Magnetic Particle Accelerator

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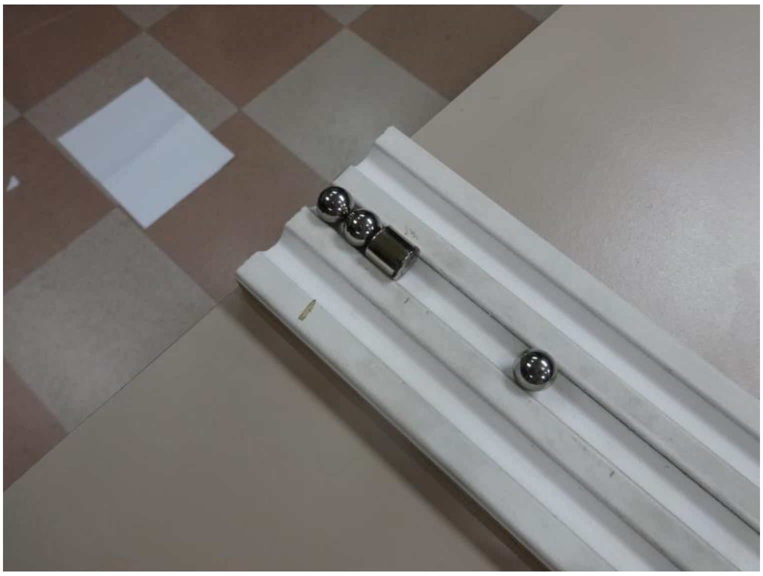
Why: The principles of particle accelerators, the main tool to study the smallest structure of matter, are to be investigated using a simple model.

What: Different designs are tested in order to produce a ball bearing travelling at the fastest speed possible at the end of the accelerator, as calculated from measurements of the ball's distance travelled and drop height from the launch point.

How: Magnets and ball bearings are used in a grooved channel, arranged in stages to accelerate the ball bearings using magnetic force.

Equipment

- a length of grooved molding, about 1 foot long,
- some steel ball bearings (BBs)
- some Neodymium magnets to accelerate the BBs along the grooves
- a white sheet of paper and carbon paper
- a metre ruler
- tape



One possible stage of the accelerator is shown here – the BB to the right is attracted to the cylindrical magnet in the middle and the BB to the far left then gets "kicked" to the left at high speed, launching off the table.

Procedure

After setting the magnets and BBs in the molding, align the end of the molding with the edge of the table.

Test fire your accelerator and observe approximately where the BB strikes the floor. Repeat for various different apparatus set-ups (vary the number and type of stages) until you think you have the optimum one that fires the BB furthest. Draw diagrams of your optimum apparatus set-up and the other variations you made in the set-up.

Now use masking tape to attach a piece of white paper to the floor near the location where the BB struck with the optimum set-up.

Place (do not tape) a sheet of carbon on top of the white paper.

Reload and fire several times.

Before you remove the white paper from the floor, measure the horizontal distances x from the end of the accelerator to the BB marks.

Measure the height y of the accelerator from the floor.

In order to calculate the final ball-bearing speed as it exits the accelerator one can use the definition

$$v = x / t \qquad \text{(Speed = Distance divided by Time)}$$

Here, x is the *horizontal* distance travelled by the BB while in flight and t is the time of flight. While it is straightforward to measure x with a ruler, it is difficult to measure t precisely with something like a stopwatch because it is so short. We can use a trick, however, to calculate t very precisely by measuring y, the height through which the BB falls, and using Galileo's equation of free fall

$$y = ½\, g\, t^2$$

$g = 9.80\ m/s^2$ is the acceleration (downward) due to gravity. Combining the last two equations allows us to eliminate t and we get an equation for the BB speed v as it leaves the accelerator in terms of quantities that are known or easily measured:

$$v = x \sqrt{(g / 2y)}$$

Use your measurements of x and y to calculate several values of v (take care that your units for distance are consistent when using the formula). Average the results and quote the final answer with an uncertainty.

Results

	x	y	v
Measurement 1	__________	________	__________
Measurement 2	__________		__________
Measurement 3	__________		__________
Measurement 4	__________		__________
Measurement 5	__________		__________
		Average Value	__________

Conclusions

Write a paragraph summarizing the key things you *learnt from your data*, quoting data to support your conclusions.