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P3_8 Levitation

J. Bettles, I. Clarke, M. Perry and N. Pilkington

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH.

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Abstract

This paper aimed to explore the validity of levitating a small car through a process of magnetic levitation. The case assumed a car with a large electromagnet suspended over a super conductor. The calculations showed that for a small car, a large flat electromagnet would need to operate with a magnetic field of 0.19T.

Introduction

The concept of levitation has long been a point of fascination for the human race. The notion of hovering above the ground with no discernable means of lift can be seen in religion, myth and fiction. Levitation has also inspired many scientists over the years to attempt to build craft capable of such a feat. With the advent of many new modern technologies there is now perhaps a chance for this long-held dream to become a reality. Therefore, this paper aimed to test the possibility of successfully levitating a car. The car is used merely as an easily identifiable object for the reader to relate to, any similarly weighted object would be equally affected.

Theory

The principle of magnetic levitation is, at a basic level, very simple. A force generated by a magnet must act equally and oppositely to the force produced by gravity acting upon the object that is to be levitated. However, this principle gets significantly more complex when the reality of a practical situation is applied. Firstly, the magnetic field produced by the object must have something to interact with to produce the force. While the Earth's magnetic field is ever present, it is far too weak to produce a lifting force with any magnet of realistic strength. There is the possibility of using diamagnetic levitation, where by a diamagnetic material can be suspended above a permanent magnet. However, this requires strong fields, around 1-10T [1], and reacts badly to the presence of any ferromagnetic materials that a car would almost certainly possess.

There is a more efficient way to achieve magnetic levitation using a smaller magnetic field strength. An electromagnet can be levitated above a superconductor, as a property of superconducting materials is that the magnetic susceptibility χ_s = -1 [2]. The superconductor generates high currents and hence a magnetic field is generated which would oppose that of the electromagnet [3]. As such, the electromagnet would be repelled resulting in levitation as seen in Figure 1.

Figure 1 – A photograph of a magnet levitating above a superconductor [4].

Analysis

The car is assumed to be a Mini Cooper, with a 1 m diameter circular magnet attached to the bottom. The weight of the magnet and power supply is not taken into account as it is assumed that the weight gain would be counterbalanced by the removal of unnecessary parts, such as the engine and drive systems. To reduce the number of variables involved, the experiment is assumed to take place inside a vacuum chamber. The mass of the Mini Cooper is assumed to be 1150kg [5].

The force exerted by the magnet is found by multiplying the area of the magnet A by the magnetic pressure exerted over the superconductor. Magnetic pressure is just the energy density associated with the magnetic field, and is given by [6],

$$P_{mag} = \frac{B^2}{2\mu_0}, \tag{1}$$

where P_{mag} is the magnetic pressure, B is the magnetic field strength and μ_0 is the permeability of free space ($4\pi\times10^{-7}$ Hm^{-1}). To suspend the car above the superconductor, the magnetic force must equal the weight of the car, as shown in equation (2),

$$mg = \frac{B^2 A}{2\mu_0}, \tag{2}$$

where m is the mass of the car, g is the acceleration due to gravity and A = 0.785 m^2 is the area of the magnet. This is then rearranged to give the magnetic field strength needed to levitate the car,

$$B = \sqrt{\frac{2mg\mu_0}{A}}. \tag{3}$$

Using the values stated above, an electromagnet would require magnetic field strength of 0.19 T to lift a Mini Cooper.

Conclusion

This paper has found that under highly specialised circumstances a car can indeed be made to levitate with a magnetic field strength of 0.19 T. Such a field is large and would be difficult to generate outside of a lab as a lot of energy would be required. Because of this, the concept is unrealistic. Also, the reality of applying this to a more common situation would necessitate a higher field to account for the permeability of air. Also the cost of cooling the superconductor, and powering the magnet would be very high.

References

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