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P1_2 The Deflection of Bullets Using Magnetic Fields

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Abstract

This article demonstrates how low strength magnetic fields can be used to curve the trajectory of a moving particle, requiring a field in the order of 10^{-9}T to loop an electron. The theory is expanded to investigate whether such an arrangement would curve a bullet at its maximum velocity, in order to investigate the feasibility of using the magnetic field as a form of defence for an object. It is found that for the assumptions made in this model, the magnetic field strength required is $\sim 10^{18}$T, far too high to have any practical use.

Introduction

When a charged particle moves through a magnetic field, it is subject to a force which curves its trajectory.

If this phenomenon could be exploited for use with bullets in place of charged particles, then it could be used as an alternative to bullet-proof jackets, deflecting the bullet away from the body, avoiding any contact entirely.

Theory
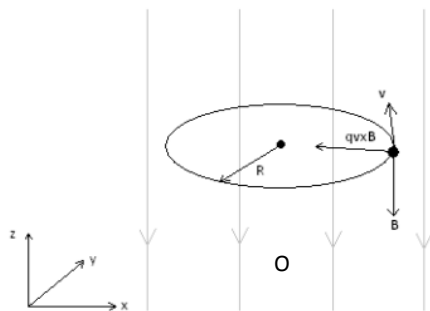

Figure 1: A particle moving in a B-field

When a particle of charge q moves through a magnetic field $\boldsymbol{B}$ at velocity $\boldsymbol{v}$, it is subject to a force F

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

which is directed towards the centre of the loop, (O) as indicated in Fig.1.

The mechanical centripetal force felt by the particle is

$$F = \frac{m\boldsymbol{v}^2}{R}, \qquad (2)$$

In equilibrium this force is analogous to (1); equating (1) to (2) and rearranging then gives

$$\boldsymbol{B} = \frac{m\boldsymbol{v}}{qR}, \qquad (3)$$

where R is the radius of curvature of the loop.

An Electron Gun

Initially, a simple model is considered in which a hand gun fires electrons at the same velocity as it would fire a bullet. The electrons are fired perpendicular to the field, and R is set arbitrarily to 1m for the purpose of this article.

The 9x19mm Parabellum is the 'world's most popular and widely used military handgun cartridge'[1], whose 9.1g bullet has a maximum velocity of 305ms^{-1}[2].

Using (3) where $\boldsymbol{v}$ is the velocity of the electron, (the same as that of a bullet, 305ms^{-1}), m is the mass of an electron, 9.11x10^{-31} kg and q is the electron charge, 1.60x10^{-19}C, the resultant magnetic field strength required is 1.73×10^{-9}T.

A magnetic field of this order of magnitude can be easily induced by a current carrying wire; using

$$B = \frac{\mu_0 I}{4\pi},$$

1

where μ_0 is the permeability of free space (taken as 1.26×10^{-6} NA^{-2}) and I the current in the wire. The current can be immediately calculated to be 0.0173A. A low current such as this is entirely achievable, so the idea has practical worth when the projectiles are electrons.

Real Bullets

No values for the charge on a fired bullet could be found. Therefore a calculation is made based on assumptions about the initial charge on the bullet, and orders of magnitude only are considered.

A bullet may pick up a small charge from being transferred by hand into the gun chamber. As it travels down the barrel, the rifling inside the barrel forces it to deform and spiral. It is expected that the bullet would become statically charged due to this contact between surfaces.

Let the charge on the bullet be of the order of 10^{-19}C, then using (3) and the magnitudes of the bullet velocity and mass previously stated in the electron gun model,

$$B = \frac{(1 \times 10^{-3} kg)(1 \times 10^{2} m.s^{-1})}{1 \times 10^{-19} C}, \qquad (4)$$

and the field strength required to loop the bullet is of the order of 10^{18}T.

(4) clearly shows that the field strength required is highly dependent on the mass to charge ratio of the projectile. Since this charge is expected to be small relative to the mass, the field strength required will be very large.

Discussion

The current record for a continuous magnetic field is 45T[4], thus the required field strength of 10^{18}T is utterly unattainable.

An MRI-strength magnetic field can be around 4T[5]. Knowing that this sized field can at least be created, (2) can be rearranged to find the required charge when the field is set at this value, calculated using a rearrangement of (3) to give

$$q = \frac{m\boldsymbol{v}}{\boldsymbol{B}R} = \frac{(9.1\times10^{-3} kg)\times305 m.s^{-1}}{4T\times1m} = 0.69C$$

Whilst this is only an estimate, it is indicative of the order of magnitude of charge the bullet must have before firing. It was previously assumed that any charge picked up

by the bullet during its movement down the barrel would be small. This result shows that a much greater charge than previously estimated would be necessary in order for the looping to occur.

Based upon the assumptions made of the magnitude of initial bullet charge, it can be seen that for this model to work, pre-charged bullets would be required. So too would a uniform magnetic field, otherwise the bullets would not curve regularly, and protection could not be guaranteed.

Conclusion

This article has calculated the magnetic fields necessary to deflect fired electrons, showing that an easily attainable low magnetic field of 1.73×10^{-9}T is required to curve their trajectories.

The model has been extended to use values for fired bullets, with assumptions made for the initial bullet charge, and it has been found that an impossible field strength of the order of 10^{18}T is required.

The relationship between charge and magnetic field strength has been examined, and it has been determined that whilst it is possible to fix one variable in a realistic range, in practice, the other becomes unreasonable to compensate. Hence for the current assumptions, this concept would not be feasible as a means of protection for an object.

References

[1]Barnes, Frank, Cartridges of the World, 11th Ed, p295 (2006)

[2]Vihta Vuori, *Reloading Guide for Centerfire Cartridges,* 7th Ed, p50

[3]http://www.magnet.fsu.edu/education/tutorials/magnetacademy/mri/page2.html

[4]http://www.magnet.fsu.edu/mediacenter/factsheets/records.html

[5]http://hypertextbook.com/facts/1997/AllaReyfman.shtml