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A2_3 Diamagnetic Levitation of a Human

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Abstract

In 2000, Nobel Laureate Geim successfully levitated a frog, in a magnetic field, using the diamagnetic response of water molecules. The below shows that a 70.6T magnet would be required if we were to levitate an average adult human by the same means.

Introduction

Many magicians claim to have the ability to levitate but would true levitation be possible by using a magnetic force. In 2000, Geim [1] levitated a frog using the diamagnetic response of the water molecules present. By extension, this could be used to levitate any diamagnetic material given that there is a sufficiently large magnetic field.

Does this make me look fat?

In order to calculate the strength of field needed, we must first define an average adult. Humans are composed of roughly 60% [2] water, if we then consider the rest of the body to be composed of half bone and half muscle; we can calculate an average density by Eqn (1) and the values in Table 1.;

Material	Density (kg/m^3)
Water[3]	1000
Bone[3]	1439
Muscle[4]	1060

Table 1. Densities of the main materials in the human body

$$\rho_{ave} = \sum_i \rho_i \, . P_i, \tag{1}$$

From Eqn.(1), the product of the density, ρ_i, and the percentage composition, P_i , we get a result, ρ_{ave}, for the average density of the human body of 1100 kg/m^3, 10% greater than that of water. Now that we have an indication of the density of a human, we can look at balancing the magnetic force F_B and gravitational force F_g.

$$F_g = \rho_{ave} V_o g, \tag{2}$$

Above, Eqn (2) gives us the force exerted on a person due to Earth's gravity, where V_o is the volume of the object and g is is the approximate gravitational acceleration $9.81 m/s^2$ on the Earth's surface.

The below expression, Eqn (3) [5], gives the magnetic force as the product of the magnetisation of the sample, $\boldsymbol{M}$, and the gradient in the magnetic field, ∇B,

$$F_B = \boldsymbol{M} . \nabla B, \tag{3}$$

meaning we can equate Eqns (2) and (3). By then substituting in for the magnetisation [6], using Eqn(4), we can cancel the volume term in Eqn(2) using the assumption we have already used; that the volume of water,V_{H20}, is 60% of the total volume,V_o;

$$\boldsymbol{M} = \frac{\chi_D V_{H20} B}{\mu_0} = \frac{3}{5} . \frac{\chi_D V_o B}{\mu_0}, \tag{4}$$

χ_D is the diamagnetic susceptibility of water given as a 9.035x10^{-6} m^3/kg [7] and μ_0 is the permeability of free space (4πx10^{-7} H/m).

$$\frac{3}{5} \cdot \frac{\chi_D V_o B}{\mu_0} \nabla B = \rho V_o g. \quad (5)$$

As we are only concerned with the force acting against gravity, we can define ∇B as equal to dB/dz, where z is the vertical direction. Thus rearranging Eqn(5), we get;

$$B\frac{dB}{dz} = \frac{5}{3} \cdot \frac{\rho_{ave} g \mu_0}{\chi_D}, \qquad (6)$$

by comparison, the $B\,dB/dz$ value of water is given as 1400 T^2/m [8] whereas using our current values; we get 2501 T^2/m for a human.

By then integrating over both dB and dz, we can get a peak magnetic field strength;

$$\int BdB = \frac{5}{3}\frac{\rho_{ave} g \mu_0}{\chi_D} \int dz, \qquad (7)$$

$$B^2 = \frac{10 \cdot \rho_{ave} g \mu_0}{3 \cdot \chi_D} z, \qquad (8)$$

by then substituting in the given values and a z value of 1.80m (approximately the height of an adult male), we get that $B$is equal to 70.6 Tesla

Discussion and Conclusion

As can be seen by the large field needed, it is not currently possible to use diamagnetic levitation on a human. While magnetic fields this strong do exist, it is technologically impossible to package such a field into a small usable levitation device.

It is also worth noting that this paper assumes there is no contribution from any material other than water in the body, when in actual fact other materials, including proteins, have a diamagnetic response. As well as this there is ferromagnetic material such as iron in the blood and dental fillings, which would oppose the diamagnetism and likely cause pain for the person being levitated.

Moreover, the above assumes that water is evenly distributed throughout the body. This is not the case as certain regions, such as the brain, contain a far higher than average percentage of water. This would lead to extra stress on these areas, hence having an ill effect on the subject's health.

References

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