circle of nickel that can be hung from the copper hanging pieces.
2. Now, bend your copper hanger wire into a hook at one end and some sort of stopping shape on the other.

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- a.  is the shape we used. The hook on the right is where it hangs from the frame, and the curls at the bottom keep the nickel loop from falling off.
 - b. The nickel loop should be able to slide on the hanger from the hook, but be stopped from falling off by the bottom curls.
3. Make the hangers in multiple lengths, varying by around a quarter to half an inch.
 - a. Make sure to test your hanger lengths and that at least one works! Ours worked well with a 3 inch length of wire made into a hanger.

Note: Make sure that everyone agrees what to call the different hanger lengths and spacers. (For example, say the hangers are small, medium, or large and the spacers are numbered so it's in position 1, 2, 3, or 4)

How it works

Hang the copper hanger behind a spacer and set up the magnet. The nickel piece on the end is attracted to the magnet. However, when the candle is lit, it heats the nickel to its Curie point, causing the hanger to swing away from the candle. When the nickel is hanging away from the candle, it cools off below the Curie point, making it magnetic again. The hanger then swings back toward the magnet and into the flame.

Pre-activity questions

- What are the independent variables in this activity?
 - Hanger length, hanger placement, and magnet height
- Can you think of anything magnetic?
 - Probably magnets. Students might also mention their fridge.
- What build do you think will work the best?
 - Completely up to them. Should have a position and hanger length.

Discussion topics/topics to know

- How magnets work/magnetic fields
- The basics of a Curie point
- Heat conductivity of metal (metal heats and cools relatively quickly)
 - Relates that the entire hanger will be hot immediately after blowing out the candle
 - Also how fast the nickel heats and cools – the driving force of this

Instructions

1. Either set up a lighter station with cups of water, pliers, and lighters/matches, or give students the materials in the beginning.
2. Give each student or group the set of pieces they need.
3. Explain the process of how a Curie engine works and either demonstrate with your own Curie engine or a video so the students know the motion they need.
4. Show how components fit together.
5. Set students loose to experiment with different magnet heights, hanger positions, and hanger lengths.
 - a. A good goal for “success” is to have 10 swings away, then sticking back on the magnet. The nickel has to hold toward the magnet and freeze for this to count, as if you use lightweight nickel pieces the hanger will naturally swing a little when not attracted to the magnet.

- b. After lighting the candle, the nickel piece, hanger, a small bit of the frame, and the nails will all be hot and mildly sooty. The nickel piece + hanger can be easily cooled by removing the hanger hook from the frame with pliers/tongs/tweezers, then dunking it into a cup of water. The water will gain a lot of soot. The nail and hanger cool enough to be touched after 30 seconds-1 minute, so as long as students are careful it should be fine. Paper towels should also be available to clean soot off of hands.

Post-activity questions

- What combination of position and hanger worked the best? Why?
 - Name the combination. An engine works because the hanger isn't too long/short and is close enough to the magnet.
- One piece of being a scientist is looking at unsuccessful experiments and learning from them. Why didn't one of your designs work?
 - The hanger may have been too short or too far from the magnet.
- How could you improve the design?
 - Up to the student. They could make it larger, have a different hanger size, more powerful magnet, guard against wind, or be able to place their hanger in any position.

Possible extensions

- For older/more advanced students, have them completely build their own Curie engine without a lot of diagrams
- Challenge the entire class to design one that works as a wheel
 - Ex: <https://www.youtube.com/watch?v=bE0TBaBUd1g>