Journal of Physics Special Topics
An undergraduate physics journal

P2_2 Magneto: Can bullets be deflected using magnetism?

E. Coleman, T. Nottingham, S. Robinson and K. Zimolag

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

October 30, 2018

Abstract

In a scene in the film "X-Men: First Class", a character called Magneto deflects bullets being shot at him. We investigate the strength of magnetic field required to deflect a bullet at arm's length, and whether that would be possible with existing magnets. We found that the magnetic field strength required to bend a bullet at that range would be $5.4 \text{x} 10^9$ T, which is far greater than the highest record field for a continuous field magnet at 45 T.

Introduction

During the last battle of "X-Men: First Class", agent MacTaggert (Rose Byrne) is firing a hand gun at Magneto (Michael Fassbender) in order to stop him from blowing up a fleet of ships after turning around ballistic missiles in the air. Magneto then proceeds to deflect the bullets to avoid getting shot.

We assumed that the hand gun used in the film would be firing 9x19mm Parabellum Federal FMJ rounds. These bullets have a mass of 7.45 g and a muzzle velocity of 360 ms $^{-1}$ [1]. We took the average value of 500 pC for the electrostatic charge of the bullet after being fired [2]. Furthermore, we assumed Magneto creates a uniform magnetic field and that air resistance is negligible.

Theory

When a charged particle (charge q) moves through a magnetic field $\boldsymbol{B}$, the magnetic force $\boldsymbol{F}$ acts in a perpendicular direction to the velocity $\boldsymbol{v}$ of the particle. This force bends the path of the particle into a circular orbit during uniform motion as shown in Figure 1.

From Tipler [3], we obtained the equations for the magnetic force and Newton's second law in order to relate the radius of the orbit to the magnetic field and velocity of the particle:

$$\boldsymbol{F} = q(\boldsymbol{v} \times \boldsymbol{B}) \tag{1}$$

$$F = m\boldsymbol{v}^2/r \tag{2}$$

Where F is the centripetal force, m is the mass of the particle, v is the velocity of the particle and r is the radius of the circular path.

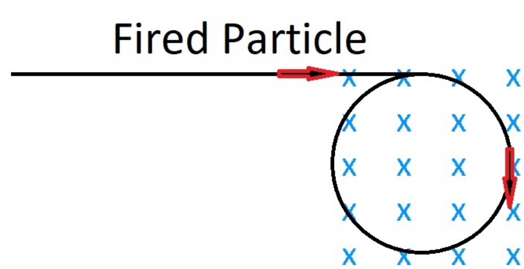

Figure 1: Our diagram showing a negatively charged particle being fired into a magnetic field (going inwards) and entering circular motion due to the field.

Equating (1) and (2), we obtained the equation for the strength of the magnetic field:

$$\boldsymbol{B} = m\boldsymbol{v}/qr \tag{3}$$

Method

Using the 9x19mm bullet specifications listed in the introduction and the average arm length of 91 cm for a 1.83 m male [4][5], plus an extra distance of approximately 9 cm allowing for bullet deflection before collision with his arm. We applied (3) in order to obtain a result for the required magnetic field strength in order to deflect the bullet. This gave us a result of 5.4x10^9 T, which we thought was far too high for a real life scenario.

We then compared this result to the highest recorded magnetic field strength value for a continuous field magnet, which we found to be 45 T [6]. Then we decided to use this value in order to test how much charge would have to be contained within the bullet in order to be deflected by an achievable magnetic field strength. To do this, we rearranged (3) for q giving us $q = m\boldsymbol{v}/\boldsymbol{B}r$. From this we found that charge to be 0.060 C.

Conclusion

In this investigation, we calculated the required magnetic field strength to bend a bullet away from Magneto at approximately arm's length. We found the value to be 5.4x10^9 T, which is far greater than any magnetic field strength ever recorded.

We then compared this to the highest achieved magnetic field by a continuous field magnet with a value of 45 T. Using this we found that the bullet would have to have a charge x10^8 higher than what was found in experimental results of static charges on small-arms projectiles.

Furthermore, humans have never experienced such high magnetic field strengths, the effects it would have on the human anatomy are unknown, however we believe it would be harmful due to the public exposure limit being x10^{11} times smaller [7] than our calculated value.

References

[1] `https://en.wikipedia.org/wiki/9%C3%9719mm_Parabellum` [Accessed 12 October 2018]

[2] `http://spie.org/Publications/Proceedings/Paper/10.1117/12.920572` [Accessed 12 October 2018]

[3] P. A. Tipler, *Physics for scientists and engineers, sixth edition*, p.861-867.

[4] `http://www.mybarong2.com/dress-shirt-sleeve-length-art-1080.html` [Accessed 13 October 2018]

[5] `https://tinyurl.com/yb2kgp3e` [Accessed 13 October 2018]

[6] `https://nationalmaglab.org/about/facts-figures/world-records` [Accessed 13 October 2018]

[7] `https://tinyurl.com/y927g86b` [Accessed 14 October 2018]