Part 1 – Estimating the bound current in a magnet

You know that currents create magnetic fields, but how *much* current does it take? You now have all the tools to estimate the bound current of an everyday toy magnet. The first part of this tutorial will guide you through an experiment to estimate the bound current within an ordinary toy magnet.

i. A compass needle is a magnet, and the arrow represents its north pole. If the compass needle is attracted towards the Earth as shown in Figure 1, label the magnetic poles of the Earth. Label them ("N" or "S").

ii. Which direction is the current flowing inside the Earth? Label it with arrows.

iii. If the compass needle deflects as shown in Figure 2, which pole of the toy magnet is closer to the compass? Label it ("N" or "S").

iv. Which direction is current flowing on/in the toy magnet? Label it with arrows.

Figure 1

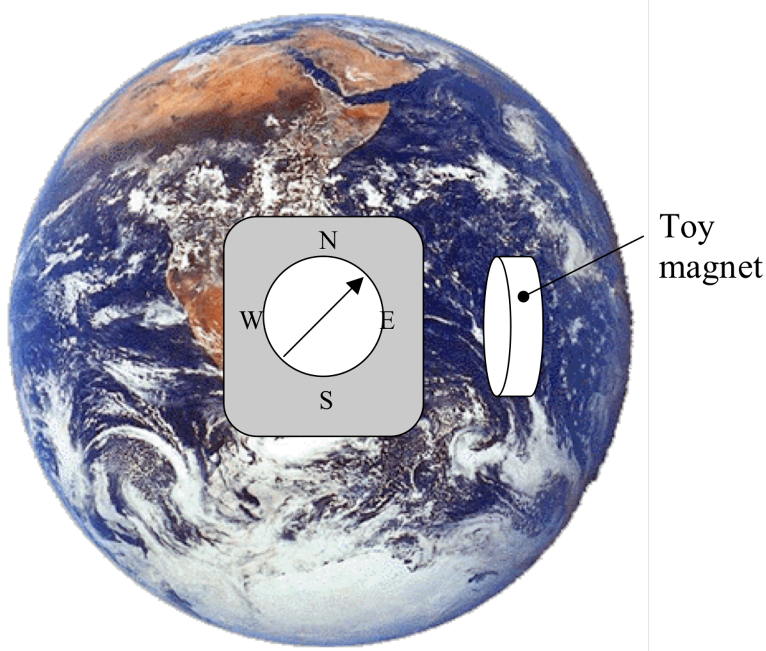

Figure 2

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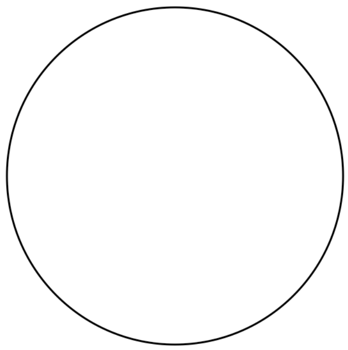
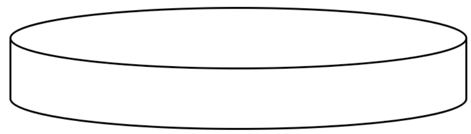
iv. Before you start estimating the bound currents of the toy magnet, do you expect there to be a bound surface current, bound volume current, or both? Sketch the atomic currents in the magnet to illustrate your claim.



Top view of magnet



perspective view of magnet

iv. With your compass and toy magnet (and the earth) oriented as shown in Figure 2, estimate the magnetic dipole, **m**. You should use a meter stick. The following information may be useful:

$$\mathbf{B}_{dip}(r) = \frac{\mu_o m}{4\pi \cdot r^3}(2\cos\theta \cdot \hat{r} + \sin\theta \cdot \hat{\theta}) \qquad \mu_o = 4\pi \times 10^{-7}\frac{T \cdot m}{A}$$

Earth's magnetic field is about 5E-5 T.

v. Now you can find **M**, the magnetic dipole moment per unit volume.

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vi. In another step or two, you will have an estimate for the bound current, $\mathbf{I}_b$.
Potentially useful equations: $\mathbf{J}_b = \nabla \times \mathbf{M}$; $\mathbf{K}_b = \mathbf{M} \times \hat{n}$

vii. You have just estimated the bound current in/on a magnet, but is there *really* a current going around the magnet? i.e. Does an electron make a lap around the whole magnet?

viii. Do you think that the bound current is an effect of electron "orbital current" or electron "spin current?"

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Part 2 – Magnet Demos

Demo #1: Push me a grape

i. When we bring the magnet close to the grape, the magnetic flux in and around the grape is changing. Does magnetism, Lenz's law, or a combination of both, cause the observed effect? (PHYS1120 refresher: Lenz's law says that a current is induced that opposes changing magnetic flux.) How could you experimentally test your answer?

ii. What type of magnet is the grape?

iii. What is going on atomically inside the grape? (electron spin and orbit, bound currents, magnetic field lines, etc.)

Demo #2: Superconductor levitation

i. Why does the material only superconduct at very low temperature?

ii. If what's levitated is a small permanent magnet, what type of magnet is the superconductor?

iii. If we turn the superconductor upside-down, will the permanent magnet "hover" underneath the superconductor?

iv. If we replaced the superconductor with a very powerful magnet (a HUGE solenoid), would the small permanent magnet still levitate?

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