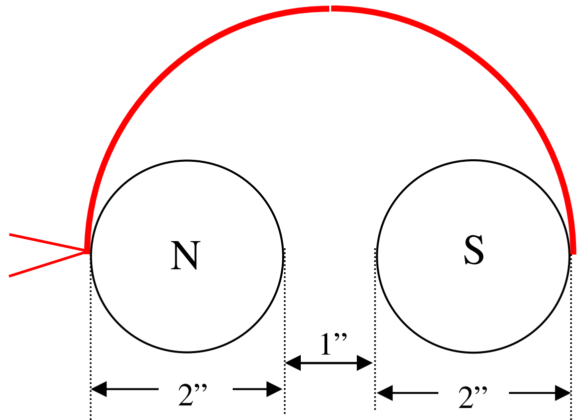
Experiments for Discovering Longitudinal Induction

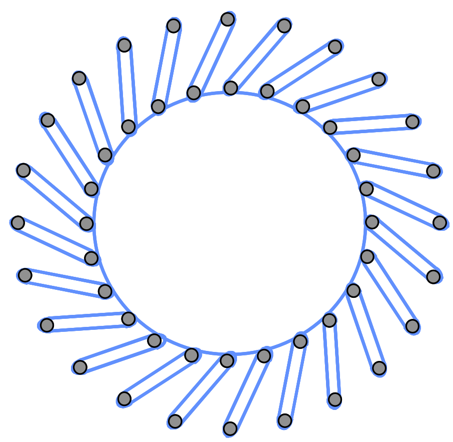
1. Distinti style set-up using two magnets

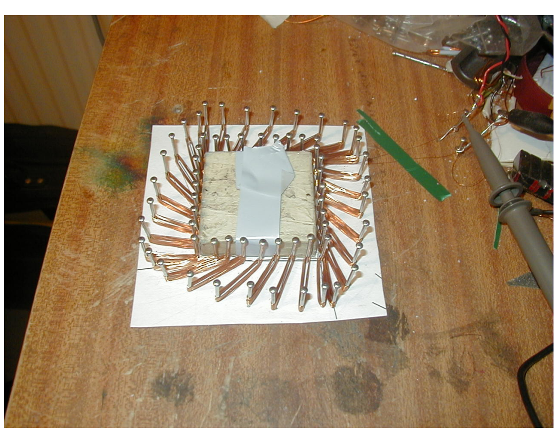
The two NdFe magnets could be placed close to each other, and a half turn fixed "slip-ring" placed as shown. This half circle can have many wires threading back and forth on it. The expected resistance change, expressed as a normalised percentage, is independent of the current and of the wire gauge (see Appendix). The average $\delta A_x/\delta x$ over the semi circle is found to be 0.075 weber/m^2, obtained from a spreadsheet simulation of the **A** field. In this simulation an average **B** of 0.357 Tesla was used in the magnets. This value was obtained from an FEMM simulation of the 37MGO magnet (note this is much lower than the $\mathbf{B_R}$ of the basic material because of the demagnetisation factor present in such short magnets.) The **A** field produced in the spreadsheet agrees quite well with point measurements of the **A** field in FEMM. In this experiment with two magnets, the mean value for $\delta A_x/\delta x$ of 0.075 weber/m^2, using equation (9) from the appendix, gives $\Delta R/R_0$=0.0321%. This could be measured with a precision bridge. The wire gauge and the number of "turns" is left to the experimenter, choose that which allows the measuring instrument to operate within range.



2. Single magnet experiment

This experiment exploits the **A** field close to the magnet, where $\delta A/\delta x$ is a maximum. There is maximum longitudinal induction when the conductor is at 45° to the radial vector. Thus a series of correctly inclined elongated coils placed around the magnet should intercept this $\delta A/\delta x$. Taking coils which are about 1 inch long we get a mean $\delta A/\delta x$ of about 0.1 weber/m^2. This should give $\Delta R/R_0$=0.0428%.





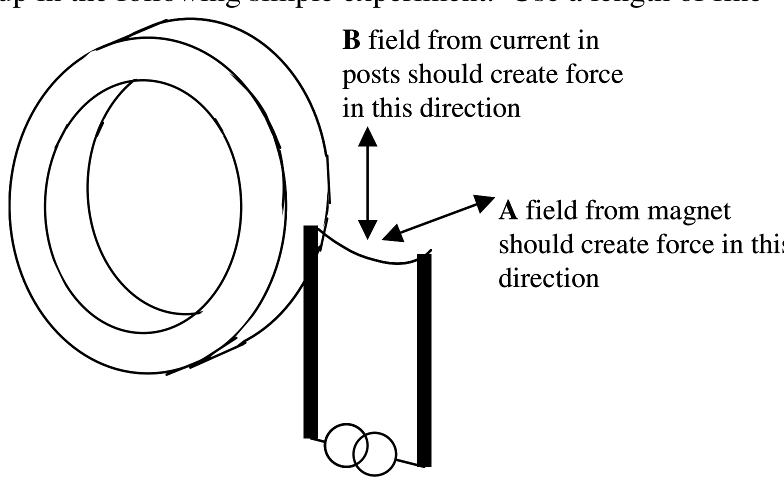
The photograph shows my attempt at this experiment using a 2 inch square magnet. Each elongated coil has about 20 turns, and there are 32 in total. They are wound using 0.224mm dia. Wire and are all connected in series. Experiments using a bench power supply in current limit mode have just now given a positive result. With a current of about 0.35A the voltage is about 8.5 volts (i.e. a resistance value of about 24Ω), using analogue panel meters. The DC voltage was fed to a ‘scope via a series battery so as to back off the DC level, then filtered to get rid of stray AC pick-up. With the ‘scope set to its maximum sensitivity of 1mV per cm, it was just possible to discern a DC voltage change of about 0.1mV between magnet present and magnet absent. This measurement was difficult to perform as there was still some HF noise present making the scope trace appear as a 0.2cm thick line, and there was slow DC drift. However after repeated observation there was no doubt that this change really did occur. It represents a resistance change of 0.0012%, about 1/40 of the value predicted by the theory. However the state of my NdFe magnet is unknown, it has been used to reverse magnetize small ceramic magnets which would result in loss of energy.

3. Using Ceramic Magnets

Experiments similar to the ones suggested above could be performed.

4. Using Dave’s Ring Magnet

In the single magnet experiment the 45 degree orientation gives max longitudinal $\delta A/\delta l$. This $\delta A/\delta l$ comes from a component of the transverse $\delta A_x/\delta y$ that occurs from radial δy movement through the **A** field. This transverse force ought to show up in the following simple experiment. Use a length of fine wire loosely supported between two fixed posts. These posts could also be the conductors which carry the DC current needed. View the wire using a telescope or similar optical magnifier to look for a change of position when there is a magnetic force on the wire. Clearly placing this current carrying wire in a B field will create an observable displacement. The experiment places the wire in a non-uniform A field where there is no B. Such a field is found outside a magnetized ring. The wire must be radial to the core, as shown in the figure. The current flowing in the posts will create their own **B** field to influence the wire movement, which will be an outward movement in the direction shown. With the ring magnet present it’s non uniform **A** field should yield a transverse force along the **A** field lines. This should be discernible.



Resistance Change in Ring Magnet Experiment

Take a conductor of length l and cross section area a_S laying along a longitudinal **A** field, pointing in the x direction. Let the **A** field have a constant $\delta A/\delta x$ along it. If the electron drift velocity is v_D, we can expect an induced voltage V_I

$$V_I = -v_D l\left(\frac{\delta A_x}{dx}\right) \tag{1}$$

We can relate the drift velocity to current I and volume density of mobile charge Q_v from

$$I = \frac{\delta q}{\delta t} = Q_v a_S v_D \tag{2}$$

giving

$$V_I = -\frac{I}{Q_v a_S} l\left(\frac{\delta A_x}{dx}\right) \tag{3}$$

The external voltage we would normally apply to the conductor to get the current I is equal to the voltage drop V_D

$$V_D = IR_0 = \frac{Il}{\sigma a_S} \tag{4}$$

where σ is the conductivity of the conductor material (5.8×10^7 for copper) and R_0 is its normal resistance.

Because of the induced voltage V_I, the actual voltage we have to supply is

$$V = V_D + V_I = \left(\frac{Il}{\sigma a_S} - \frac{Il}{Q_v a_S}\left(\frac{\delta A_x}{\delta x}\right)\right) \tag{5}$$

Thus the resistance R takes on a new value

$$R = \frac{V}{I} = R_0\left(1 - \frac{\sigma}{Q_v}\left(\frac{\delta A_x}{\delta x}\right)\right) \tag{6}$$

Thus the change in R value due to the presence of the non-uniform **A** field is

$$\frac{\Delta R}{R_0} = \frac{\sigma}{Q_v}\left(\frac{\delta A_x}{\delta x}\right)\times 100\% \tag{7}$$

Volume charge density can be estimated assuming one free electron per atom as

$$Q_v = \frac{N_A \rho e}{W_A} \tag{8}$$

where N_A is Avogadro's number (6.025×10^{26} atoms per Kmole), ρ is the material density (for copper ρ=8920 Kg/m^3), e is the electron charge (1.602×10^{-19} Coulombs) and W_A is the atomic weight (for copper 63.54 Kg per Kmole). For copper we get a value of $Q_v=1.355\times10^{10}$ Coulomb/m^3.

We can eliminate Q_v from (7) giving

$$\frac{\Delta R}{R_0} = \frac{\sigma W_A}{N_A \rho e}\left(\frac{\delta A_x}{\delta x}\right)\times 100\% \tag{9}$$

Note that this percentage change is independent of the current and the conductor dimensions.