Quantum Magnetic Levitation
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Abstract
The purpose of this project is to demonstrate the principles of quantum magnetic levitation in a way that will get prospective students excited about participating in the STEM (Science, Technology, Engineering, and Math) field. A superconductor made of yttrium barium copper oxide (YBCO) can suspend a magnet in the air when the superconductor is cooled to a point below its critical temperature. This process gives the impression that the magnet is “floating” by itself. The floating magnet will be an exciting sight for students as they learn about the Meissner effect through this simple demonstration.

Background
Quantum magnetic levitation is a principle based off of the Meissner effect. The Meissner effect states that if a material is cooled to a certain temperature, magnetic fields will pass around that material. At normal temperatures, these magnetic fields would pass through the material. For example, when a magnet is placed above a superconductor that has been cooled to below its critical temperature, the magnet will “float” above the superconductor due to the magnetic fields being forced to pass around the superconductor and are bent back to the magnet creating repulsion.

Superconductors have been applied to multiple technologies with practical uses. For example, Lexus released a video demonstrating the “hoverboard” that they had developed. This was actually done by using liquid nitrogen, superconductors, and a fixed magnetic track. While the hoverboard was only able to travel on the track of magnets, it still displayed the principles of quantum magnetic levitation.

MAGLEV technology was also used in Japan to create the MLX01 (shown below) with the use of superconducting magnets. The MLX01’s testing reached a speed of 374 miles per hour. However, due to the large scale of this project, the strong magnetic fields can create a bio-hazard, so this isn’t ready for commercial use yet.
Materials and Methods

Materials
- Styrofoam cup
- Liquid nitrogen
- Small neodymium magnets
- Yttrium Barium Copper Oxide (YBCO) tablet

Methods
1) Using a knife, cut a styrofoam cup approximately one inch from the bottom of the cup until you are left with just the bottom of the cup.
2) Set the YBCO tablet in the cutout section of the styrofoam cup.
3) Pour enough liquid nitrogen in the cutout section so that the YBCO tablet is not completely submerged.
4) Place a neodymium magnet above the YBCO tablet.
5) The magnet will start to float.
6) Experiment with different sizes of magnets, and take notes about which magnet sizes will stay suspended and at what height above the styrofoam cup. Is there a correlation?
7) Once the magnet stops floating, repeat steps 3-5 to refill the liquid nitrogen as necessary to keep the magnet floating.

Results and Discussion
The largest question behind this entire experiment was how magnet size and vertical displacement were related in regards to the superconductor. After conducting multiple trials with different size magnets, the conclusion was made that magnet size does not have a correlation with the vertical displacement of the magnet above the chilled superconductor. A quarter inch square magnet was compared to a sixteenth inch square magnet. The two were found to have practically the same vertical displacement above the chilled superconductor. From this observation, it’s safe to say that with the magnets we used, the size of the magnet and the magnet’s vertical displacement are not correlated. This is only true for the magnets we used, this hypothesis would need to be tested with more magnet sizes to tell whether or not the hypothesis is true for all magnet sizes.

Conclusion
This experiment was a fun way to make the complicated concept of quantum magnetic levitation approachable for students that are interested in STEM. For younger audiences, the magnet being able to float in the air by pouring liquid nitrogen into a container will hopefully prompt them to find an aspect of STEM related to this experiment, or even just an aspect of STEM in general,
that they are able to get excited about. For older audiences, the application of the Meissner Principle could help someone find a topic that they are interested in researching for later study.

Acknowledgments
We would like to thank Travis Walker for giving us the ability to participate in the STEM Outreach program. We hope to continue to get students excited about participating in STEM. We would also like to thank Jun Li for assisting us with the process of making a superconductor and Mas Subramanian for allowing us to use his lab to make the superconductor.

Works Cited


Appendix

YBCO Superconductor Creation Process
(In case of not having access to pre-made YBCO tablet)

Materials
- Yttrium Oxide (Y₂O₃)
- Barium Carbonate (BaCO₃)
- Copper Oxide (CuO)

Methods
1) To make a 10 gram “1-2-3” superconductor from the above compounds, mass out 1.6948 grams of Yttrium Oxide, 5.9243 grams of Barium Carbonate, and 3.5821 grams of Copper Oxide, It’s important to measure each compound out as accurately as possible to ensure that the mole ratio of the desired compound is 1-2-3.
2) Using a mortar and pestle, grind the compounds together until the powder in the mortar is a full grey color. For maximum efficiency, conduct three five minute grinds. After each grinding use a chemistry spatula to mix the powder.

3) Now that your compounds are mixed, place the powder into a half inch diameter metal casted dye and press the dye using 1000 psi of pressure using a hydraulic press.

4) Remove the powder from the metal casted dye, the powder should be formed into a tablet.
5) Place the tablet into a crucible placing the unit into a furnace.

6) For the first heating, set the furnace to increase 3 degrees celsius per minute until it reaches 925 degrees celsius where it will heat for 24 hours. Set the furnace to decrease at a rate of 1.5 degrees celsius per minute to cool the tablet down after the 24 hour heating to 30 degrees celsius.
7) Once the first heating is completed, your tablet should be black. If your tablet is not black but green, your mole ratio could be off. If your tablet is green you can go ahead and follow through with the second heating, the carbonate may have no fully reacted during your first heating.

8) Grind your tablet up into a powder once again using the mortar and pestle grinding method described in step two.
9) Repeat steps three through five to recreate your tablet.

10) For the second heating, set the furnace to increase 3 degrees celsius per minute until it reaches 950 degrees celsius where it will heat for 24 hours. Set the furnace to decrease at a rate of 1 degrees celsius per minute to cool the tablet down after the 24 hour heating to 30 degrees celsius.

11) If your tablet is still not black by the end of the second heating, your mole ratio was off. Consider restarting the entire process of creating the superconductor from scratch. If your tablet is black, proceed to step 12.

12) Grind your tablet up into a powder once again using the mortar and pestle grinding method described in step two.

13) Repeat steps three through five to recreate your tablet.

14) For the third and final heating, set the furnace to increase 3 degrees celsius per minute until it reaches 960 degrees celsius where it will heat for 12 hours. Set the furnace to decrease at a rate of 0.5 degrees celsius per minute to cool the tablet down after the 12 hour heating to 30 degrees celsius.
15) Remove your tablet from the furnace, it should still be black.

16) Your superconductor is now ready to be test!