Dyson Day Outreach Activity: Levitation using Superconductors

Ed Pearson
University of Cambridge

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1 Introduction

The aim of this outreach activity was to give students a first-hand demonstration of superconductivity and magnetic levitation using cryogenically cooled type-II superconductors. Students from Year 12 observed a physical demonstration of the theory discussed at the start of the session, observing the remarkable effects of flux pinning and stable levitation over a magnetic track.

The activity linked key theoretical concepts from materials science and condensed matter physics to an accessible and exciting live demonstration. The topic also served as a bridge to emerging energy technologies such as flywheel energy storage systems (FESS), which make practical use of superconducting bearings.

2 Theory

Superconductivity is a quantum mechanical phenomenon observed in certain materials, where electrical resistance drops to zero below a critical temperature. Type-II superconductors allow for the penetration of magnetic flux lines in the form of quantised vortices, which are then "pinned" in place by defects in the material.

This pinning creates a force that stabilises the superconductor's position relative to the magnetic field. This means that type-II superconductors can be used for stable magnetic levitation that can resist potential disturbances to the flywheel's position. This effect is the basis of superconductor bearings in flywheels and was the main focus of the demonstration.

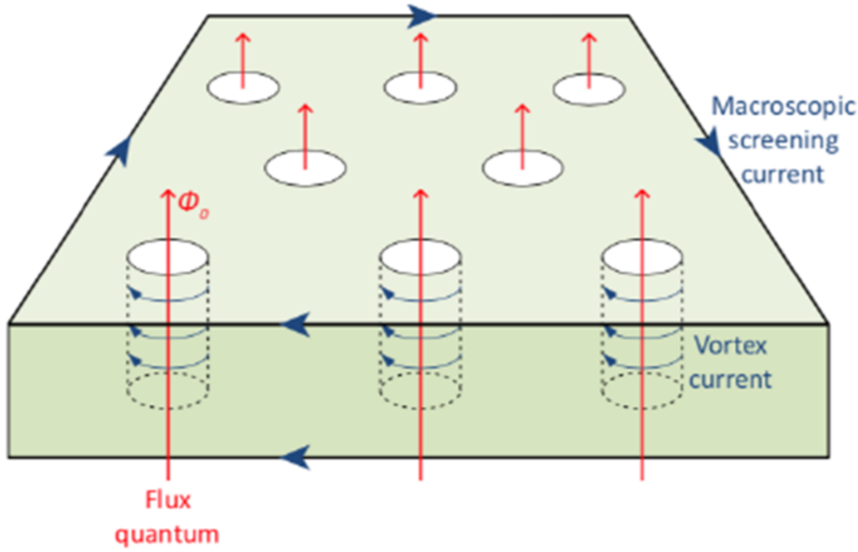

Figure 1: Schematic of flux line pinning in superconductor [1]

In the FESS described in the final report, this effect is exploited to create near-zero-friction bearings. The flywheel is levitated by a superconductor cooled to cryogenic temperatures. The stability and energy efficiency stem from the same pinning effects demonstrated to the students.

3 Demonstration Activity

Students were gathered around a bench-top cryogenic setup. The core equipment included:

- Several samples of superconductors
- A liquid nitrogen dewar for cooling
- A magnetic track composed of strong NdFeB permanent magnets
- The necessary safety equipment to handle liquid nitrogen

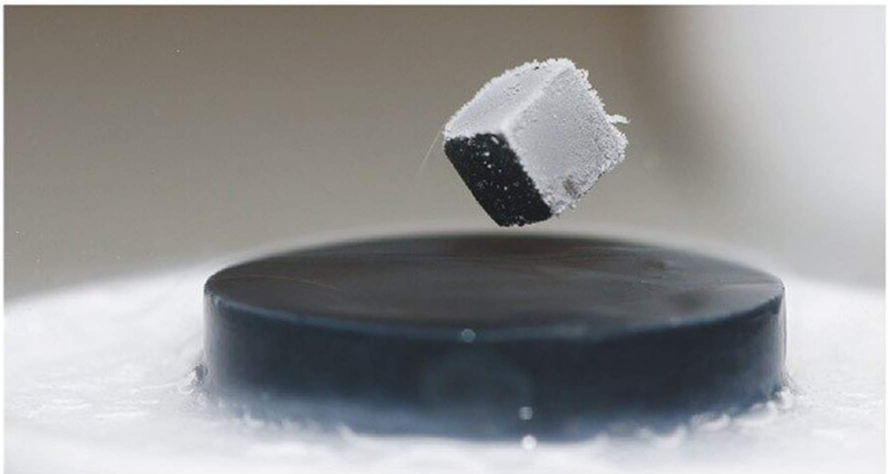

Figure 2: Example of superconductor levitation demonstration [2]

The superconductor was cooled using liquid nitrogen (boiling point: around 80K). Once cooled below its critical temperature, it was placed above the magnetic track. Students were invited to observe:

1. Levitation forces produced by the magnet-superconductor interaction
2. The stability of the levitated puck (flux pinning)
3. The puck's ability to move along the track while maintaining altitude

The puck was gently pushed along the track and observed how it returned to its original equilibrium. This shows a the physical effects of the stabilising forces created by flux pinning.

The simplicity of the demonstration helped students appreciate the underlying physics of the system. This showed how the same principles can be used to eliminate bearing friction in advanced energy storage.

4 Linking Theory to Application

Following the demonstration, students were presented with a simplified overview of how this effect is applied in engineering:

- **Flywheel Levitation:** Superconductors hold a spinning flywheel without contact.
- **Energy Efficiency:** Frictionless operation drastically reduces energy losses.
- **Flux Pinning Stability:** Ensures the flywheel remains centered even at high RPMs.

An image was shown from the FESS project, where a cylindrical magnet was levitated above a Europium-based bulk superconductor. The role of cryogenic cooling was emphasised as a practical constraint and opportunity in such systems.

5 Closing Remarks

This outreach activity successfully introduced students to both the spectacular phenomena of superconductivity and the practical applications of this physics in modern engineering.

The direct experience of observing levitation gave students a memorable and intuitive grasp of what can otherwise be an abstract topic. By framing the phenomenon in the context of energy storage and future technologies, the activity sparked curiosity and engaged a broad range of scientific interests.

It is hoped that this encounter has inspired students to pursue further study in physics and engineering and to appreciate the power of fundamental science when applied with creativity and innovation.

References

[1] J. Durrell, Department of Engineering, University of Cambridge, "Figure 4.6 from 4C3 lecture notes: Unfilled magnetic and electrical fields in materials M24," Lecture Notes, 2024, accessed: May 21, 2025. Available at: https://www.vle.cam.ac.uk/pluginfile.php/13533292/mod$_resource/content/7/4C$3

[2] Open Horizons, "Physics and Fascination: Levitation and Superconductivity," available at: https://www.openhorizons.org/physics-and-fascination-levitation-and-superconductivity.html, accessed June 20, 2025.