University of Kentucky Department of Physics

Lab 7: Floating Wire

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1 Introduction

The purpose of this experiment is to determine the value of the **magnetic permeability of free space** μ_0, which is the measure of the ability of free space to support the formation of a magnetic field $\mathbf{B}$ within itself. The **exact** value[1] of μ_0 is $4\pi \times 10^{-7}\,\mathrm{N\,A^{-2}}$. We experimentally estimate this value by means of the following "floating wire experiment": two wires held within a small distance d from each other, though which an identical electric current I passes. This creates an **induced** magnetic field $\mathbf{B}_{\text{ind}}$ in both wires, and a concomitant magnetic force $\mathbf{F_B}$. We adjust the current such that the induced $\mathbf{F_B}$ balances with gravitational force $\mathbf{F}_g$. Hence by writing Newton's second law $\sum \mathbf{F}_{\text{net}} = 0$ for the force balance, we may solve in closed form for μ_0.

Problem 20
Explain how group ariived at calculation of μ_0 Start your argument with newtons second law and include your solution to prelab question 2

2 Data Analysis

	Trial1	Trial2	Trial3	Trial4	Trial5
Weight[mg]	10	20	50	70	100
Amps [A]	6.5	8	10	12	14
Space [mm]	6.22	6.08	5.7	5.45	5.1
$\mu_0[\mathrm{N\,A^{-2}}]$	3.4×10^{-7}	4.4×10^{-7}	6.6×10^{-7}	6.1×10^{-7}	6.0×10^{-7}

$$F_{\text{net}} = \sum F = \left(\frac{\mu_0 i^2 L}{2\pi r} - mg\right) \Rightarrow \left(\frac{\mu_0 i^2 L}{2\pi r} - mg\right) = 0 \tag{2.1}$$

$$\Rightarrow \mu_0 = \frac{(mg)(2\pi r)}{i^2 L} \tag{2.2}$$

2.1 Calculation of Uncertainty $\delta\mu_0$

1. $\mu_0 = \frac{(mg)(2\pi r)}{i^2 L}$
2. $\bar{\mu}_0 = \frac{3.4\times10^{-7} + 4.4\times10^{-7} + 6.6\times10^{-7} + 6.0\times10^{-7}}{4} = 6.62 \times 10^{-7}$
3. $\bar{r} = \frac{6.22+6.08+5.7+5.45+5.1}{5} = 5.71\,\mathrm{m}$
4. $\delta r_1 = 0.05\,\mathrm{mm}$
5. To find δr_2, we refer to the figure below.

   5.1. $\frac{\delta_{\text{laser}}}{L_{\text{mirror to clipboard}}} = \tan 2\theta \Rightarrow \frac{6.22\,\mathrm{mm}}{2060\,\mathrm{mm}} = \tan 2\theta \approx 2\theta$
   5.2. $\theta = \frac{1}{2}\frac{6.22\,\mathrm{mm}}{2060\,\mathrm{mm}} = 1.5 \times 10^{-3}$
   5.3. $\frac{\delta r_2}{L_{\text{fulcrum to wire}}} = \tan\theta \approx \theta$
   5.4. $L_{\text{fulcrum to wire}} \tan\theta = \delta r_2$
   5.5. $\delta r_2 = (215\,\mathrm{mm})(1.5 \times 10^{-3}) = 0.3225\,\mathrm{mm}$
6. Thus $\delta r = \delta r_1 + \delta r_2 = (0.05 + 0.3225)\,\mathrm{mm} = 0.3725\,\mathrm{mm}$
7. $\bar{i} = \frac{6.66+8.16+10.16+12.16+14.16}{5} = 10.26\,\mathrm{A}$
8. $$\begin{aligned}\delta\mu_0 &= \bar{\mu}_0\left(\frac{\delta r}{\bar{r}} + \frac{\delta i}{\bar{i}} + \frac{\delta l}{\bar{l}}\right) \\ &= 6.62 \times 10^{-7}\left(\frac{.37}{5.71} + \frac{0.05}{10.26} + \frac{0.05}{26.6}\right) \\ &= 1.45 \times 10^{-9}\,\mathrm{N\,A^{-2}}\end{aligned}$$
9. Then $\mu_0 = \left(1.45 \times 10^{-9} \pm 1.27 \times 10^{-9}\right)\mathrm{N\,A^{-2}}$[2]

3 Procedure

4 Conclusion

Problem 21
Your graphic must provide a visual representation of your final results so the ta can assess your data quickly. make sure you include the scientifically accepted value of μ_0 in your graph

Problem 22
make sure you report on your final results in the form $\mu_0 = \bar{\mu}_0 \pm \delta\mu_0$.

Problem 23
What is the largest source of error in this experiment? Is it random or systematic? Could this error account for the discrepancy between your value and the scientifically accepted value?

Largest source of error is measurement of r, the distance between the wires. This is a fine measurement which blahblah...

Problem 24
Remember that the report should be two pages or less and follow the guidelines.

[1] Source:
[2] This answers Problem 22