Magnetic train

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1. Introduction

When button magnets are placed on both sides of a cylindrical battery, they make up a "train" which starts to move if it's placed in a coil made from uninsulated wire such that the magnets contact the wire.

2. Experimental setup

The experimental setup (Fig. 1) consisted of one main coil through which the train would travel, and multiple smaller coils wound around it that would record the passage of the train by the small voltage induced by the movement of the magnets.

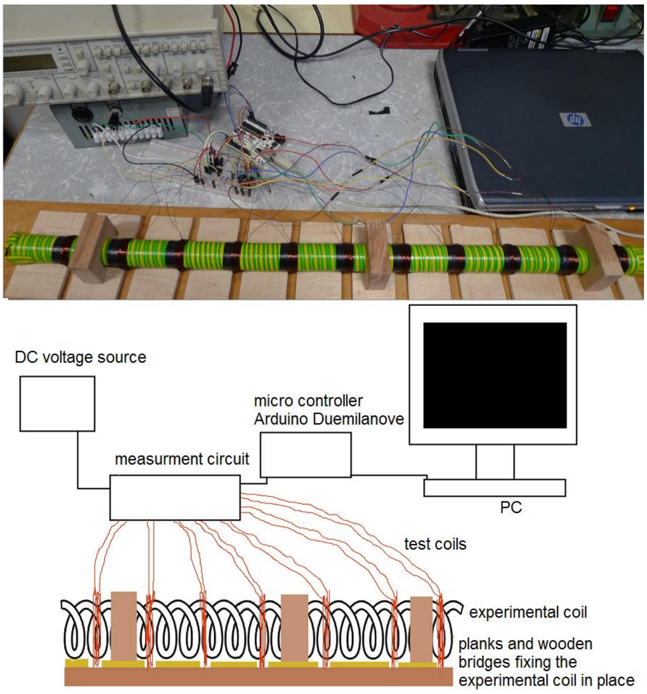

Fig 1 Experimental setup

3. Results

The magnets must be placed in the coil such that they are facing each other with the same pole. The current carrying part of the coil then pulls one and pushes the other magnet.

The driving force is modeled by summing up the influence of each current loop on each magnet. The main damping force was caused by the resistance of the coil towards the change of flux, modeled in a similar manner as the driving force. Besides them, the only other force relevant for the description of movement is the force of friction. The train reaches terminal velocity in less than 0.2s.

$$v_t = \frac{1}{\frac{L}{R_\Omega}\sum_{i=1}^{n}\frac{d\Phi_i}{dz}}\left(I - \frac{mg\mu}{3\mu_0 m_m R^2 \cdot \sum_{i=1}^{n}\frac{z_i}{(R^2+{z_i}^2)^{5/2}}}\right)$$

Eq 1 final equation for the terminal velocity

L - coil inductance, R_Ω - coil ohmic resistance, z - loop distance from magnet, n - loop number, Φi - magnetic flux through one loop, I - current, m - mass, μ -dynamic coefficient of friction, g - gravitational acceleration, μ_o - magnetic permeability, R - coil radius, m_m - magnet's magnetic dipole moment

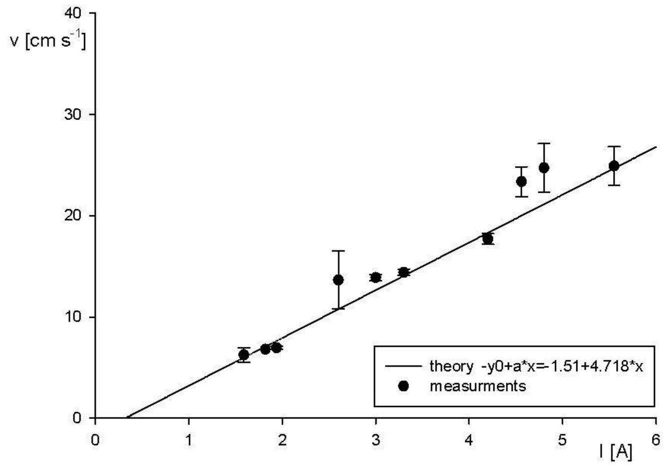

Fig 2 Terminal velocity vs battery's current

4. Conclusion

A theoretical model was developed to model the train's motion. By experimental examination, train's terminal velocity's was found to be positively dependant on battery's short circuit current and magnets' surface magnetic field, no dependence was found on electromagnet length and negative dependence was found on coil radius.

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5. References

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