BACKGROUND

How does a Gauss rifle work? When you give the trigger ball a slight nudge, it moves forward. As it gets closer to the neodymium magnet, the magnetic force pulls the ball toward the magnet. The ball bearing accelerates toward the magnet due to the magnetic force acting on it. When the trigger ball bearing hits the magnet, it transfers its energy and momentum to the magnet. Without moving, the magnet then transfers the momentum from the trigger ball to the first ball bearing on the opposite side of the magnet. This concept is called conservation of momentum. The ball bearing then hits the ball bearing next to it and momentum keeps getting transferred until the last ball bearing shoots off. In a rifle with more than one magnet stage, the magnetic field from the second magnet attracts this last ball bearing, the ball bearing accelerates toward the second magnet, and the process starts again. The only difference is that the ball bearing from the previous magnet stage gives the second magnet *more* energy than the ball bearing that started the chain reaction. (Science Buddies Staff)

How is the energy transferred? A Gauss rifle uses magnetic stages containing magnets and ball bearings. (Science Buddies Staff) When you use opposite ends of magnetic poles to move magnets forward, it changes the magnetic energy into moveable, or kinetic energy (Department of Energy) (Chemin et al.). All of these magnets are lined up in a straight line to minimize error and friction (Vedantu). The reason the magnets gain velocity is because the different poles of magnets push the balls forward which changes the magnet's energy into kinetic energy, which is the energy of movement (Department of Energy) (Chemin et al.). The more magnet stages the Gauss rifle has, the more magnets it has, which increases the ending projectile's velocity (Science Buddies Staff).

So how fast is the final ball bearing going when it leaves the rifle? What is its velocity? How far will it go? In this project, I will answer these questions and look at how the velocity of the final ball bearing depends on the number of magnet stages. The distance that the ball travels will depend on how fast the ball was going when it was shot, as well as on earth's gravitational force which will eventually pull the ball down. (Science Buddies Staff)

PROBLEM

What effect does the number of magnet stages have on the flight distance and velocity of ball bearings? What is the effect of magnet spacing on the flight distance and velocity of ball bearings?

HYPOTHESIS

If there are more magnet stages, then the ball bearing will travel further, and with more velocity.

MATERIALS

- Wooden dowels, 16 inches long and ⅜ inch diameter (4)
- Neodymium magnets, ½ inch thick and ½ inch diameter (8)
- Nickel-plated steel balls, ½ inch in diameter (20)
- Elmer's® Wood Glue
- Clear tape, ½ inch in diameter
- Tape measure
- Table
- Calculator
- Digital lab notebook
- Big soft blanket

PROCEDURE

1. Place the two dowels together and glue them with wood glue, then wait for them to dry completely (Repeat with the other two dowels).
2. Tape the glued dowels together to make one long dowel and place the dowels on the table and spread the big soft blanket over the floor in front of the table. Measure and record the height of the table.
3. Tape one magnet on the wooden dowels 2 ball bearings away from the edge.
4. Place 2 ball bearings in front of the magnet (next to the edge) and gently nudge another ball bearing to the back of the magnet.
5. Watch the ball bearing fly and watch where the ball bearing lands.
6. Measure the distance from where the ball bearing lands to the table.
7. Repeat 5 times measuring the distance each time.
8. Tape another magnet 10 centimeters away from the first magnet.
9. Place two ball bearings in front of the first and second magnets and slide another ball bearing to the back of the second magnet.
10. Repeat steps 5-8 until you measured the distance the ball travels from 8 stages 5 times each.
11. To measure the distance the ball travels with further spacing, conduct the same experiment but placing them 15 centimeters apart each time.

DATA

DATA CHART: Distance and Velocity the Ball Bearing Traveled

RESULTS

One source of random error in our experiment was that I had to physically launch the starter ball for each trial. Despite my efforts to be consistent, we still obtained reliable and consistent results. Unfortunately, this error could not be controlled in any way.

VARIABLES

Independent Variable: The number of magnet stages and magnet spacing

Dependent Variable: The distance the ball bearing traveled away from the table, and the initial velocity the ball bearing has when it was launched from the table

CONCLUSION

In conclusion, our hypothesis is accepted. The number of magnetic stages significantly impacted the ball's flight distance by increasing both the distance and velocity of each stage. As we added more magnetic stages, the flight distance dramatically increased. However, when we added another magnetic stage to an already high number of stages, the impact on distance was not as pronounced. This is likely due to friction, which causes energy loss as the ball passes through more stages. Our results also showed that increasing the spacing from 10 to 15 centimeters resulted in the highest flight distance around three magnetic stages, but the distance eventually decreased with the 15 centimeter spacing, while it continued to rise with the 10 centimeter spacing. However, if we continued the experiment, we would expect the 10 centimeter spacing to eventually decline as well. Overall, our results showed a pattern of increasing distance until a certain number of stages, after which the distance remained relatively constant or decreased slightly.

BIBLIOGRAPHY

Vedantu. “Gauss Rifle.” VEDANTU, 27 Apr. 2022, www.vedantu.com/physics/gauss-rifle. Accessed 25 Oct. 2022.

Chemin, Arsène, et al. “Magnetic Cannon: The Physics of the Gauss Rifle.” American Journal of Physics, 16 June 2017, aapt.scitation.org/doi/10.1119/1.4979653. Accessed 25 Oct. 2022.

Department of Energy. “How Maglev Works.” Energy.gov, 14 June 2016, www.energy.gov/articles/how-maglev-works. Accessed 25 Oct. 2022.

Science Buddies Staff. "Build a Gauss Rifle!" Science Buddies, 3 June 2021, https://www.sciencebuddies.org/science-fair-projects/project-ideas/Phys_p081/physics/gauss-rifle. Accessed 25 Oct. 2022.