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A1_7 No Strings Attached

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Abstract

This paper will discuss the possibility of using electromagnetic phenomena to levitate the author of this paper by inducing a safe and non-lethal current through her. It is found that if the current is at a non-lethal level, then the magnetic field required for levitation is 1670 T and if the current is safe, then the magnetic field needed is 3.33×10^8 T. Both of these magnetic fields are far larger than those available on Earth with current technology. However, by investigating magnetic levitation using a superconductor, the magnetic field strength required is minimised to 0.0457 T.

No Strings Attached

Magicians have always been fascinated with levitating their glamorous assistants, proving that there are no strings aiding with this illusion. But this can be achieved by using the right hand rule, magnets and a non-lethal current flowing through the body. This paper will explore the magnetic field needed to levitate the 60 kg, 1.77 m female and then explore the method of magnetic levitation.

Equations and Theory

The right hand rule of electromagnetic induction, it is seen that with a perpendicular magnetic and electric field, a force is induced on the wire which carries the current to create the electric field. However, in this scenario, instead of a wire will be a human. Figure 1 shows the diagram including the body, two magnets either side of the body creating a magnetic field which goes from left to right, a current which is flowing towards the reader and therefore a force upwards to levitate the body.

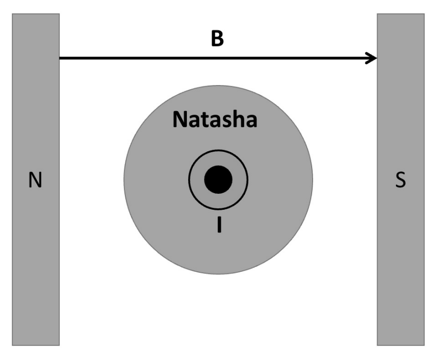

Figure 1: The experimental set up, including north and south magnets creating a left-to-right magnetic field, B, a current flowing out of the page toward the reader, I and the body which experiences a force upwards.

This investigation uses the equation to calculate the Lorentz force (equation 1) on the body, which in this case will have to be at least equal to the weight of the body (calculated by using equation 2).

$$F = B \times I \times L, \tag{1}$$

$$W = m \times g, \tag{2}$$

In equation 1, F is the Lorentz force in N, B is the magnetic field strength in T, I is current in A and L is the length of the conductor (the body in this case) in m. This equation is applicable in this scenario due to the magnetic field and conductor being perpendicular to one another, so the cross-product becomes a simple multiplication. Equation 2 is simply using Newton's Second Law of Motion in the case of a mass, m in kg, in Earth's gravitational field, g which is 9.81 m s^{-1}, to calculate the weight of the human.

Applying the theory to the scenario

The conductor in this scenario is the author, so the mass is 60 kg and the length (or height) is 1.77 m. It is known that a safe (mild scarring and burns) current for a human to withstand is 10 mA and the non-lethal (would require resuscitation) current is 200 mA. The magnetic field required when the current is safe is 3.3×10^6 T, which is in the limits of a neutron star's magnetic field [1], which is impossible to reach on Earth. Even with the non-lethal current is 1670 T, which is around 37 times the largest magnetic field ever generated on Earth [2].

Now that the possibility of levitating a human via this method has been proven impossible without the human dying from a lethal current, the limit of Lorentz Force to length of conductor was found with equation 3,

$$F/L = B \times I, \tag{3}$$

To make this levitation possible, a magnetic field of 8.3 T as this is the magnetic field sustained by the Large Hadron Collider [3] used to accelerate particles at CERN and the non-lethal current are used. From this, it is found that the ratio of force to length is 1.66 N/m, which is more than the ratio for the smallest mammal known on Earth, an Etruscan Shrew [4], which is on average 1.8 g in mass and 5 cm long. This means that this shrew would be able to be levitated and proves that a less massive but longer conductor is the most effective option for this type of levitation.

Magnetic Levitation

Magnetic levitation is a method of suspending an object using only magnetic fields which oppose each other, meaning that a current is not required like in the previously discussed situation. Due to the increased safety in the 'maglev' scenario, it is a more realistic option for levitating the author. A superconductor would be used beneath the author, with the back of the author's body being covered in permanent magnets, so that the body experiences lift from magnetic pressure (P_{mag})(4), which is equal to the weight of the body (2):

$$P_{mag} = B^2/2\mu_0, \tag{4}$$

Where B is the magnetic field strength (T) and μ_0 is the permeability of a vacuum. By rearranging for B, it is found that a field strength of only 0.046 T is needed to levitate the author.

Conclusion

After finding the impossibility of the safe levitation of a human (notably the author of this piece) via the method outlined, it is found that magnetic levitation using a superconductor is the preferred method as it is much safer and requires an obtainable magnetic field strength.

References

[1] `https://imagine.gsfc.nasa.gov/science/objects/neutron_stars1.html` [Accessed 24 Oct 2022]

[2] `https://newatlas.com/physics/worlds-strongest-steady-magnetic-field/` [Accessed 26 Oct 2022]

[3] `https://home.cern/science/engineering/pulling-together-superconducting-electromagnets` [Accessed 24 Oct 2022]

[4] `https://animalia.bio/etruscan-shrew` [Accessed 23 Oct 2022]