Small Levitating Disk

What Happens

A magnet will levitate above a piece of superconductor which is kept cold in liquid nitrogen. The magnet can be spun like a spinning top and will continue to spin for a great deal of time. The magnet can be pushed down – a great deal of force is required. The magnet can be picked up and the superconductor will also be raised up.

How to make it Work

1) Remove top foam cover, but leave Pyrex dish in foam base
2) Ensure foam spacer is present in bottom of Pyrex dish
3) Place a 2.5cm YBCO superconductor disk into the Pyrex dish on top of the foam spacer
4) Balance a glass microscope slide across the top of the Pyrex dish
5) Place a 2cm magnet on top of the glass slide, directly above the piece of superconductor
6) Taking all required safety precautions (see risk assessment) use a plastic cup to carefully remove a small amount of liquid nitrogen from a 2 litre nitrogen bucket and tip into Pyrex dish.
7) Top up dish as required.
8) Once superconductor is cooled (bubbling will reduce), it will move sideways in the Pyrex dish if the glass slide and magnet are moved slightly sideways.
9) Glass slide can now be removed and magnet is levitating.

If magnet becomes ‘detached’ from the superconductor (usually either by being pulled off or if the superconductor is allowed to warm up) the superconductor needs to be allowed to warm up in the room for a few minutes before it is re-set by following the above instructions.

Why it Works

This is an example of the Meissner effect - the weak magnetic field from the nearby permanent magnet can be expelled by the superconductor. This is because current flows in the surface of the material, generating a perfect mirror repulsive magnetic field i.e. the superconductor is a perfect diamagnet. Diamagnetism is a quantum mechanical effect arising from the change in the orbital velocity of the electrons around the nucleus of the atom in response to an applied magnetic field. All materials show this diamagnetic response to an applied field although, because this is a weak effect, it is overpowered in those materials which also exhibit ferromagnetism or paramagnetism. Common materials such as water, organic compounds (such as wood, plastics), metals (copper, gold, mercury) and even your body are all diamagnetic, but only very slightly so we don’t usually notice it. There is also another effect at work here which explains why the superconductor can be lifted up by the magnet. As the superconductor was cooled in the presence of the magnetic field so the magnetic field is 'pinned' into the sample by the presence of impurities in the superconductor. If the magnet is spun, the spinning continues for a great deal of time as there is only air resistance and no friction!

Figure 1: Set up, ready to add liquid nitrogen

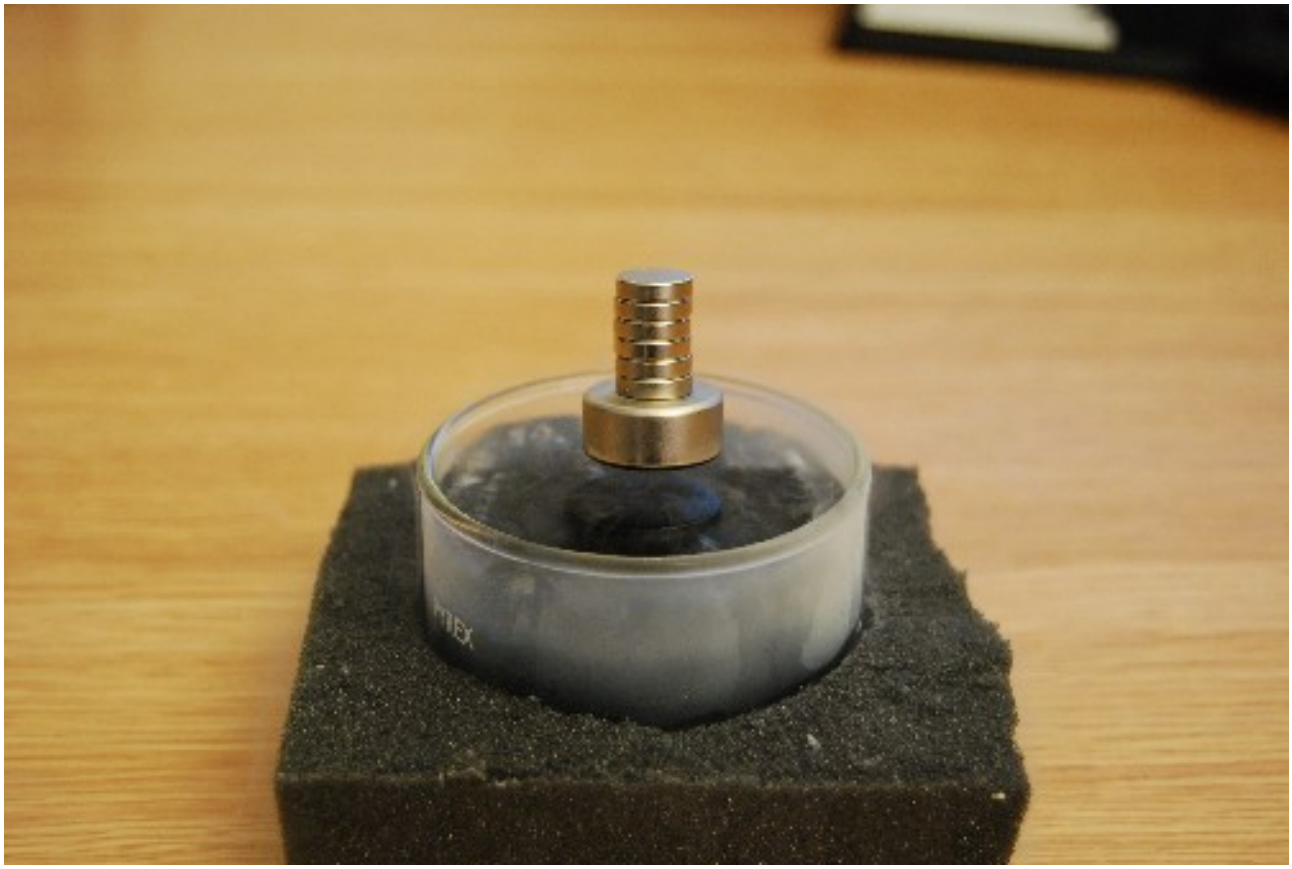

Figure 2: Levitating, after liquid nitrogen added and glass slide removed.

Figure 3: Superconductor raised up with magnet

Large Levitating Disk

What Happens

A magnet will levitate above a piece of superconductor which is kept cold in liquid nitrogen. The magnet can be spun like a spinning top and will continue to spin for a great deal of time. The magnet can be pushed down – a great deal of force is required. The magnet can be picked up and the superconductor will also be raised up.

How to make it Work

1) Ensure foam spacer is present in bottom of Pyrex dish
2) Place a 5cm YBCO superconductor disk into the Pyrex dish on top of the foam spacer
3) Balance a two glass microscope slides stuck together with sticky tape across the top of the Pyrex dish
4) Place the 4cm magnet on top of the glass slide, directly above the piece of superconductor
5) Taking all required safety precautions (see risk assessment) use a plastic cup to carefully remove a small amount of liquid nitrogen from a 2 litre nitrogen bucket and tip into Pyrex dish.
6) Top up dish as required.
7) Once superconductor is cooled (bubbling will reduce), it will move sideways in the Pyrex dish if the glass slide and magnet are moved slightly sideways.
8) Glass slide can now be removed and magnet is levitating.

If magnet becomes 'detached' from the superconductor (usually either by being pulled off or if the superconductor is allowed to warm up) the superconductor needs to be allowed to warm up in the room for a few minutes before it is re-set by following the above instructions.

Why it Works

Same as for the small disk described above.

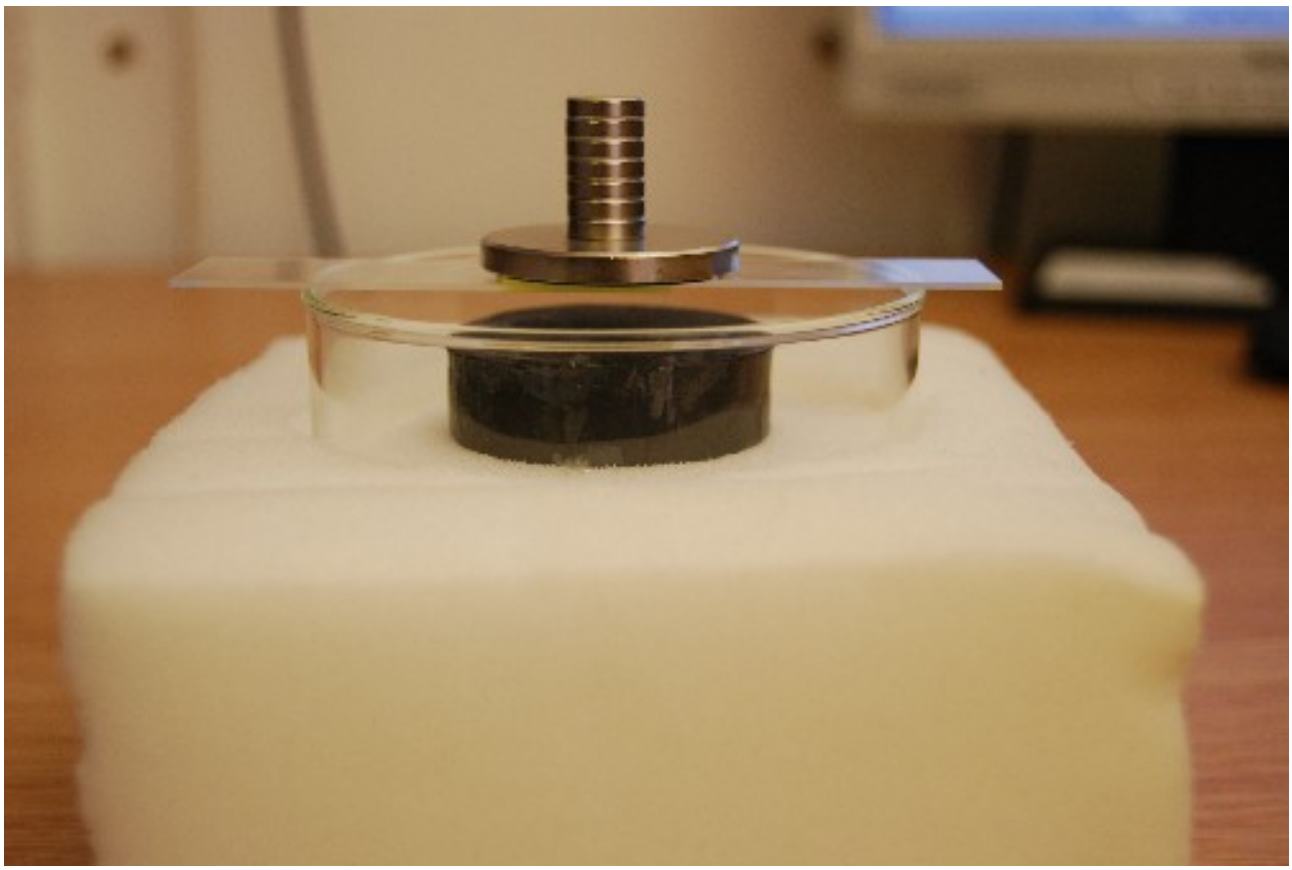

Figure 4: Set up, ready to add liquid nitrogen

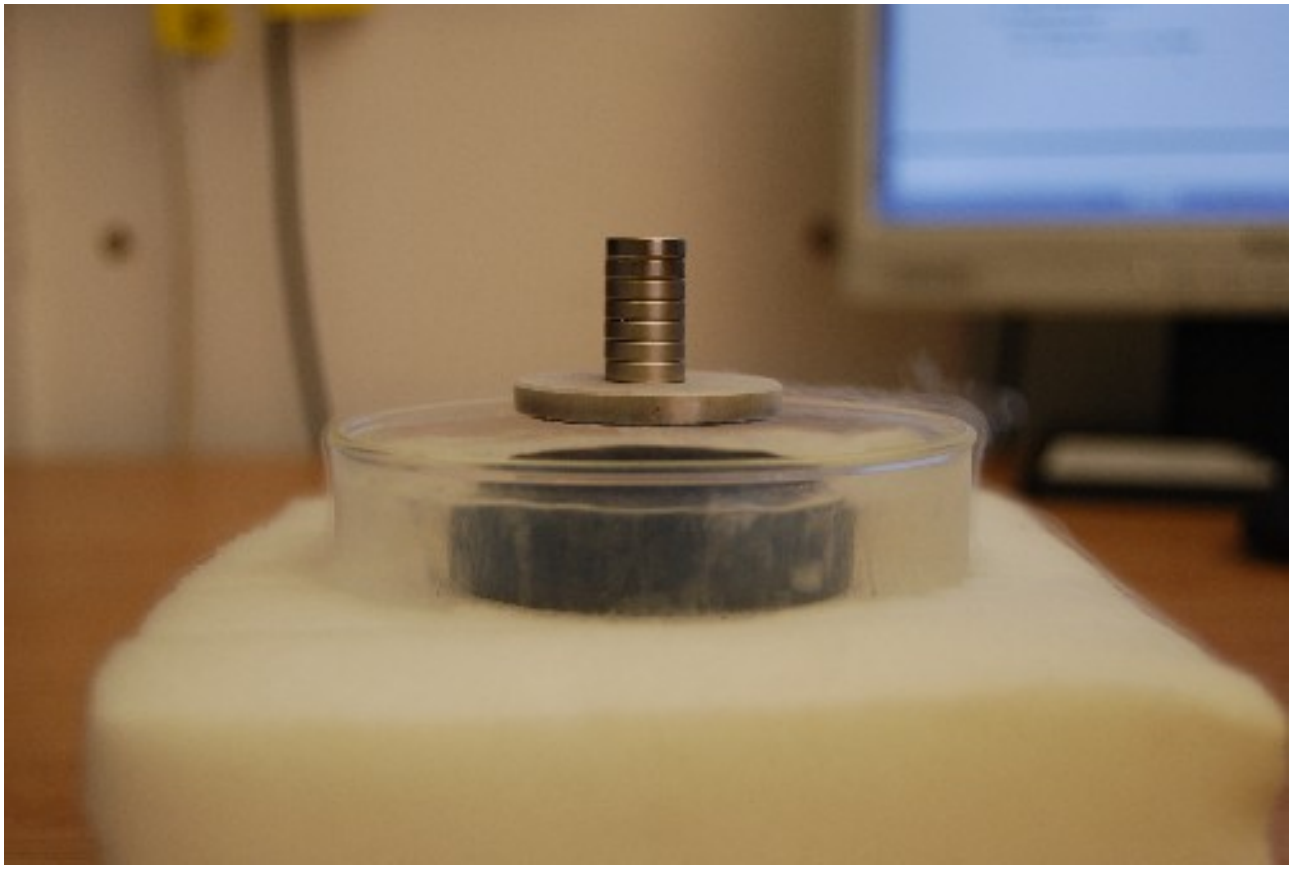

Figure 5: Levitating, after liquid nitrogen added and glass slide removed.

Figure 6: Superconductor raised up with magnet.

Linear Track

Note – when not in use always keep track in foam packaging and tied up with bungee. This prevents the track sticking to other magnetic objects and from being damaged.

What Happens

Piece of YBCO superconductor will levitate above magnetic track and oscillate back and forth.

How to make it Work

1) Unpack magnetic track, unfold and place on flat surface.
2) Place a 2.5cm piece of YBCO superconductor in a Pyrex disk or plastic cup and carefully add liquid nitrogen.
3) Once cooled, use non-magnetic tongs to remove superconductor from liquid nitrogen and place onto track.
4) Use tongs or a gloved hand to push the superconductor down onto the track to 'pin' in the magnetic field.
5) Gently push superconductor and it will oscillate back and forth.
6) When superconductor warms up, it will gently come to rest on the track. Just use tongs to place back into liquid nitrogen to re-cool and then start again from step 3

The pieces of YBCO are best used when they are wrapped in cotton wool using yellow tape. (Yellow 1350 polyester tape is made by 3M and can be ordered from www.farnell.com order code 753002). This only needs to be done once before use (it survives being cooled many times) – but can be reapplied when it becomes tatty. This simply provides insulation, preventing the superconductor warming up so quickly meaning the levitation lasts longer.

Why it Works

It's the same principle as for the levitating disks described above but on a track. The three magnets across the width of the track create a magnetic valley which the superconductor sits in. At the ends of the tracks the magnets are reversed so as to bounce the superconductor back.

How to Build/Repair it

The magnets in the track need to be set up to create a magnetic valley - so the track needs to be three magnets wide, usually with the magnets stuck to a piece of steel. Each magnet along the length of the track needs to have a top face of one pole and the opposing downward face of the other pole. Looking across the track three magnets are needed, the two edge magnets have, say north upwards and the middle magnet has south upwards. On a linear track, the superconductor can be stopped and sent in the reverse direction at the ends by reversing the arrangement of the magnets so that the outer magnets are south upwards and the inner magnet is north upwards. Typically around the last eight magnets are reversed. Sometimes the magnets will dislodge – especially around the fold in the track. They can be replaced by referring to the text above, and diagram below and remembering that opposite poles attract and like poles repel.

Figure 7: Configuration of magnets for a magnetic track. Green is north and blue is south. Top is side view at edge of track and bottom is top view.

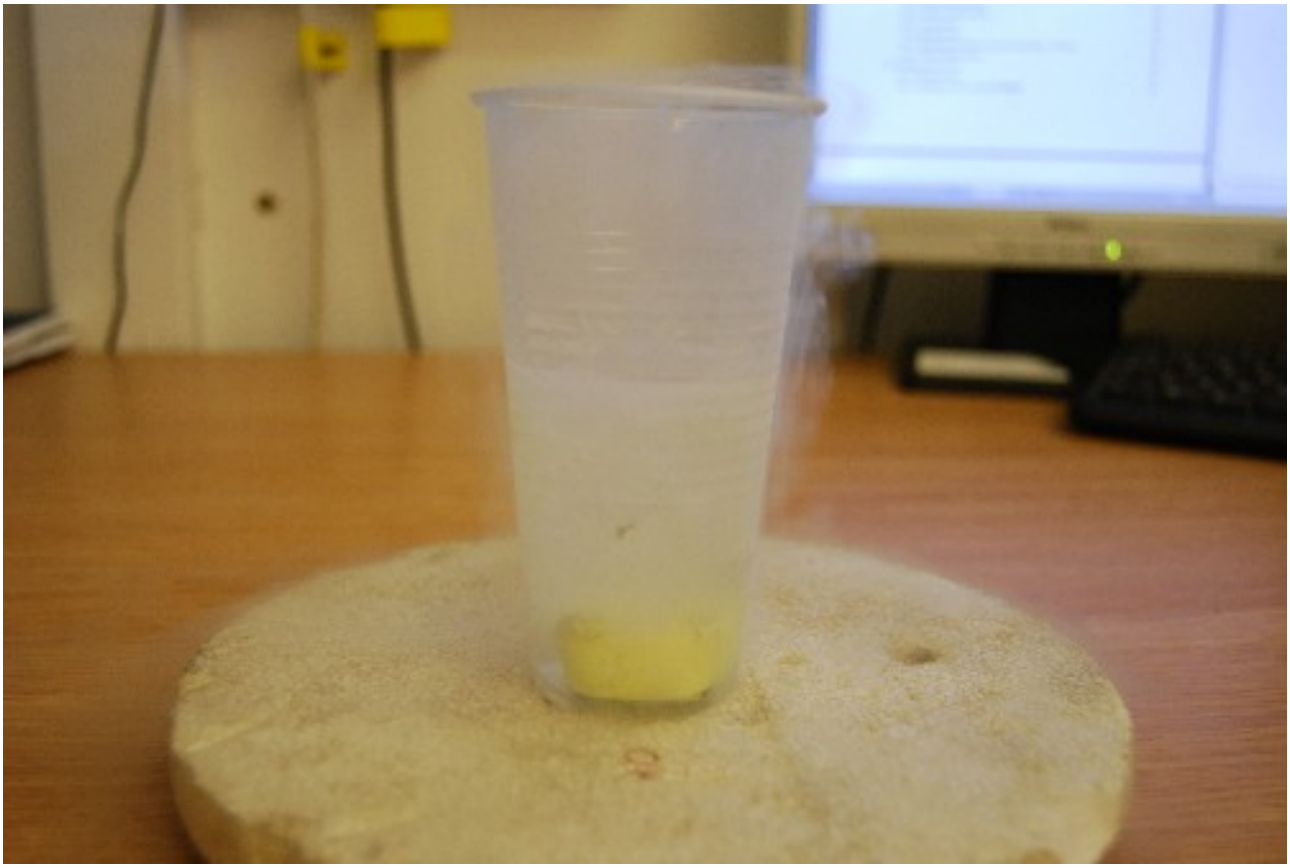

Figure 8: Superconductor wrapped in yellow tape and cotton wool cooling in a plastic cup of liquid nitrogen.

Figure 9: Superconductor levitating above a linear track.

Oval Track

Note – when not in use always keep track in foam packaging and tied up with bungee. This prevents the track sticking to other magnetic objects and from being damaged.

What Happens

Piece of YBCO superconductor will levitate above magnetic track and loop around.

How to make it Work

1) Unpack magnetic track and place on flat surface.
2) Place a 2.5cm piece of YBCO superconductor in a Pyrex disk or plastic cup and carefully add liquid nitrogen.
3) Once cooled, use non-magnetic tongs to remove superconductor from liquid nitrogen and place onto track.
4) Use tongs or a gloved hand to push the superconductor down onto the track to 'pin' in the magnetic field.
5) Gently push superconductor and it will loop around the track.
6) When superconductor warms up, it will gently come to rest on the track. Just use tongs to place back into liquid nitrogen to re-cool and then start again from step 3

The pieces of YBCO are best used when they are wrapped in cotton wool using yellow tape. (Yellow 1350 polyester tape is made by 3M and can be ordered from www.farnell.com order code 753002). This only needs to be done once before use (it survives being cooled many times) – but can be reapplied when it becomes tatty. This simply provides insulation, preventing the superconductor warming up so quickly meaning the levitation lasts longer.

Why it Works

It's the same principle as for the levitating disks described above but on a track. The three magnets across the width of the track create a magnetic valley which the superconductor sits in.

How to Build/Repair it

This is the same as for the linear track, except there is no reversal of the order of the magnets needed at the 'end' of the track.

Figure 10: Superconductor levitating above the oval track.

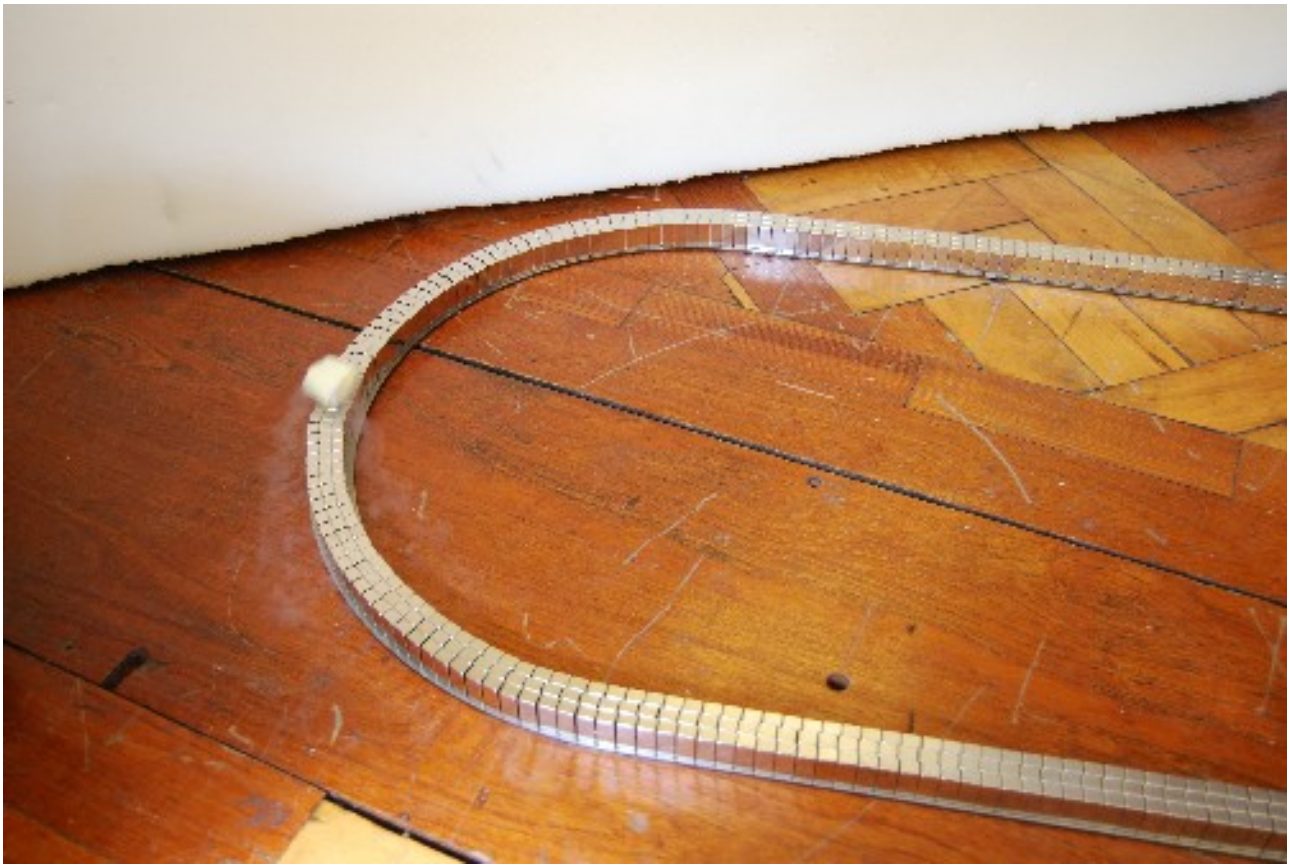

Figure 11: Superconductor levitating above the oval track.