# Magnetic Linear Accelerator

**A simple, low cost practical activity which launches steel balls at surprising speeds using magnets**

**Health and safety**

Beware strong magnets. Safety glasses should be worn. The steel balls can be launched at high speed. The neodymium magnets can shatter.

**Aim**

To investigate the velocity of a steel ball launched from a simple magnetic accelerator.

**You are provided with:**

* two smooth cylindrical dowel rods 150mm × 6mm diameter to act as a rail
* two cylindrical neodymium magnets N45 3mm × 8mm diameter
* five chrome steel balls 8mm diameter
* blu tack.

**Procedure**

* Use the blu tack to secure the two rods to the bench so that they make an initially horizontal and parallel rail for the steel ball.
* Place one magnet in the groove approximately 3 cm from the left end of the rail and, while holding the magnet, attach two steel balls to the right side of this magnet so they are all aligned on the rail.
* Place the second magnet approximately 1 cm from the right end of the rail and place two steel balls to the right side of this second magnet so they are all aligned in the rail.

****To see the accelerator in action, roll the remaining steel ball gently from the left hand end of the rail towards the first magnet, as shown in Fig. 1. Watch what happens. You may initially wish to put a target obstacle in the path of the final ball bearing so you don’t lose it!

**Fig. 1**

The nature of the chosen investigation will determine the number of magnets and of steel balls required.

The magnets should be of the same diameter as the steel balls. You may wish to consider modifying the equipment. For example:

* Use larger magnets which can be secured to the rail.
* Use longer dowel rods to allow more magnet stages to be used to increase the velocity of the launched ball. **Caution:** The magnets can shatter at high ball velocities so we would not recommend rods over 300 mm in length.
* Modify the strength of the magnets used.

**Investigating the magnetic accelerator**

There are lots of opportunities here for open investigation. Here are some considerations for any investigation.

How can we measure the velocity of the final ball?

e.g. camera software, measuring the range of the ball/projectile etc.

How does the experimental configuration affect the velocity of the final ball?

e.g. The number of ball bearings used with each magnet, the number of magnet stages used, the size of the steel balls, the strength of the magnets etc.

How can we analyse the results and what conclusions can we make?

How can we improve the experiment?

**Theory**

Discussions around the science behind the magnetic accelerator can include many topics from the GCE and GCSE specifications including conservation of momentum, conservation of energy, forces, motion, collisions and magnetic fields.

A summary of what is happening in the experiment is detailed below.

* The closer the rolling ball gets towards the magnet, the stronger the magnetic attraction force. This force accelerates the steel ball to a much greater velocity.
* The ball hits the first magnet and the kinetic energy of the ball is transferred to the far ball on the opposite end of the magnet. This ball is further away from the magnet (due to the extra ball between itself and the magnet) so there is a much smaller magnetic force acting on it.
* This ball then starts moving at nearly the same velocity as the impact velocity of the original ball, minus kinetic energy losses which include the energy needed to overcome the (smaller) magnetic force.
* The ball then accelerates again as it approaches the next magnet and the process repeats.
* Theory suggests the greater the number of magnet stages, the greater the kinetic energy of the final ball.
* The kinetic energy *E*K of the ball is related to the velocity *v* of the ball by the equation

*E*K = ½*mv*2, where *m* is the mass of the ball.



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