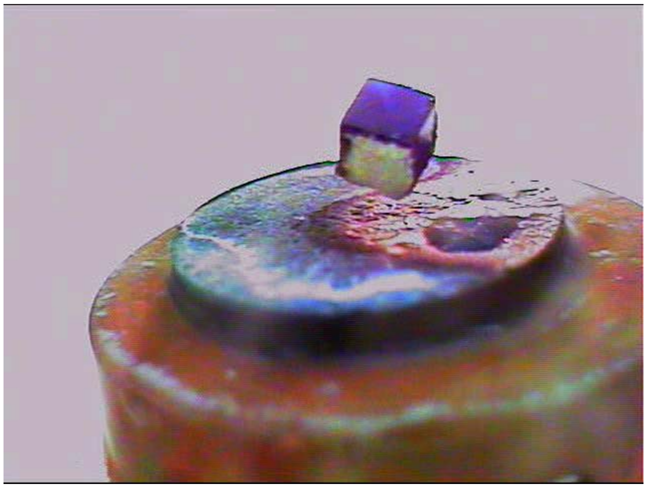
Question #355

It's been a while since our last electromagnetic adventure, and hope the few weeks in between have provided enough time to have your batteries recharged (no pun intended). This week we explore the phenomena of magnetic levitation in the realm of a superconductor. Since the topic may be foggy for many people (pun intended this time), click here to hide further explanation on the topic.

About Magnetic Levitation

Magnetic levitation can be achieved either one of two ways. The naive approach (and I say that from experience) is to take two magnets and attempt to balance them with like poles repelling each other. As anyone who has tried this knows, the magnets never balance quite completely and the attempt is rather futile. This can be slightly improved upon by using a gyroscope to balance to the hovering magnet, as is done in the popular *Levitron*--though this too is rather finicky and frustrating at moments. The bottom line is such contraptions are inherently unstable, and the unstable equilibrium of such approaches is summarized mathematically by Earnshaw's Theorem.

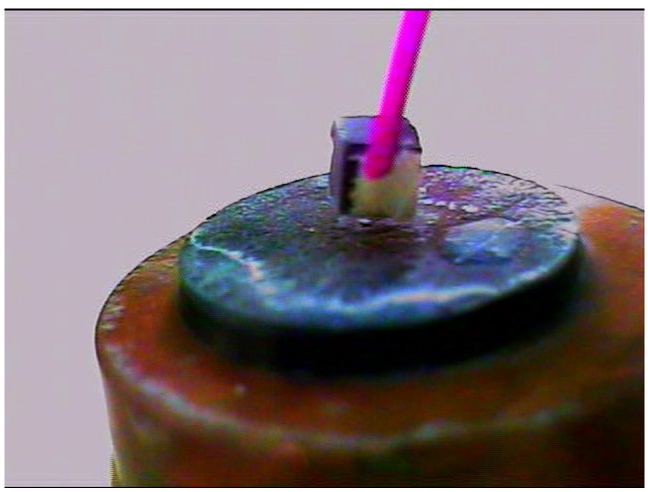
The second and better way to go is to *induce* an electromagnet that will repel the physical magnet instead. This is achieved through magnetic induction: as a magnet is lowered towards a conductor eddy currents are induced according to Faraday's and Lenz's Law to repel the magnet being lowered. Why might this way be more stable you ask? The induced electromagnet effectively allows for more "degrees of freedom" as the eddies are induced in all directions, in just the right way to repel the magnet. In short, Nature does the work and she always does it perfectly.



Alternate high-res version.

Magnetic levitation is not confined to superconductors and can be achieved, for brief moments of time, even with highly cooled, non-superconducting materials such as copper. The eddy currents induced under normal circumstances however die out quickly as a result of the electrical resistance present within all conductors (like aluminum, copper, gold, etc). However in a superconductor--a material in which there is zero (yes, exactly zero) electrical resistance--these currents *persist* and continue to levitate the magnet perpetually. These persistent currents allow the electromagnet to push on the physical magnet indefinitely, and thus are the critical advantage to magnetic levitation using superconductors.

A copper stand is bathed in a sea of liquid nitrogen, supporting a curious, black disc of Yttrium Barium Copper Oxide (YBCO). The copper being an excellent conductor, chills the YBCO that rests above it to liquid nitrogen temperatures while safely keeping it from being submerged in the liquid. YBCO, a manmade superconducting material discovered in 1987, is unique among its kind due to its relatively high superconducting-transition temperature of 93 K; though that is *still* colder than our South Pole, temperature is "high" enough for scientists! YBCO's high transition temperature saves scientists the trouble of procuring ~~unwieldy~~ novel methods to study superconductivity, and instead enables them to use the readily available supply of liquid nitrogen, whose boiling point is mere 77 K in comparison.



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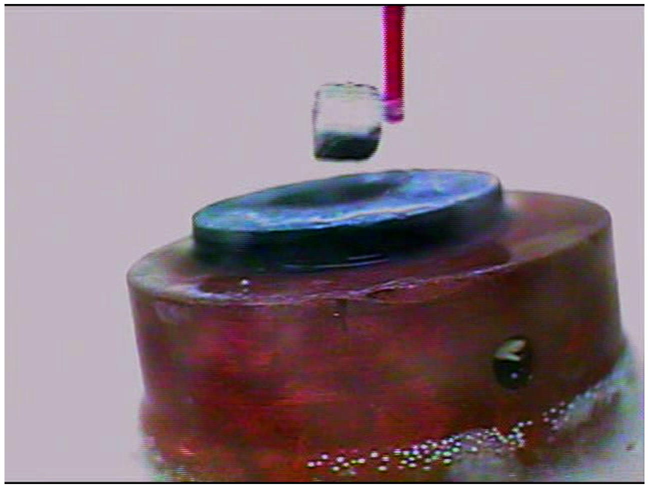
A levitating magnet is surely fun in its own right, but sadly does not make an interesting question. A non-conducting piece of plastic is used to give the magnet a small torque allowing it to spin freely in midair, as can be seen in the video above. Two pieces of white tape are used to mark the direction of rotation.

The question: What would happen instead if the levitating magnet were given a torque along the other axis of rotation?



- (a) Of course the magnet will spin!
- (b) Of course the magnet won't spin!

You must, of course, explain your answer to the best of your ability using physics laws and ideas.

Click here for Answer #355 after November 2, 2009.

Question of the Week

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For questions and comments regarding the *Question of the Week* contact
Dr. Richard E. Berg by e-mail or using phone number or regular mail address
given on the Lecture-Demonstration Home Page.