PHYSICS PROJECT

GAUSSIAN GUN

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INTRODUCTION

GAUSSIAN GUN is a type of projectile accelerator consisting of one or more coils used as electromagnets in the configuration of alinear motor that accelerate a ferromagnetic or conducting projectile to high velocity. In almost all coilgun configurations, the coils and the gun barrel are arranged on a common axis.

WHAT IS A GAUSSIAN GUN ?

The core of a gauss gun consists of a single neodymium magnet with several steel balls stuck to it. When another, single steel ball rolls towards the magnet, the attractive force from the magnet accelerates this ball. The closer the ball gets to the magnet, the stronger this acceleration force becomes. It impacts the magnet at a higher speed than it was traveling before.

When the impact occurs, the energy is transferred to the ball on the opposite end, giving it a speed that is almost the same velocity as the first magnet, right at the moment before impact.

A multi-stage Gauss Gun uses several stages in succession to achieve faster speeds.

MECHANISM

Let's break down the action step by step.

First, a single steel ball is rolled towards the magnet at a slow speed, as shown in step 1 at right.

In step 2, the ball is attracted to the magnet more and more as it gets closer to it. The closer the ball gets, the stronger the attraction force. All this pull acting on the steel ball accelerates it to higher speeds. $F = ma$.

In step 3, the ball hits the magnet. Pow!

In step 4, the energy from the first magnet is transferred to the ball on the opposite end. This opposite steel ball then starts moving at about the same speed, minus losses that occurred during the impact.

This transfer of energy is very similar to how a Newton's Cradle works. With a Newton's Cradle, there are no magnets, only steel balls. One is lifted, and allowed to impact the balls at the bottom. The energy is transferred to the ball on the opposite end.

With a multi-stage Gauss Gun, each stage follows the same steps described above. The difference is that the ball is rolling at a faster initial speed before approaching the next stage.

AN ANALOG WITH GRAVITY

While magnetic forces can sometimes seem mysterious, what's happening here is readily explained by Newton's Laws of Motion. Consider an analogy to help our understanding of this mechanism. The setup uses only steel balls and no magnets. Gravity is the force that accelerates the balls.

Again, we can break the process down into the same four steps:

1. The ball rolls slowly, approaching the ramp.
2. The ball accelerates down the ramp, because gravity exerts a force on the steel ball.
3. The ball impacts the set of balls at the bottom of the ramp with much greater speed than it initially started with.
4. Thanks to conservation of energy, the ball on the left end takes off at about the same speed

TO IMPROVE PERFORMANCE

While there is a limit, adding stages will increase the exit speed of the last ball. Plus it's fun to see multiple stages snap!

In the slow motion videos above, the magnet and remaining balls are sometimes seen to slide to the right. This represents wasted energy that could have been used to propel the ball even faster. Consider securing/clamping/gluing the magnets in place to prevent this motion.

Consider larger magnets. While all these examples used cylinder magnets, one could also use block magnets, which have a bit more magnet material. For example, a B888 block can be used with 1/2" diameter NSB8 balls, rather than a D88 cylinder.

Launch a smaller ball. The energy put into the last ball in the sequence is determined by the mass and speed of the ball hitting the magnet. Using a smaller ball at the end can produce greater speeds. The energy is equal to one half times the mass time the square of the velocity (here). With energy constant, a smaller mass will give much greater speeds.

CONCLUTION

Have fun and be safe. Extremely hard impacts can chip or crack a brittle neodymium magnet, so be sure to wear eye protection.