Magnetic Battery Considerations.

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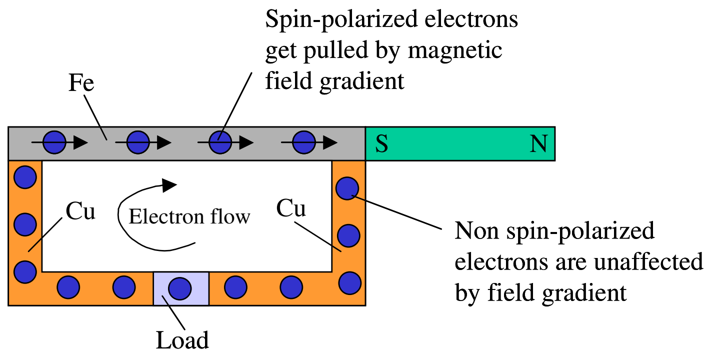

Figure 1. A Magnetic Battery

Figure 1 shows the possibility for a magnetic battery. An asymmetric magnetic field is applied to an iron rod by a permanent magnet close to one end of the rod. The conduction electrons become spin-polarized by the field and then get pulled along by magnetic force caused by the field gradient. They get attracted to the maximum field point. There they pass into a copper conductor where the spin polarization is lost. Thus they are able to return through the copper to the other end of the rod, unaffected by the field gradient. This perpetual current flow can then deliver power to a series connected load. *However a word of warning, there is a characteristic of the electro-chemical potential across junctions between dissimilar metals known as the magneto-Seebeck effect. The Seebeck coefficient is affected by a magnetic field, and it is possible (likely?) that the Cu-Fe junction at the low B field end will have a different voltage to the Fe-Cu junction at the high B field point which would nullify the magnetic battery effect.* However if this perpetual current is found to exist in reality, the question to be asked is where does the energy come from? It is instructive to consider forms of motor which utilize the same principles, and examine their energy sources.

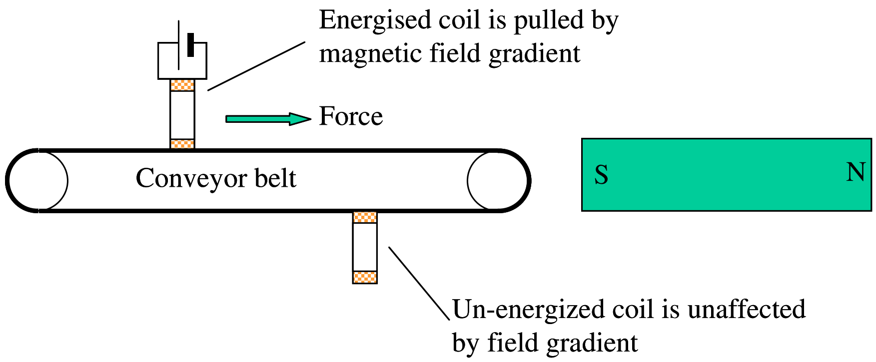

Figure 2. Conveyor Belt Motor

Figure 2 shows an electric motor which, although being impracticable, is nevertheless entirely feasible. Coils are mounted onto a moving conveyor belt which is placed in a magnetic field gradient. The coils are energized at the position of minimum magnetic field, then de-energised when they reach the maximum field position. The energized coils endure a linear magnetic force pulling them towards the higher field point, thus providing the motive power for this motor. Ignoring copper losses in the coils, the inductive energy put into each coil when energized can be recouped when de-energized. Clearly this motor can do useful work, so where does the input power come from? The answer to that can be found in the energizing source needed to maintain the current in the coil *while it is passing through the field gradient*. The changing field will induce a voltage in the coil of a polarity which will draw energy from the source. Calculations will show that this electrical power input exactly accounts for the mechanical power output.

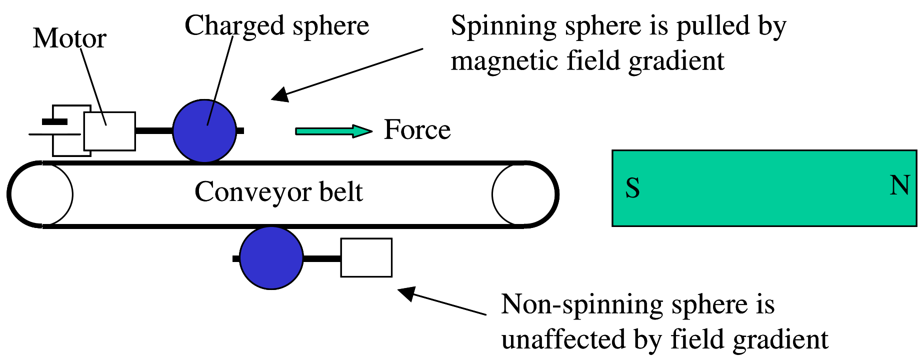

Figure 3. Alternative Conveyor Belt Motor.

Figure 3 illustrates a variation on the conveyor belt motor. Electrically charged spheres are spun by motors. The spinning charge acts like a small magnet and is pulled along by the magnetic field gradient. On the return journey the spin motor is turned off. Analysis of this machine shows that the work done is supplied by the spin motor; movement through the field gradient creates a circular E field as seen by the charged sphere, and that E field imparts a torque on the sphere which loads the spin motor. The analogy to the magnetic battery of Figure 1 is now clearly seen, the charged sphere represents an electron. With that in mind, we can now apply the energy audit to the magnetic battery. Considering each conduction electron as a current loop or a spinning charged sphere, the power is drawn from whatever drives that circulatory charge movement. The space properties which maintain the perpetual spinning of electrons supplies the power to force the electrons through the load. *We have discovered a method of extracting energy from space where we can pinpoint exactly where that space connection is made.*

Taking the magnetic dipole moment of the conduction electron as μ_B (the Bohr magneton), if it is 100% aligned with the applied field (say in the x direction) the force F_x on it is given by

$$F_x = \mu_B \frac{dB_x}{dx} \qquad (1)$$

Integrating this force along x yields the energy U gained as

$$U = \mu_B \cdot \Delta B_x \qquad (2)$$

where ΔB_x is the change in B_x over the working length. If we transport a bulk charge Q the energy gained is

$$U = \frac{Q}{e}\mu_B \cdot \Delta B_x \qquad (3)$$

where e is the electron charge. If the bulk charge Q is transported at a rate of I amps then the power P gained is

$$P = \frac{I}{e}\mu_B \cdot \Delta B_x \qquad (4).$$

Equation (4) tells us that we can access free space energy at the rate of 57.88µW per Amp per Tesla. A current of 1 amp of spin polarized electrons passing through a 1T gradient will deliver 57.88µwatts of free power. Note that the length along which the current flows is not material, the 1T gradient can occur over a kilometre, a millimetre or a micron. Clearly the shorter length is preferred, and this opens up the possibility of having magnetic battery "cells" in series. Unfortunately the voltage of each cell is extremely small, so we need many cells to get useful voltage. The effective electric field E to produce the force F in (1) is

$$E = \frac{\mu_B}{e}\frac{dB_x}{dx} \qquad (5)$$

which integrated over the working length gives a voltage V of

$$V = \frac{\mu_B}{e}\Delta B_x \qquad (6).$$

This is a voltage of only 57.88µV per Tesla.

One way to create a magnetic field gradient within ferromagnetic material is by choice of geometry. A tapered geometry will concentrate the internal field, and that feature can be put to good use to create small cells. Small triangular shaped ferromagnetic (e.g. Fe) flux concentrators can be deposited onto a substrate, and connected in series using non-ferrous (e.g. Cu) conducting deposits. When supplied with a magnetic field from an external permanent magnet, and with appropriate spacing between the ferromagnetic triangles, each one will act like a magnetic battery cell. It is possible to conceive of large numbers of such miniature cells connected in series so as to generate useful output voltage. Figure 4 shows the FEMM result for an array of supermalloy flux concentrators between a pair of NdFe slabs (the slabs are just outside the picture.

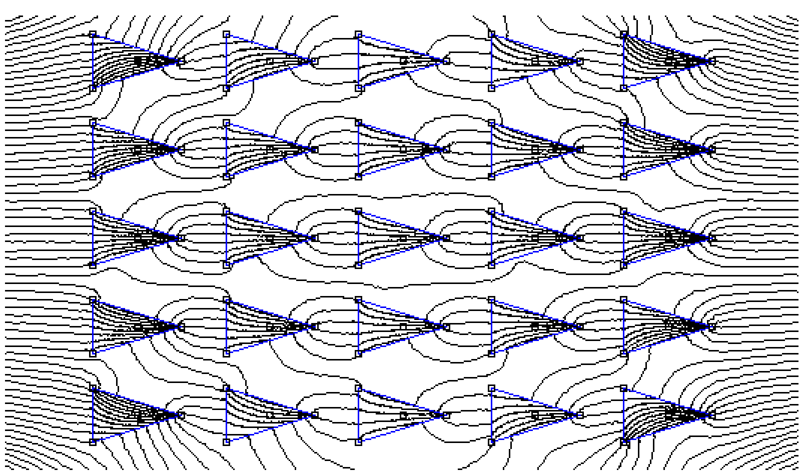

Figure 4. Showing Flux-concentration Gradients

Figure 5 illustrates the electrical connections between the flux concentrators.

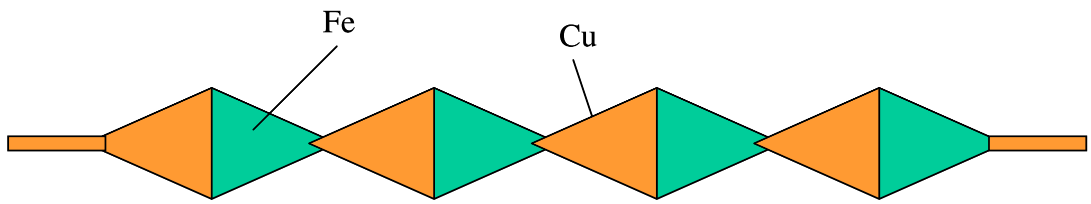

Figure 5. Electrical Connections

A variation on this scheme is to supply each flux concentrator with its own local deposited PM material. The conduction direction is not then determined by the external field but can meander across the surface of the substrate. Figure 6 shows an FEMM result for a small portion of such a scheme, where the rectangles are the individual PM's (copper interconnections not shown).

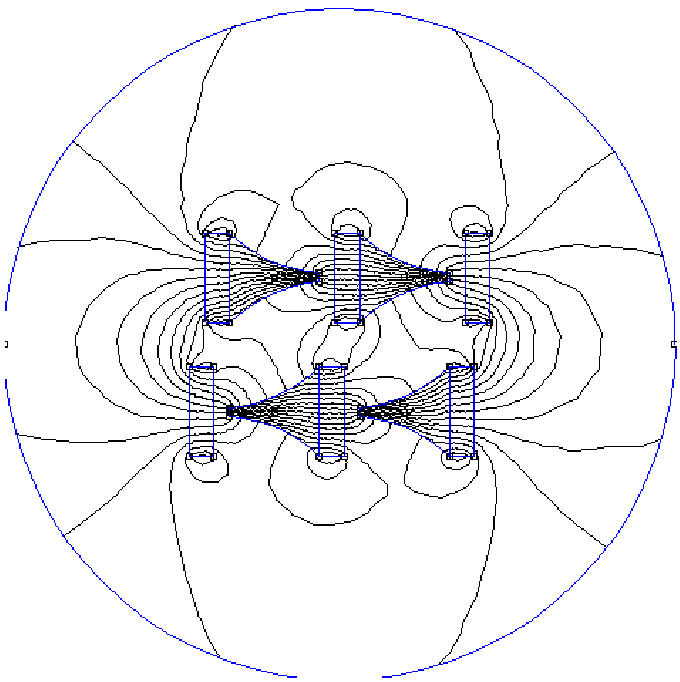

Figure 6. PM Flux Concentrators

Depositing PM material in this form yields the maximum flux gradient per cell, and the cells can be micro-size, although this limits the current available from the cell. A 160×160 array of series connected cells will produce in the region of 1.5V. Arrays could be stacked and paralleled to provide greater current capacity.