Publisher

www.singhpublication.com

E-ISSN:2583-2468

Applied Science and Engineering Journal for Advanced Research

2025 Volume 4 Number 6 November

Research Article

Hysteresis Loop

Magnetic Levitation and Superconductors

Rawat K[1*]

DOI:10.5281/zenodo.18043615

[1*] Kanishk Rawat, H.N.404, Type-4, Law Faculty, Dr. Shakuntala Misra National Rehabilitation University, Lucknow, Uttar Pradesh, India.

This paper explores how stable magnetic levitation can be achieved using a combination of permanent magnets and superconductors. When these materials interact, magnetic fields create a lifting force due to the Lorentz effect. By designing a proper magnetic field pattern and adjusting the magnetic strength and material hardness, the system can reach a point of stable balance, or equilibrium. This study also dies into the difference between active and passive reputation and their responses affecting levitation stability, The results suggest that with suitable magnetic geometry and alignment, a permanent magnet and a superconductor can produce a reliable levitation effect.

Keywords: coercivity, hysteresis loop, magnetisation, critical current density, diamagnetism response

Corresponding Author	How to Cite this Article	To Browse
Kanishk Rawat, H.N.404, Type-4, Law Faculty, Dr. Shakuntala Misra National Rehabilitation University, Lucknow, Uttar Pradesh, India. Email: kanishkx183@gmail.com	Rawat K, Magnetic Levitation and Superconductors. Appl Sci Eng J Adv Res. 2025;4(6):9-12. Available From https://asejar.singhpublication.com/index.php/ojs/article/view/172	

Manuscript Received	Review Round 1	Review Round 2	Review Round 3	Accepted
2025-10-06	2025-10-24			2025-11-14
Conflict of Interest	**Funding**	**Ethical Approval**	**Plagiarism X-checker**	**Note**
None	Nil	Yes	7.33	

1. Introduction

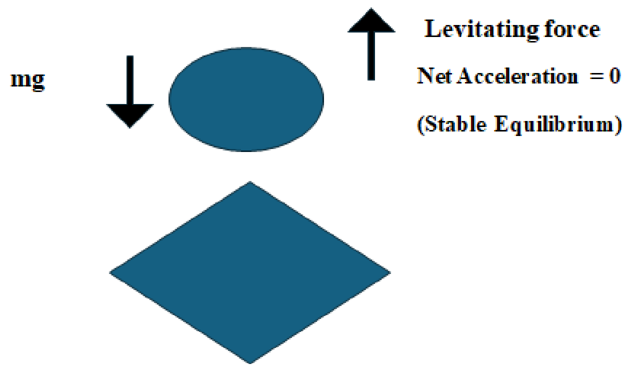
In this paper we are describing levitation is the phenomenon where an object is at some height from the surface and occupies some space in our co-ordinate system countering the influence of gravitational force without being in direct physical contact to any object, and does not in volve magnetism. In this paper we are discussing to achieve magnetic levitation using superconductor.

2. Approach to Magnetic Levitation

Our approach to levitation is to place a body in levitated stable equilibrium position in coordinate system under the influence of gravitational force by using non-contact force. We'll discuss here a magnetic levitation by electromagnetic forces because they work even in vacuum. One of the strongest electromagnetic force is magnetic force including superconductors also. The magnitude of levitation force depends upon interaction between magnet & superconductor and also intrinsic property of magnetic material and superconductor, such as measure of density of magnetic dipole moments in per unit volume within a magnetic material(magnetisation of current) and maximum current in per unit area superconductor can carry which beings in superconducting state(critical current density). However, when we think of long range non-contact force like gravity, electricity and all other long range contact forces turns out to be unstable equilibrium or neutral equilibrium. Because, in electric forces that is electrostatic force, pure electro static equilibrium is unstable or neutral under solely influence of electrostatic force. Gravity can provide stable equilibrium but depends upon potential energy. But in magnetic field(**B**), if magnetic moment(**m**) aligned with potential energy(**U**)

$U= -(mB\cos\theta)$

So, In magnetic forces we can accomplish this we use hard permanent magnet with large rectangular shape hysteresis loop under field weaker than coercive field. Using hard magnet because of high coercivity, so that they keep their magnetisation against opposing fields, so that they make good permanent magnet.



For representational purpose

3. Active to Passive Levitation

Active levitation uses electromagnets and external control systems to dynamically adjust magnetic fields for stability. Equipments like sensors detect the position of the levitated object, sending data to a controller that modulates the current in the electromagnets, where as Passive levitation achieves suspension using inherent properties of materials without active electronics or power, relying on mainly repulsive forces, this leads to the concept of development of active magnetic bearings and active magnetic suspension system, where instead of holding current constant, we vary the current in the electromagnetic coils in such a manner conditioned by feedback from the actual state of motion of the body to be levitated. Thus, stability can be achieved. Not holding the current constant because magnetic force depends upon relative position thus it can be difficult for the object to be in stable equilibrium. Alternatively, if we replace permanent magnets with soft magnets so that its magnetic moment can be changed to control the motion of the levitated body through feedback, we end up with active levitation using an electromagnetic coil. The response of paramagnetic of soft magnetic materials to permanent magnets is akin to positive feedback in control systems. This result for the magnetic case is known as Earnshaw theorem[1]. From this perspective the stabilisation by negative feedback in an active system could be mirrored by a passive diamagnetic response. In Lenz's law in electromagnetic induction, the induced current would begin to decay even as it is being built up, because normal electrical resistance, However, most of the loss can be recovered by increasing the rate of change of magnetic flux in the induction process.

For example, a magnet moving at constant height above a horizontal metal sheet with high conductivity will generate both a drag force and a lift force. At low speeds, v, the drag force is proportional to v, but the lift force is proportional to v^2. So, that's how drag force dominates. As speed is increases, due to the ac skin effect, the drag force eventually peaks and comes back down as $v^{-1/2}$ shown by Rossing and Hull,[2] This is one of the principles in magnetic levitation trains utilising the repulsive mode. Somehow, as soon as the speed is high enough so that the lift force becomes greater than the drag force, a negative damping coefficient for vertical oscillations could develop,[3,4]

4. Diamagnetism Levitation

A diamagnetic response can be obtained by coupling parametrically to the inductance of an L– C–R resonance circuit with a high quality factor, carrying alternating current at a frequency slightly above resonance. This technique was developed in passive magnetic suspension systems which were predecessors to the active systems.[5] In fact, we can expect a diamagnetic response from all materials since Lenz's law should be universally valid, even organic matter and live organisms. The response of diamagnet ism is usually weak Even in, live objects have been levitated, using this Meager response[6]. Perfect diamagnetism means that the inside of the bulk of a superconductor is always protected from magnetic fields by proper surface currents. The interaction between a perfect diamagnet and a permanent magnet gives rise to a conservative force field that can and does exhibit positions of stable equilibrium with an appropriate geometry of the diamagnet magnet and permanent magnet combi nation. Stable levitation can be achieved with a permanent magnet and a superconductor in its perfectly diamagnetic state.

5. Magnetic Properties of Superconductor

The magnetic properties of superconductors cannot be explained by assuming they are conductors having electrical resistivity zero, the electrical resistivity drops when the temperature ranges in liquid helium range or lower.

The perfectly diamagnetic state of a superconductor can only be maintained if the total magnetic field is lower than the critical field which depends on temperature and the superconducting specimen used. This critical field is one constituent that determines the critical current density that can flow inside the superconductor without destroying its superconductivity. The critical current density is one of the main factors administering the levitation pressure that can be sustained by the superconductor.

6. Type-1 v/s Type-2 Superconductors

The superconducting phase cohabit with the normal phase which contains the magnetic field in the bulk of the material cause when the magnetic field on the surface of the superconductor surpass the critical value, it starts to penetrate the superconductor, which then phase separates. Type I superconductors are materials where a clear and stable boundary forms between the superconducting part and the non-superconducting part when a magnetic field tries to penetrate the material. This boundary or surface separates the two phases — the superconducting phase, where magnetic fields are excluded, and the normal metal phase, where magnetic fields can exist inside. In these type I materials, this interface between the superconducting and normal regions is stable and well-defined, meaning the material doesn't break up into smaller pieces of superconducting and normal areas. All the high temperature superconductors were discovered after 1986 are materials of type-2. The behaviour of high temperature superconductor materials with high critical current densities compared by melt-texture growth method[7,8] , our attention will be on this because it provides significant levitating forces. When magnetic field being to penetrate bulk superconductor, the type 2 material enter in mixed state. The lines in superconductors are tiny tubes or threads inside a type II superconductor through which magnetic flux penetrates in discrete units called flux quanta(Magnetic vortex), these lines being forming at the superconductor's surface once the magnetic field strength exceeds the lower critical value. After this they slowly move inward through the bulk of the materials, as the external magnetic field keeps increases, more vortices enter until they become so dense that superconductivity is completely lost at a higher value called theupper critical field.

Magnetic vortex lines continue to collect inside the material until they become so dense that they destroy superconductivity in the material al together. This happens at the upper critical field. The lower critical field is lower, and the upper critical field is higher than the thermodynamic critical field, which is the critical field expected on the basis of the difference in free energy between the superconducting and normal states of the material.

7. Levitation with Superconductors

The Levitation force between magnet and superconductor generates from Lorentz force, acting on the supercurrent with density J, lowing in the superconductor by the magnetic flux density, K, from the magnet. This magnetic flux density can be taken to be that which would have been present in the volume occupied by the superconductor in the absence of the superconductor itself. The force can be written as $\int J \times K \, dv$, which can be equivalent to $\int M.\nabla B \, dv$, under most common circumstances. Here M is the magnetisation of superconductor induced in reaction to the magnetic field. Hence, with proper geometrical arrangements stability in influence of levitation force can be achieved.

8. Conclusion

The research demonstrates that stable magnetic levitation is achievable through careful magnetic field geometry and material properties in permanent magnet-superconductor systems. Lorentz forces, combined with active and passive responses, enable equilibrium by balancing field strength, hardness, and alignment against instability.

References

1. S. Earnshaw. (1842). *Trans. Cambridge Philos., Soc. 7*, 98.

2. T. D. Rossing, & J. R. Hull. (1991). *Phys. Teach., 29*, 552.

3. L. C. Davis, & D. F. Wilke. (1971). *J. Appl. Phys., 42*, 4779.

4. F. C. Moon. (1994). *Superconducting levitation*. New York: Wiley.

5. R. H. Frazier, P. J. Gilinson, Jr., & G.A. Oberbeck. (1974). *Magnetic and electric suspensions press*. MA: Cambridge.

6. M. V. Berry, & A. K. Geim. (1997). *Eur. J. Phys., 18*, 307.

7. M. Murakami, M. Morita, K. Doi, & K. Miyamoto. (1989). *Jpn. J. Appl. Phys., Part 1, 28*, 1189.

8. K. Salama, V. Selvamanickam, L. Gao, & K. Sun. (1989). *Appl. Phys. Lett., 54*, 2352.