Eddy Currents

Demonstration

By dropping a magnet through a copper tube, participants learn how magnetic fields can be observed.

Number of Participants: 2-30

Audience: Middle (ages 11-13) and up

Duration: 5-10 mins

Difficulty: Level 1

Materials Required:

- Eddy current tube (any size, aluminum, copper, or brass), ~1 m recommended
- Neodymium magnet appropriate for your sized tube
- Pencil or other non-magnetic item of the same size and color as magnet
- PVC pipe (similar diameter and length as metal tube)

Setup:

1. Collect the supplies listed above.

Presenter Brief:

This demonstration gives a visualization of magnetic field interactions to a large group. Be familiar with the concept of eddy currents and why the magnet falls slower in the pipe. A basic understanding of Lenz's law, Faraday's law of induction, and resistivity are helpful.

Vocabulary:

- Current – the flow of an electrical charge
- Permanent magnet – a magnet that retains its magnetic properties in the absence of an inducing field or current.
- Eddy Current – Loops of electrical current that are induced within a conductor by a change in magnetic field within the conductor.

Physics & Explanation:

Middle (ages 11-13) and general public:

Gravity is one of the fundamental forces of nature, is attractive, and exists between any two objects with mass. Since the Earth has a lot of mass, the force of gravity between the Earth and an object will cause the object to accelerate towards the Earth (and be easily observed). This is why things fall toward the center of Earth.

> Drop a strong magnet by itself so that it falls straight to the floor, as expected. Be careful because magnets can be fragile. Next, holding a PVC pipe perpendicular to the ground and drop a magnet through it. Be sure the magnetic falls in the center of the pipe so that there is no friction between the magnet and the side of the PVC pipe.

The magnet will fall at the same speed when dropped through the PVC pipe, which is what most participants will expect.

> Next, drop the magnet through the metal pipe. It will take several seconds for the magnet to fall through. The longer the pipe and the stronger the magnet, the starker the difference.

The participants will most likely be surprised. Many will immediately make the connection that the reason is magnetism, but might not understand the details.

> To prove that the reason for the slow fall is not friction or any other trick with the pipe, drop the pencil by itself, through the PVC pipe, and through the metal pipe to show that it falls at the same speed through each one.
>
> If your metal pipe's diameter is large enough, encourage participants to look down the pipe as you drop the magnet.
>
> If available, have a second pipe where a small slit is cut along the axis on the entire length of the pipe. The magnet will not be slowed by the cut pipe, again surprising the audience.

The magnet falls slowly within the metal tube because of magnetism, but not because there is a magnetic force between the pipe and magnet. Put simply, the magnet does not fall slowly because it wants to stick to the pipe.

> To demonstrate this is not the case, hold the magnet on the outside of the pipe and show that there is no magnetic force between the two.

While the pipe is metal, it is not magnetic like, for instance, iron.

Explain that the magnet has a permanent magnetic field that moves through space when the magnet is dropped. Moving magnetic fields create electrical currents within electrical conductors such as the metal tube.

Electric currents also create their own magnetic fields. As the magnetic field of the magnet moves through the metal tube, it induces an electrical current within the tube which also creates its own magnetic field. However, the magnetic field created by the current is in the opposite direction, so the two magnetic fields oppose each other. This is illustrated in Figure 1.

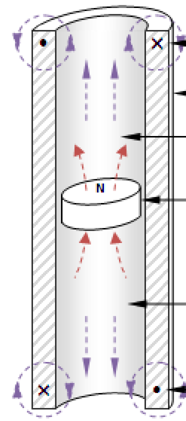

Figure 1: Bored of Studies

The metal tube with the slit will NOT slow the magnet because a current around the radial axis of the tube cannot be complete, because of the slit. Thus, the magnet falls quickly if there is a slit along the long axis of the tube.

Even though the metal tube does not have a permanent magnetic field, the presence of the falling magnet induces a current and therefore an opposite magnetic field in the pipe. These opposing magnetic fields also exert a force on the magnet which is opposite of the force of gravity.

Additional Resources:

- K.D. Hahn, E.M. Johnson, A. Brokken, & S. Baldwin (1998) "Eddy current damping of a magnet moving through a pipe", American Journal of Physics 66:1066-66.

Click or tap here to enter text.