

U45051 Diamagnetic Levitation Apparatus

Instruction Sheet

1/04 ALF



- ① Base plate
- ② Plastic bell housing
- ③ Plastic plate
- ④ Graphite plate
- ⑤ NdFeB-magnet
- ⑥ Retaining ring
- ⑦ Hex nut
- ⑧ Ring magnets

The Diamagnetic Levitation Apparatus allows the demonstration of the mode of action of diamagnetic materials.

1. Safety instructions

- Keep all the magnets away from electronic equipment, magnetic media and delicate instruments.
- The ring magnets are brittle and may break if dropped.
- The graphite plates are easily broken or scratched. Handle with care.
- The cube shaped magnet is very brittle and may break merely by flying to the ring magnets.
- Use only finger pressure to tighten the hex nuts.
- If needed clean only with mild dish soap. Do not use abrasive cleaners or solvents.

2. Description, technical data

Within a plastic bell housing there are two graphite plates. Between these plates a cubic shaped NdFeB-magnet, plated with 24K gold, levitates freely. The gravitational force acting on the magnet is almost entirely counteracted by the force of attraction from a ring magnet located above the plastic covering. The two diamagnetic graphite plates, one above and one below the NdFeB magnet, compel it into a stable equilibrium since both poles of the magnet are repelled by the graphite plates (diamagnetism).

Dimensions:

Base plate: 95 mm x 95 mm
Height: 135 mm

2.1 Scope of delivery

- 1 Levitation apparatus
- 2 Transparent plastic plates
- 1 Socket wrench

3. Theory

The physicist S. Earnshaw proposed the following theorem in 1848: it is not possible for charges or magnets to be placed in a stable levitated state in a static field obeying an inverse square law. He further stated, however, that it would be possible to achieve this with the help of diamagnetic materials.

The availability of very powerful rare-earth metal magnets has made it possible to design a levitation apparatus such as this using graphite as the diamagnets. Diamagnetic materials are repelled from both magnetic poles.

The action of this levitation apparatus may be understood in terms of either forces, or potential energy.

The force of earth's gravity pulls downward on the cube magnet, while the ring magnets exert an upward force. The position of the ring magnets is chosen in such a way, that the two forces equal each other. If the gravity is stronger than the force of attraction, the cubic magnet will fall down. In the opposite case it will move upwards.

The diamagnetic property of graphite effects the cubic magnet in such a way that it is repelled from the respective plate. This force is tiny but it is enough to stabilize the NdFeB-magnet in a state of stable equilibrium.

To get a deeper understanding of the state of equilibrium we look at the potential energy of the cubic mag-

net. The graph in figure 1 shows the potential energy of the cube if it were located at different heights within the apparatus, assuming the ring magnets and graphite plates were removed. Masses tend to move to the place where their potential energy is the lowest. To move them to a higher place where their potential energy is greater one has to do work and expend energy.

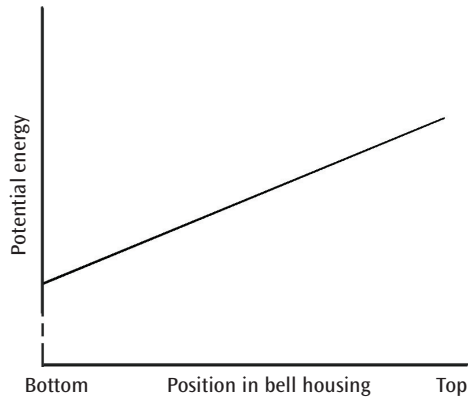


Fig.1: Potential energy of the cubic magnet at different positions in the apparatus without graphite plates and without ring magnets

The next graph in fig. 2 considers the potential energy of the cube as the result only of the nearness to the ring magnets, assuming that gravity is not a significant force. Its potential energy would be the lowest at a position closest to the ring magnets. We would have to expend energy to remove it from the magnets and it would gain this energy as potential energy.

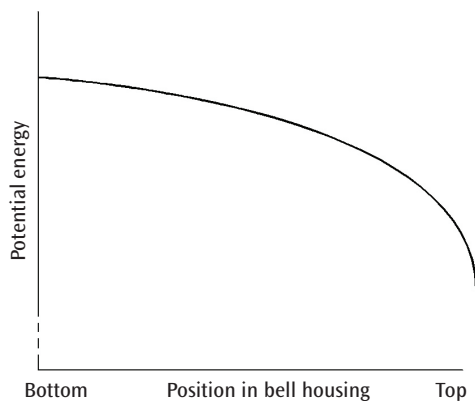


Fig.2: Potential energy of the cubic magnet at different positions in the apparatus without graphite plates and no gravity

The third graph in fig. 3 shows the total potential energy of the cubic magnet in various positions within the apparatus, when both the gravity and the attraction of the ring magnets are considered. Of special interest is the area between the vertical lines, which represent the positions of the plastic plates. Fig. 4 shows this area magnified.

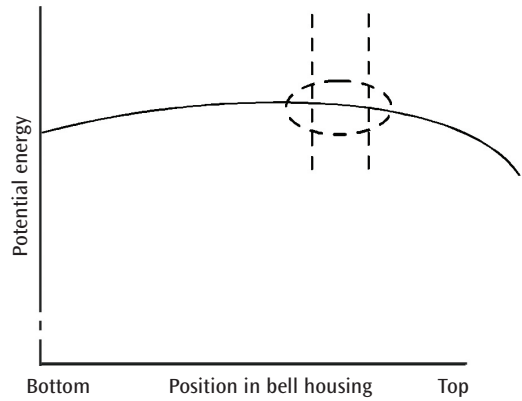


Fig. 3: Total potential energy of the cubic magnet at different positions in the apparatus with plastic plates

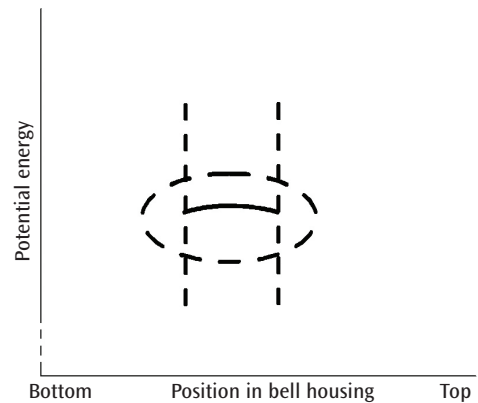


Fig.4: Magnification of fig.3

The graph shows that the cube has the greatest potential energy at a point approximately half way between the plastic plates. At this point the cube magnet is in equilibrium, but it is unstable equilibrium.

If the plastic plates are now replaced by the graphite plates, we would have to expend energy to push the cube magnet closer to the graphite plates. Its potential energy would be greater near the graphite plates. The graph in fig. 5 shows this fact.

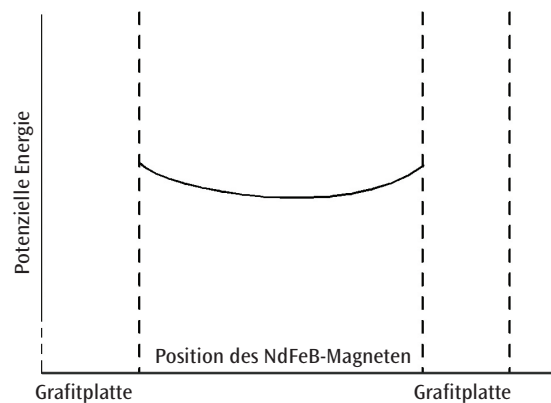


Fig.5: Potential energy of the cubic magnet between the graphite plates

The point with the lowest potential energy is about midway between the two graphite plates. In this point the NdFeB-Magnet is in a stable state of equilibrium and is able to levitate at this location.

4. Operation

- The apparatus is supplied as a sealed unit. It may be opened to permit experimentation.
- Insert the long arm of the socket wrench into the four holes in the side of the base of the apparatus. Unscrew the screws three full turns. Turn counter-clockwise.
- Place one hand on the base, and using the other hand gently lift the bell housing.
- Remove the loose side panel. The graphite plates may now be replaced by the plastic plates.
- Reassemble the apparatus in the opposite way. Care-

fully tighten the four screws. Do not use excessive force to avoid damaging the bell housing.

- To adjust the position of the NdFeB-magnet loosen the upper hex nut and move the ring magnets with the help of the lower hex nut up or down to decrease respectively increase the attraction. If necessary hold the retaining ring with one finger. Do not use tools to tighten the nuts.

5. Sample experiments

- Replace both graphite plates with the plastic plates and try to put the NdFeB-magnet into a state of equilibrium.
- Repeat the experiment with one graphite and one plastic plate (top or bottom).
- Discuss the results on the basis of the theory.