University of Kentucky Department of Physics

Prelab 7: Floating Wire

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Problem 1

Two long straight parallel wires that are carrying identical current I. Following your book or lectures notes, **derive** the magnetic forces $\mathbf{F_B}$ between these wires using the equation for the magnetic force on a wire and the magnetic field $\mathbf{B}$ from a long straight wire.

- Consider wires 1 and 2 with identical current I which we suppose are in the same direction. Magnetic field $\mathbf{B}$ at wire 1 from current in wire 2 is

$$B = \frac{\mu_0 I}{2\pi R} \tag{1.1}$$

  where $\mu_0 = 4\pi \times 10^{-7}$ is constant of magnetic permeability and R is the displacement from the source of the $\mathbf{B}$ field.

- Using $\mathbf{F} = i\ell \times \mathbf{B}$ where ℓ is the length of the wire 1 felt from the current I in wire 2

$$|\mathbf{F}| = |I\ell \times \mathbf{B}| = I\ell B = I\ell \left(\frac{\mu_0 I}{2\pi R}\right) = \frac{\mu_0 I^2 \ell}{2\pi R} \tag{1.2}$$

- Then the magnitude of force on wire 1 from wire 2 per unit length ℓ $F_{1,2}$ is the same as the force on wire 2 on wire 1: $\frac{F_{1,2}}{\ell} = \frac{F_{2,1}}{\ell} = \frac{\mu_0 I^2}{2\pi R}$

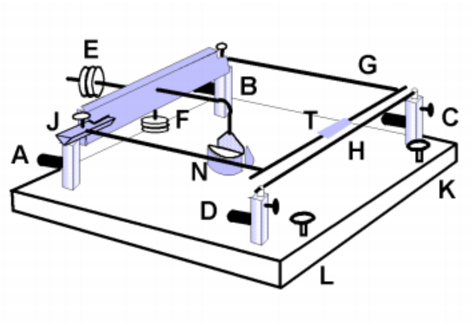
- Then the sum of the forces is

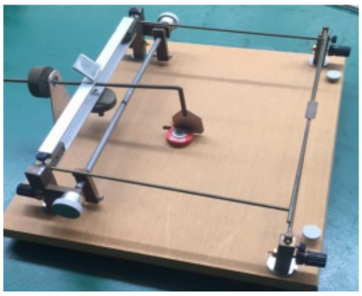
$$\sum \mathbf{F} = F_{1,2}\hat{\mathbf{i}} + F_{2,1}(-1)\hat{\mathbf{i}} \tag{1.3}$$

These forces are attractive and are equal in magnitude, and cancel ($\sum \mathbf{F} = 0$) when $R = \frac{d}{2}$ where d is the displacement between the two wires.

Problem 2

What is the goal of the alignment in steps 1-9? What are you looking for in step 10 to “make sure the equiptment is aligned properly”?



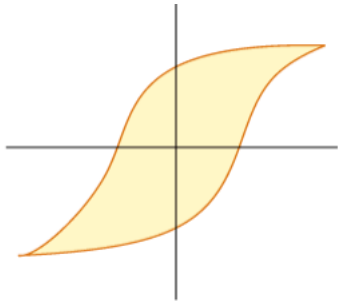


- Rotating E in Fig to change alignment ∵ this changes moment because of the mass at F.

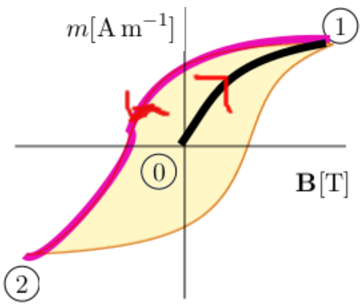
- “Proper alignment” means to balance the frame H by giving it different moments, such that the gravitational force $\mathbf{F}_g$ is equal in mag. and dir with the magnetic forces $\mathbf{F}_B$, where $F_g = 9.18\,\mathrm{m\,s^{-2}}$ and F_B is as given in problem 1 of this sheet (but with currents in each wire, spaced very closely together, running in opposite directions so they combine in magnitude).

Problem 3

Magnetic Hysteresis is a concept which states that magnetic properties of ferromagnets depend on the current external magnetic field **and** the history of that external field. Do a little research to explain the famous curve below in the context of your experimental work in Lab 6.



- The x-axis of the figure is the **B**-field and y-axis is the **magnetization** of the object. Hence the origin represents 0 magnetic field and 0 magetization **m**.
- Suppose we have a ferromagnetic bar as in Lab 6 which is not magnetized and for which no external field $\mathbf{B}_{ext}$ is applied. Then its magnetization is $\mathbf{m} = 0$.
- This is because its domains are randomly aligned and hence the internal B fields within the bar cancel.
- We next apply an external magnetic field B_{ext}. This causes the domains of the ferromagnet to become aligned, and we go from 0 to 1 in the figure below and the magnetization is now non-zero.



- Suppose we shake/vibrate the bar as in Lab 6. Then the magnetic domains within the bar once again become unaligned.
- This is where Hysteresis comes in: instead of doing so in a 1 to 0 path, the bar losses its demagnetization in from 1 to the path leading to 2 (put stopping at the y-axis, not going all the way to 2). The bar essentially has **memory** of its magnetization, so the manner which it becomes magnetized/demagnetized depends on it's previous state on the $\mathbf{B}-\mathbf{m}$ graph.