

How to simply demonstrate diamagnetic levitation with pencil lead

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How to simply demonstrate diamagnetic levitation with pencil lead

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Abstract

A new simple arrangement how to demonstrate diamagnetic levitation is presented. It uses pencil lead levitating in a track built from neodymium magnets. This arrangement can also be used as a classroom experiment.

Online supplementary data available from stacks.iop.org/PhysED/51/014001/mmedia

Introduction

Few experiments with diamagnetic levitation are well known. These experiments usually use pyrolytic graphite as a diamagnetic material, with high magnetic susceptibility and low density. For example, the widely known arrangement using four magnets and pyrolytic graphite sheet (and some modifications of this experiment) can be bought as a kit [1]. This experiment was described in detail in [2].

In another well-known arrangement, a small neodymium magnet levitates between pyrolytic graphite (or bismuth) and a magnet. This arrangement can be bought as a kit as well (see [3]), and was described in detail in [4].

An arrangement suitable for overhead projection was described in [5]—it uses two pieces of pyrolytic graphite, two ceramic magnets and one small neodymium magnet.

In all of these papers pyrolytic graphite or bismuth is needed—so substances that students do not usually have in everyday life. We would like to present a different arrangement, in which a common object can levitate. As a diamagnetic material we use mechanical pencil lead, this lead levitates in a ‘track’ built from commonly available magnets. So, this experiment can be used as a pupil’s experiment too.

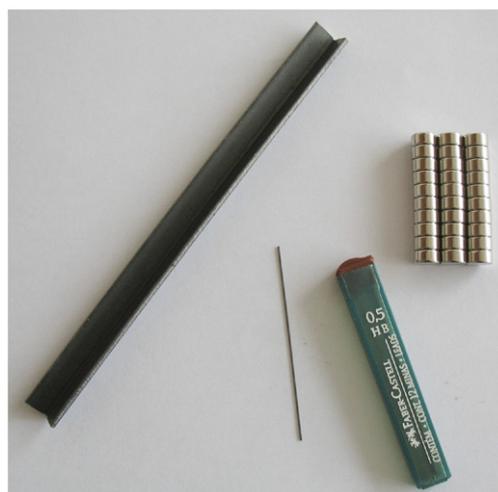


Figure 1. Equipment: iron L profile, neodymium magnets, leads for mechanical pencils.

Equipment

Experiment equipment can be seen in figure 1. We have an iron L profile rod with a width of 1 cm and approximately 15 cm in length, about 30 cylinder neodymium magnets with diameter 8 mm and 4 mm height, and a piece of lead from a mechanical pencil, 0.5 mm in diameter¹. All of these components can be bought for less than £7.

¹ We use pencil leads made by Faber–Castell, hardness HB.



Figure 2. Magnet arrangement in the track.



Figure 3. Pencil lead levitates inside the track.

The precise size of magnets is not essential, but an 8 mm diameter proved to be optimal. When magnets of a larger diameter are used, the spaces between them are too big so the lead has to jump over it and it will not freely move. It is possible to carry out the experiment with smaller magnets, but one will need more magnets for the same length of the track.

The number of magnets is also not essential—the more magnets you have, the longer track you can build. But we recommend 30 magnets as a minimum, because a track made from 30 magnets is only a bit longer than the pencil lead.

It is necessary to choose the right pencil lead because it was discovered that not every type of lead would work. The reason being that there is often a small amount of iron in graphite from which leads are made, and if there is too much iron in it the attractive force between the iron and magnets is bigger than the diamagnetic repulsive force, so the pencil lead does not levitate. According to our experience most pencil leads from Faber–Castell work. On the other hand, leads from other producers we tried proved to not be suitable for our experiment. Spectroscopic analysis done by a colleague of ours found only trace amounts of iron in our sample of Faber–Castell leads, and up to 40

times more in samples from other producers. The easiest way how to find if the lead works is just trying it, spectroscopic analysis is not necessary of course.

Arrangement

Magnets are placed on the L profile with their poles arranged alternately (see figure 2, north poles are marked). One magnet is always touching inside the L profile, and the second one is tucked inside it². For a more detailed description see video 1 (stacks.iop.org/PhysED/51/014001/mmedia).

The pencil lead placed inside this track can freely move from one side of the track to the other side (see figure 3 and video 2 (stacks.iop.org/PhysED/51/014001/mmedia)). From the side view it is possible to see, that the pencil lead levitates in a stable position about 0.5 mm above the track (see detail in figure 4).

The direction of the magnetic force which compensates the lead's weight is in the direction of decreasing magnetic field. A detailed description about the balance between magnetic force and gravity in experiments like this can be found

² Arrangement of one row of our magnets is similar to the so called Halbach configuration, but the magnetic flux is closed by the iron profile in our case, not by other magnets.

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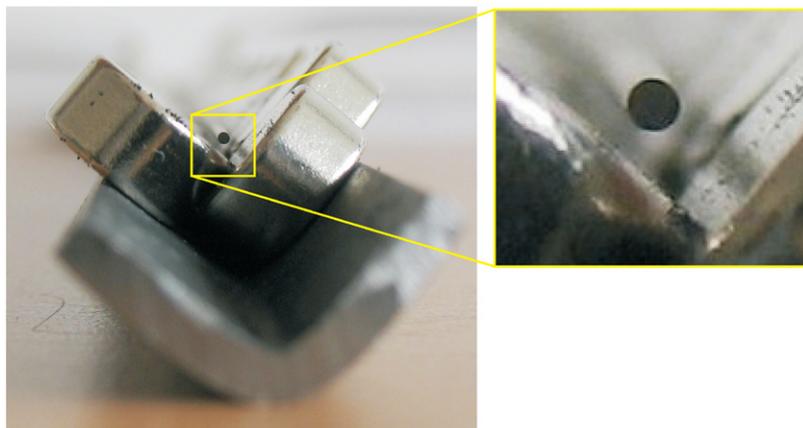


Figure 4. Detail of the pencil lead from side view.



Figure 5. End of the track.

in [6] where a widely known experiment with a levitating frog is described.

It is better to ‘close’ the track using one magnet on each side so that the lead remains in the track and does not fall out of it. See the detail of the end of the track in figure 5.

Conclusion

The experiment we described is very simple and cheap, however it can be used as an illustrative example of the behaviour of diamagnetic materials. Its advantage is that one needs only commonly available material that students know very well.

Students can build this track by themselves or a teacher can just show it to them and let them to play around with it. According to our experience, students at high school (ages 16–17) like

and appreciate this experiment. Most of them play with it with and comments like ‘Wow, it’s cool...’ are made.

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