Quantum Levitation
Lesson Plan

Amount of time Demo takes: 5 mins.

Don’t try this at home!

Materials

- Quantum Levitation Starter Kit
- LN2
- LN2 safety Supplies (including gloves and safety glasses)
- Styrofoam cooler to chill levitators and hold liquid nitrogen

Set-up/Instructional Procedures
There are a variety of demonstrations you can perform with this kit.

Quantum Levitator Experiment

1. Set out the quantum levitator board (6 magnets on one end, two circles on the other end)
2. Fill the levitator with LN2
3. Quantum Locking
   a. Place the frozen levitator above the rectangle of 6 magnets.
   b. Show how the levitator is frozen in the vicinity of the magnets
   c. Using tweezers, gently try to move it in all directions and feel the resistance due to the pinning force.
   d. Flip the superconductor upside down to show that its orientation does not make a difference.
4. Frictionless Bearing
   a. Lock the levitator above the pair of ring magnets. It will rotate freely around the axis of the magnets but will be locked in any other direction.
   b. Shift the superconductor sideways to emphasize that it rotates around the magnet axis and not around its center.
   c. The superconductor will move freely as long as the magnetic field inside it (magnetic flux) stays the same.
Magnetic Levitation

1. Take out the circular Magnetic Levitation Track. Place the two wooden supports below it so it isn’t sitting directly on the table.
2. Place the superconductor on the track top of the track
3. Show that it rotates freely along the track.
4. Show that the pinning force is stronger closer to the track but you can place the place the superconductor at different heights.

Suspension

1. Open the screw at the center of the rail.
2. Flip the rail and put it back in place.
3. Carefully place the superconductor below the rail. If it fails to lock flip it so the superconductor (and not the foam) is closer to the magnets. Be careful of excess liquid nitrogen spilling out.
4. Show how it moves around freely
5. Flip the track back to its original position after performing this demonstration.

Double Levitation

1. Place one superconductor on the rail as high as possible. Try to fill it with a minimal amount of liquid nitrogen; this will allow a maximal levitation height.
2. Now place the second superconductor as low as possible. Notice that if it is too close to the magnets it will slow down more quickly; so be prepared to give it a boost more often.
   a. Another issue to pay attention to is the wrapping: if it is not wrapped neatly the plastic/aluminum might interfere with the other levitator.
3. Show how the two superconductors move without interfering with each other.

SAFETY!

● Tape a line on the ground 3 ft. from the table to use a barrier for students when working with Liquid Nitrogen.
Goggles and protective gloves **must** be worn at all times while handling the liquid nitrogen, because liquid nitrogen is -321 °F, it can cause frostbite if it touches skin. Use caution when pouring it and follow appropriate LN2 SOP procedures. Make sure the participants stay back far enough not to be hit by splashing liquid nitrogen. Don’t be afraid to tell the kids to step back when pouring. Take extra care to ensure no droplets get into your glove, to avoid serious injury if this happens, remove the glove IMMEDIATELY. We don’t want to cause injury to yourself or the public.

- This experiment contains extremely strong neodymium magnets. If not handled properly, they can cause serious injury. Keep the magnets away from magnetic materials and far from sensitive electronics.
- Safety glasses and gloves should be worn

**Lesson’s Big Idea**

- Magnetic Fields can be used to create levitation and therefore eliminate sliding friction between two surfaces.
- The superconductor must be supercooled to take on magnetic properties (but it is not actually a magnet! (Meissner Effect))
- The superconductor and track oppose one another magnetically - much like trying to put the north ends of two magnets together.
- **Magnetic Levitation:** The track is a larger version of the ring magnets. The fact that the magnetic flux does not change along the track allows the superconductor to move around freely.
- **Suspension:** Moving around in circles is possible due to the circular symmetry of the magnetic field. In all other directions, the superconductor is locked in levitation. The levitation can, thus, be easily transformed into suspension.
- **Double Suspension:** The superconductors are not magnetic (at least not substantially). If there were magnetic, they would have affected each other. This experiment proves that the levitation is not (mainly) due to the Meissner effect. In the Meissner state the superconductor acts as a perfect diamagnet, having a magnetization of equal magnitude and opposite direction to the external field.

**Background Information**
● Meissner Effect - the expulsion of a magnetic field from the interior of a material that is in the process of becoming a superconductor, that is, losing its resistance to the flow of electrical currents when cooled below a certain temperature, called the transition temperature, usually close to absolute zero.

Assessment/sample questions you can ask
1. Why doesn’t the levitator (superconductor) leave the track/magnets?
   a. Pinning force - repulsive and attractive forces keeping the superconductor in place.
2. What is a superconductor?
   a. Materials that conduct electricity with zero resistance below a certain temperature.

Clean Up
● Note: The superconductor inside the quantum levitator is sensitive to moisture. If not handled properly, it will lose its superconducting properties. You should always let the levitator warm up and dry after usage. Store the levitator in a dry atmosphere, preferably inside a sealed container with silica gel.
● Wrap all parts of the track and quantum levitator board in bubble wrap.
● Put levitators back in their boxes once warmed to room temperature and very dry.
● Note: This demonstration is extremely valuable and fragile. Please treat carefully.

Next Generation Science Standards
● 3-PS2-1
● 3-PS2-3
● 3-PS2-4
● MS-PS2-3
● HS-PS2-5