Jul 28th, 11:00 AM - 1:30 PM

Investigation of a Magnet Falling Through a Copper Pipe

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Introduction

- The goal of this research is to explore the effects of wall thickness and temperature on the rate at which a magnet falls through a copper pipe.
- A magnet is not attracted to copper. Copper is not magnetic; however, it is a great conductor of electricity.
- Due to Faraday's law and Lenz's law, we know that a changing magnetic flux will produce an electric current that opposes the change in magnetic flux that produced it. These laws together explain why a magnet will fall slowly in a copper pipe even though it is not attracted.

Motivation

- We are interested in the factors that affect the rate at which a magnet falls through a electrically conductive pipe.
- We are interested in how well the existing theory describes the actual fall of a magnet through a conductive pipe.

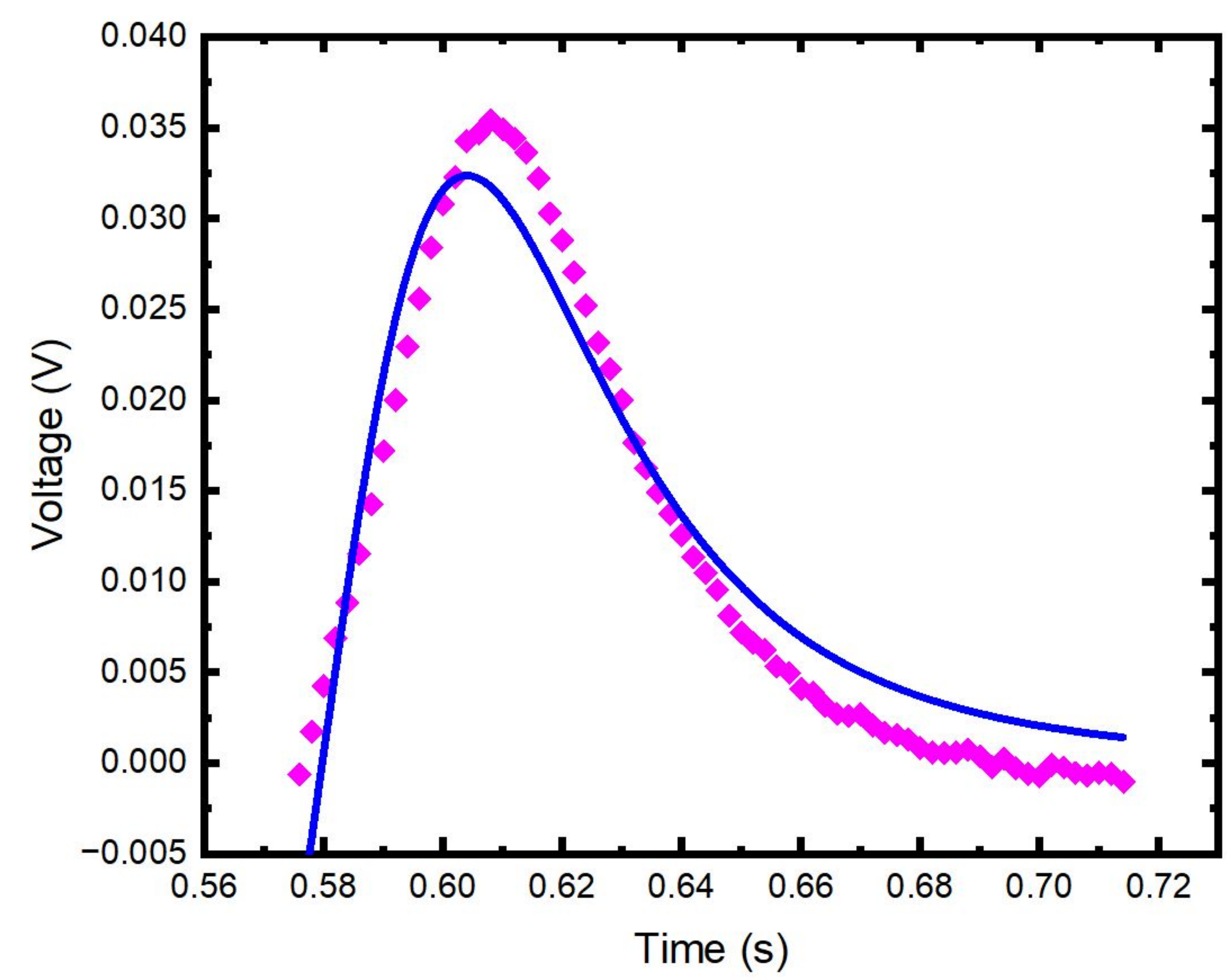
Methods

- We used two copper pipes: 1.89 mm & 1.04 mm thickness.
- We used two stacked magnets with total mass of 25.4 g and dimensions of 12.68 mm x 25.42 mm.
- We wrapped two coils identically to fit around the middle of the copper pipe; held the pipe with a ring stand and clamps, and connected the coils to a voltmeter.
- To cool the pipe, we placed liquid nitrogen in a styrofoam cup below the coils.

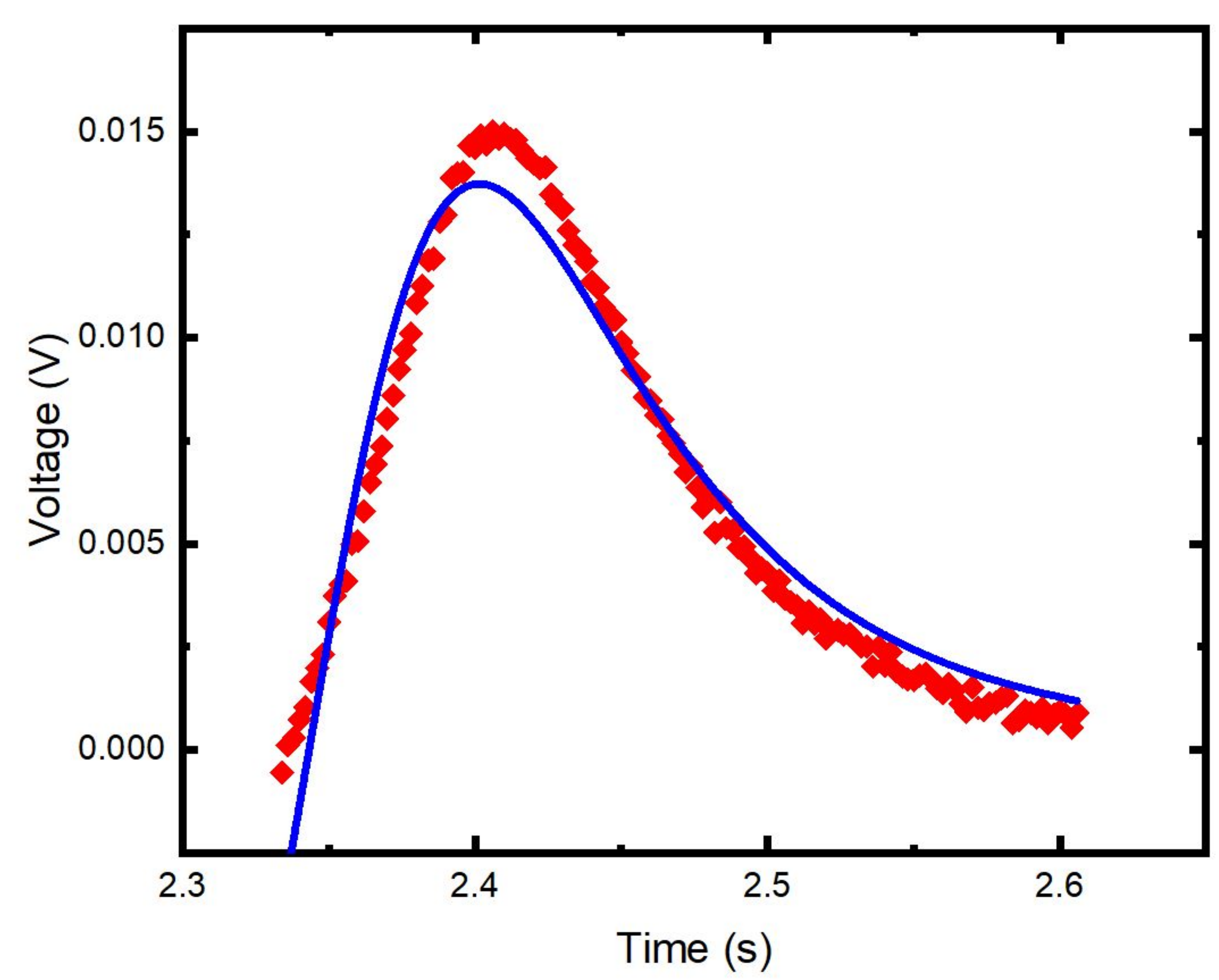
Design set up:
Testing thickness

Design set up:
Liquid nitrogen

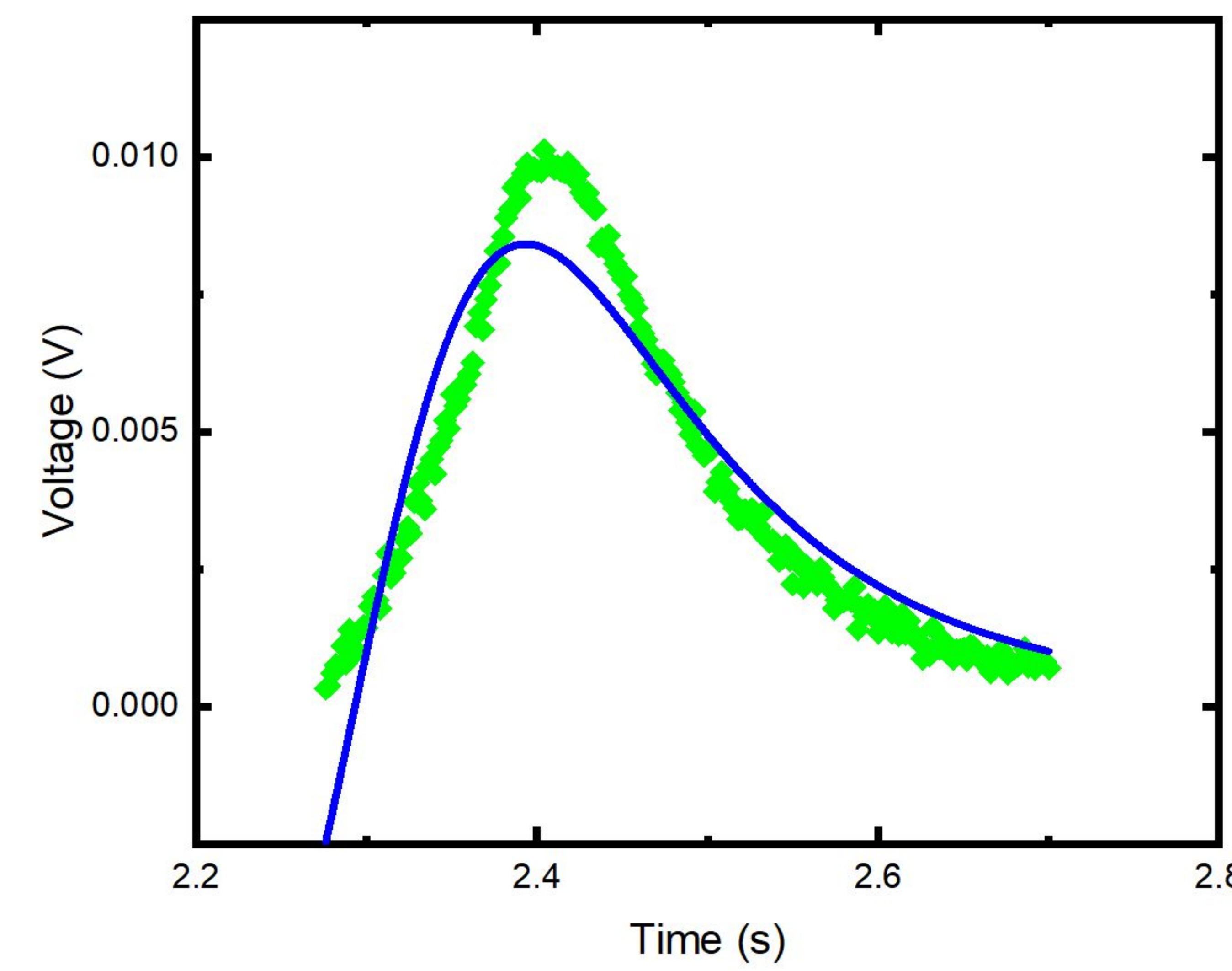
Results



Thickness of pipe: 1.04 mm
Temperature of pipe: 22.1°C
Velocity of magnet: 0.402 m/s



Thickness of pipe: 1.89 mm
Temperature of pipe: 22.1°C
Velocity of magnet: 0.137 m/s



Thickness of pipe: 1.04 mm
Temperature of pipe: -60.0°C
Velocity of magnet: 0.074 m/s

Discussion

$$\varepsilon_i = Nv(2\pi a)\left(\frac{3\mu zc}{(a^2+z^2)^{5/2}}\right)$$

- This equation was used to fit the data.

$$kv_t = mg$$

$$k \propto \sigma t$$

- When the magnet reaches terminal velocity (v_t), the resistive force due to Lenz's law becomes equal to the weight of the magnet.
- The drag parameter obeys this equation.
- k = drag parameter σ = conductivity t = thickness.

- For a fixed conductivity, if t increases, then so does the drag parameter (k), resulting in a smaller v_t as observed.
- When the tube is cooled, σ increases, so k increases, and therefore v_t decreases, as observed.

Future Work

- Improve the design to investigate the effect of temperature on the rate at which the magnet falls.
- Investigate additional pipe thicknesses and different pipe materials to obtain more quantitative results.
- Investigate the effect of different magnet shapes.

References

G. Donoso, C. L. Ladera, and P. Martin, Eur. J. Phys. 30, 855 (2009)

Acknowledgements

Funding provided by the National Science Foundation Grant No. DMR 2003828