QUEENSLAND ACADEMIES
Science Mathematics & Technology Campus

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The relationship between electrical conductivity and magnetically damped motion

Research Question:
In regards to electrical conductivity, which metal allows for maximum magnetic damping to be achieved?

Context:
Magnetic damping is used in magnetic braking systems for high speed trains.

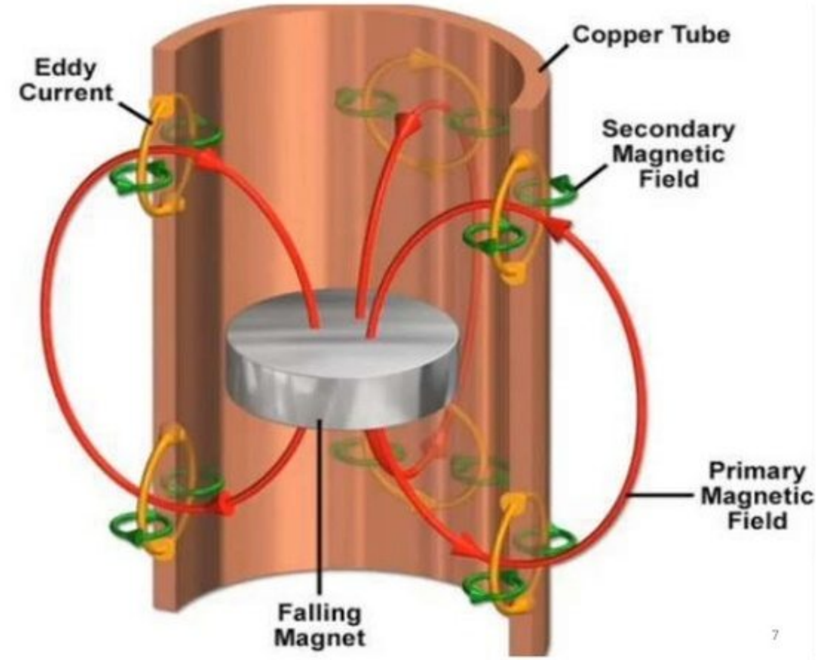
Contribution:
This research quantifies the degree of magnetic braking with different metals and alloys due to conductivity

Background

- Faraday's and Lenz's Law of Induction shows the magnitude of induced voltage when a magnetic field passes through a wire or coil

$$\varepsilon = -d\Phi\downarrow B/dt$$

where $\boldsymbol{\varepsilon}$ represents the electromotive force, $\boldsymbol{\Phi\downarrow B}$ represents the magnetic flux and $\boldsymbol{t}$ represents time.



- Stronger magnetic fields, greater electrical conductivities and faster changes in field result in greater eddy currents formed, and greater magnetic fields induced.

Methodology

Setup:

- Cylindrical Neodymium Magnet
- Various metal tubes
- Retort stand, clamp and plastic tub
- Camera and accessories
- Whiteboard and accessories

1. Apparatus and camera were set up.
2. A camera recording was taken as the neodymium magnet was dropped through the tube into the plastic tub. Trial details were recorded on the whiteboard for each trial.
3. The process was repeated 5 times for each tube.

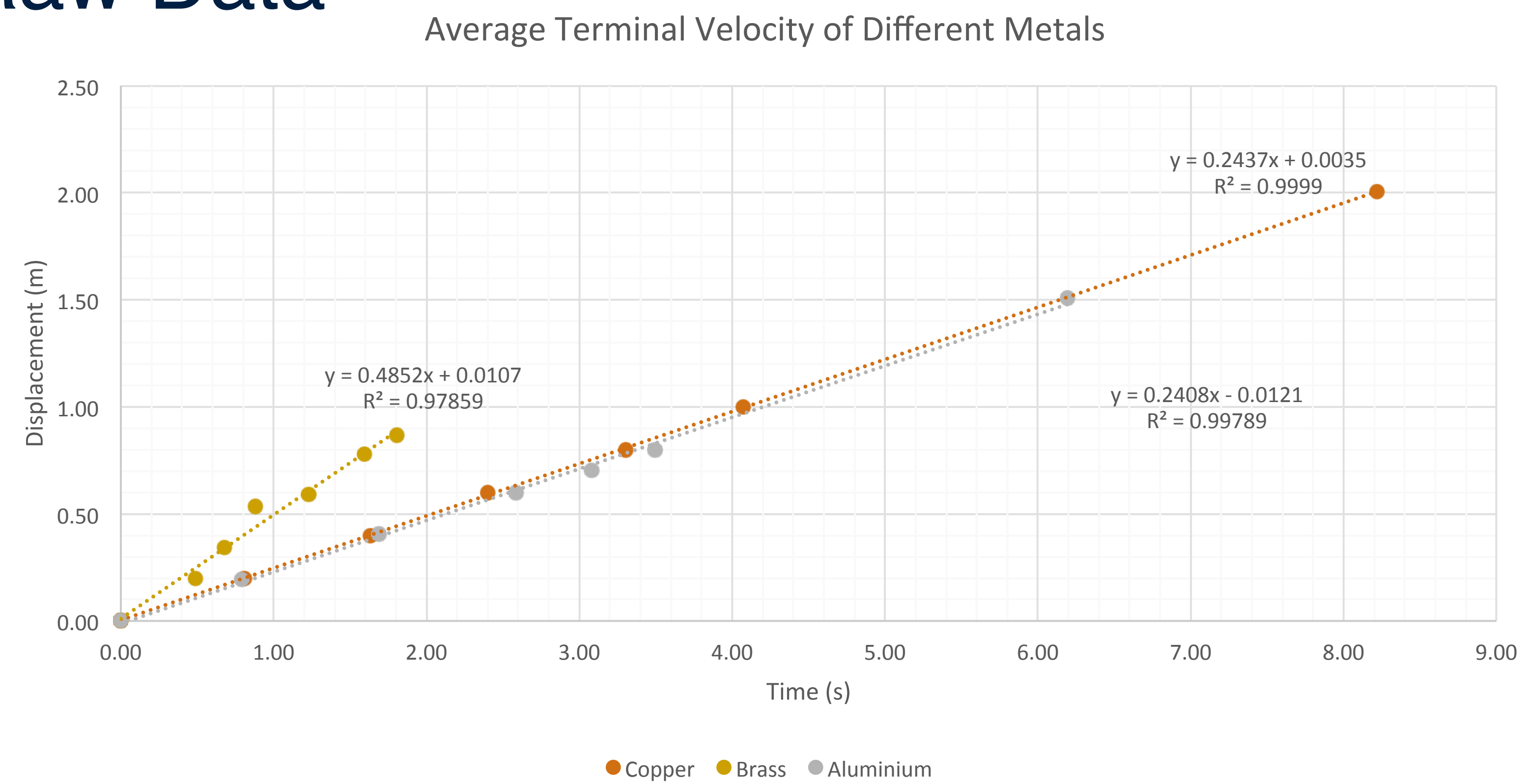
Methodology

- In the experiment, the type of metal tube was varied to measure the time taken for a magnet to pass through the tube

- All other variables were controlled

Variables Measured	Possible Effect On Results	How The Variable Was Controlled
Temperature	Increasing will increase resistivity of metal, increasing t	Experiment was undertaken with a constant temperature
Mass, shape and strength of magnet	Varying will increase t and therefore reduce terminal velocity	The same magnet was used in each trial
Thickness of tube	Increasing will increase t and therefore reduce terminal velocity	Tubes were of very similar thickness and had similar inner diameters

Raw Data



This graph shows the displacement of the magnet through the tube against time taken for the magnet to fall through the tube for all the metal types. The gradient represents terminal velocity as the gradient is displacement over time.

Analysis

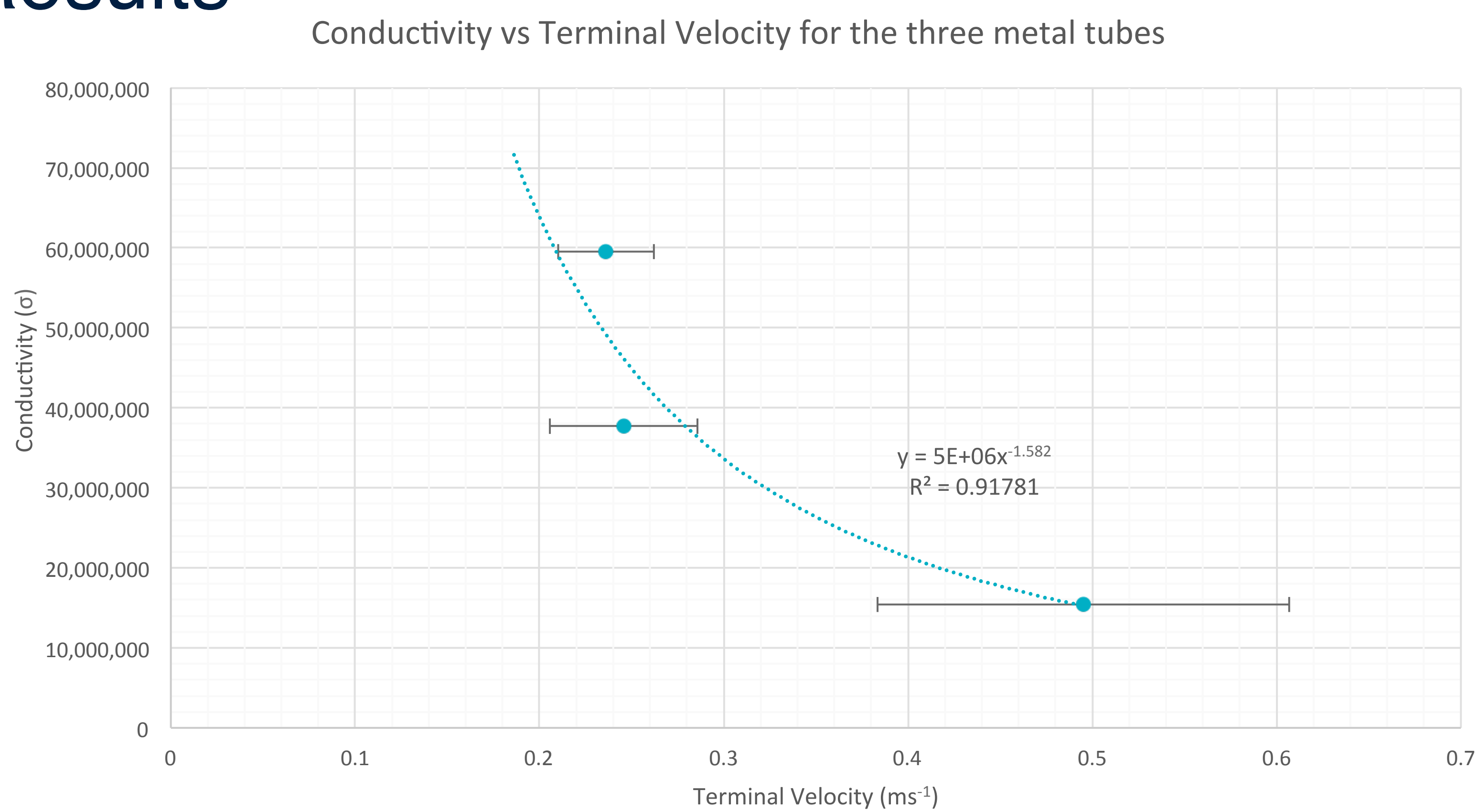
To determine a relationship between terminal velocity and conductivity, the raw data was processed using:

$$Terminal\ Velocity = displacement/time$$

This was tabulated with the respective calculated uncertainties as well as the literature values for conductivities.

Tube Material	Conductivity (S/m)	Terminal Velocity (m/s)	
		Mean	Uncertainty
Aluminium	3.77×10^{7}	0.2437	± 0.0169
Brass	1.54×10^{7}	0.4852	± 0.0689
Copper	5.95×10^{7}	0.2408	± 0.0403

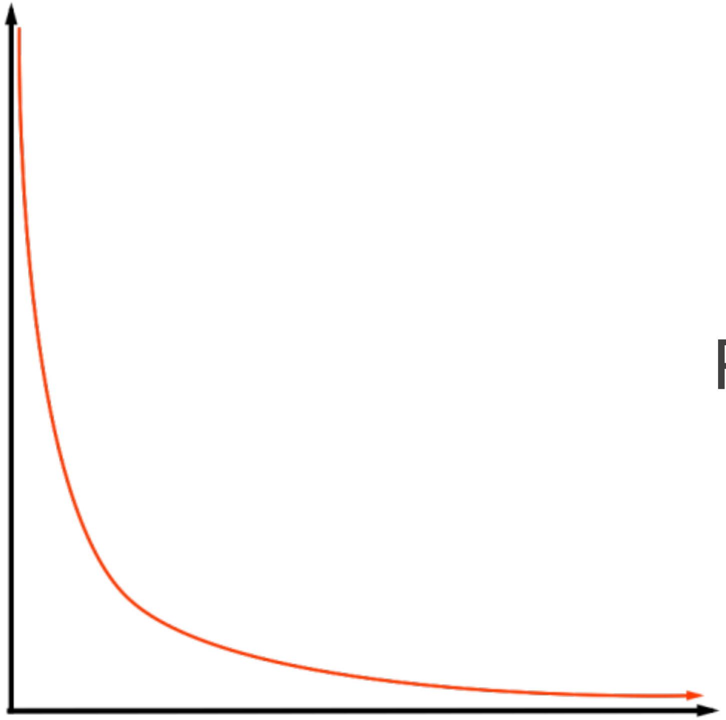
Results



This graph shows the average terminal velocity of each metal plotted against their respective conductivities. The trendline produced is inversely proportional.

Evaluation

The graph produced indicates an inversely proportional relationship between terminal velocity and conductivity; however, it is not possible to draw strong conclusions with only three metal types.



INVERSELY PROPORTIONAL

Sources of Error

Random errors:

- variations in dropping the magnet
- variation in timing the magnet

Systematic Error:

- Appropriateness of the selected frame rate for the camera

Improvements

- Increase accuracy of set up e.g. camera with higher frame
- Standardised release of magnet e.g. electromagnetic release

Conclusion

The experiment was successful in identifying the metal with the maximum dampening effect to be copper, and the hypothesis was proven to be correct as the terminal velocity was inversely proportional to conductivity.

Eddy currents have many practical applications as the unique properties of the currents allow for a very smooth dampening of motion. Some examples where eddy currents could be used are in the safe braking of high speed trains or in emergency stopping for dangerous machinery. Knowledge of the relationship between magnetic braking and conductivity would allow for the use of different metals in different applications enabling optimisation.

Possible Extension

To further the investigation, the following variables could be explored:

- Additional types of metal
- Different thickness of tubes
- Different magnet shapes, sizes and strengths
- Experimentally determining metal conductivities

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