Magnetic Free Fall

The parts just snap together

Materials

pencil (must be sharpened, but if possible only to a very dull point -- see photos below)
2 ceramic "donut" refrigerator magnets (hole must be big enough for the pencil to slide through without touching)
2 squares of mat board with 1-inch sides
paper punch, one-hole (size of the hole must be a little smaller than the diameter of the pencil)

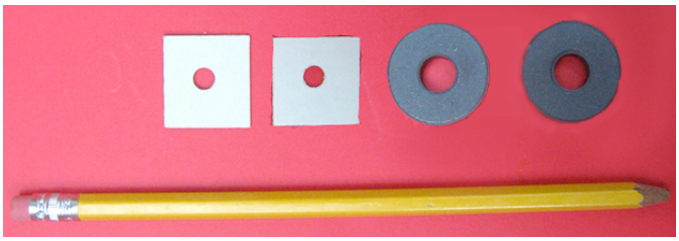

Figure 1

Assembly

• Punch a hole in the middle of each mat board square.
• Slide one of the squares onto the pencil at the pointed end. It should fit tightly -- work it on gradually so that the square doesn't bend or crease significantly. Slide it so that it is in approximately the position near the top of the pencil shown in Figure 2a (forget the magnets -- they will come in the next step). The square should fit tightly enough on the pencil so that it holds its position without easily sliding. (If the hole is too big, wrap some masking tape or scotch tape around the pencil as necessary.)
• Slide the two magnets onto the pencil so that they are on opposite sides of square, and are oriented so that they are attracted to each other (not repelled).See Figure 2a again.
• Slide the second square onto the pencil so that it is in approximately the position of the bottom square in Figure 2b.
• Pull the bottom magnet down until it rests on the bottom square. See Figure 2c.
• Slide the bottom square and magnet upward until the magnet is close enough to the top magnet that the magnetic attraction makes it jump upward and stick. See Figure 2d.
• Pull the bottom magnet down and slide the bottom square and magnet down a centimeter or two, so that the bottom magnet will rest a little below the point where it spontaneously jumps upward. See Figure 2e.

Figure 2a

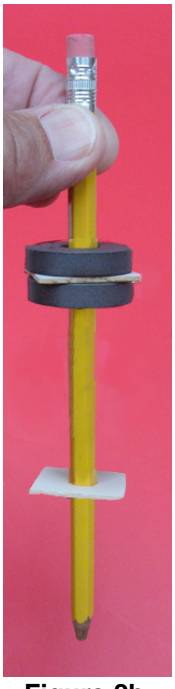

Figure 2b

Figure 2c

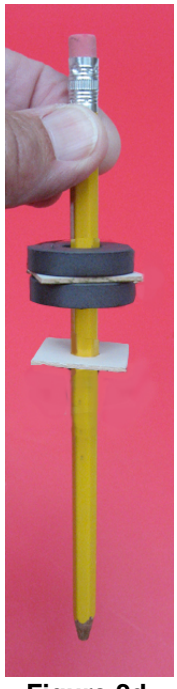

Figure 2d

Figure 2e

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To Do and Notice

Hold the device by the top of the pencil so that the pencil is hanging vertically, with the magnets in the position described for Figure 2e. The assembly should be held at approximately shoulder level.

Then release the whole assembly so that it drops to the floor, and **listen very carefully as it drops**. (If possible, drop it onto a coat , sweatshirt, or other soft material, rather than directly onto the hard floor. This will reduce wear and tear on the components.)

As the assembly falls, you should hear a clicking sound as the magnets snap together. This will likely occur fairly shortly after release, before the assembly has fallen very far. If this doesn't happen, adjust the gap between the magnets until it does.

NOTE: You can likely catch the device before it hits the floor, but after the magnets have snapped together.

What's Going On

There is a magnetic force of mutual attraction between the two magnets. This force acts downward on the top magnet, and upward on the bottom magnet.

The gravitational force on both magnets acts downward.

When you drop the whole device, the magnetic and gravitational forces on the top magnet are both downward, but on the bottom magnet the gravitational force is downward and the magnetic force is upward.

The top magnet (along with the whole assembly it is pushing on) falls with an acceleration slightly **larger** than normal gravitational acceleration. The bottom magnet (which is free to lift off its square) falls with an acceleration slightly **smaller** than normal gravitational acceleration.

The greater acceleration of the top magnet and assembly closes the distance between it and the bottom magnet as they fall. Magnetic force increases dramatically in an exponential manner as distance between the magnets decreases, so the force rapidly becomes large enough to snap the magnets together.

Going Further

• Try adjusting the gap between the magnets to see if you can get the magnets to snap together either just after being dropped, or just before they hit the floor.

• Reverse the orientation of the bottom magnet so that the two magnets repel.

• Hold the assembly horizontal, with the magnets oriented so that they attract, but separated enough so they don't snap together. Drop the assembly. Repeat with the magnets oriented so they repel.

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