Measuring the Earth's Magnetic Field

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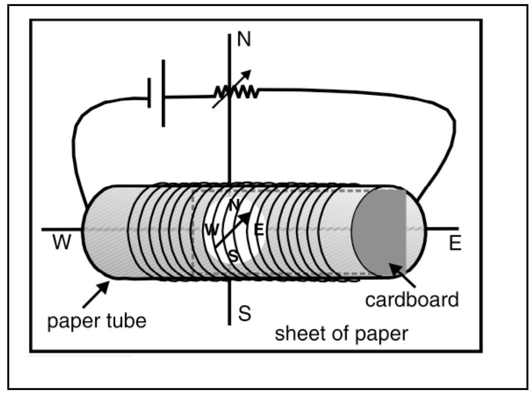
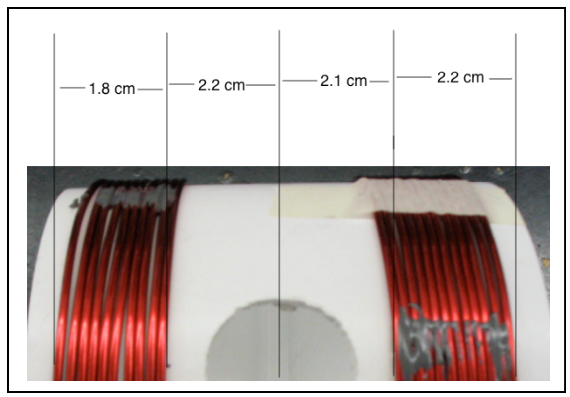


This uses a gizmo I had my students build last fall, trying to improve a bit over the "coils wrapped on a toilet paper tube" we used down in Arkansas where I learned of this from Gay Stewart (see "Measuring the Earth's Magnetic Field Simply" in the Feb 2000 issue of *The Physics Teacher*). The idea is to create an adjustable B field that adds vectorially to the earth's field and use an ordinary compass to detect when the magnitudes of the two fields are equal.

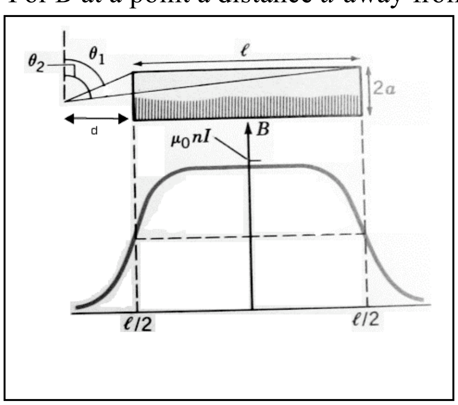
That contraption was cheap, but it was so small you could only fit a miniature compass inside the thing, and those cheap tiny compass needles always want to stick, it seems, making measurements a pain. Also, I learned from playing with magnetism simulations written in VPython that using an oversimplified model of the B field produced by your coil apparatus is a major source of error.

When the students down in Arkansas wrapped their coil around the toilet paper tube, they skipped over the middle part where they had made a hole to view the compass. But they used the uniform infinite coil formula to compute the field. It turns out the missing *middle* part of the coil is the big source of error because it is the part of the coil closest to the compass.



So we made a bigger apparatus to accommodate a larger compass inside and two coils on the sides of the central viewing hole. The plastic tube was something (a dryer vent coupler??) I found at Home Depot—it was cheap, but the nylon screws I used to hold the coils in place were expensive and didn't really do the job. I think nylon cable ties would be better.

The correct formula for the B field due to each of the coils is $B = \frac{1}{2}\mu_0 nI(\sin\theta_2 - \sin\theta_1)$, where n represents the number of turns per unit length of the coil—it's how many wraps divided by the length of the chunk of tube they occupy. I is the current flowing through the coil. For B at a point a distance d away from the left end of a coil of length l, the angles are defined in this picture—



You *don't* need to actually measure the angles for the device, because the *sines* of the angles can be found directly from the "opp/hyp" ratio of lengths on the diagram. You need to remember to use the coil formula *twice* and add the B values together since there are two coils.

My students had great difficulty deciphering the geometry and how to put all the pieces together to generate the numbers to put into the B expression for each coil. A lot of time got used up chasing calculation errors. Next time I do this I think the geometry should all be done ahead of time and in lab we should focus on having different groups measure the field in exactly the same location to see how closely different groups' results agree.

For standard B values for our location on earth, look here:
http://www.ngdc.noaa.gov/seg/geomag/jsp/IGRF.jsp