

# Design and Development of a Simple Maglev Train Miniature as a Physics Learning Media

Rani Nindya Putri<sup>1</sup>, Muhammad Sahal<sup>1</sup>, Zulhelmi<sup>1</sup>

<sup>1</sup> *Physics Education, Faculty of Teacher Training and Education, Riau University, Indonesia*

\*Corresponding author's  
email:

[rani.nindya5754@student.unri.ac.id](mailto:rani.nindya5754@student.unri.ac.id)

Submitted: 24/02/2026

Review: 24/03/2026

Accepted: 24/03/2026

Published: 30/03/2026

Vol. 4

No. 1

© 2026 The Authors.

This open access article is  
distributed under a (CC-BY  
Licenses)

**Abstract-** The rapid advancement of transportation technology has introduced magnetic levitation (maglev) trains as a modern solution for high-speed, efficient, and environmentally friendly mobility systems. However, students often face difficulties in understanding the fundamental physics concepts behind maglev technology due to their abstract nature. This study aims to design and develop a simple maglev train miniature as an effective learning medium in physics education. The system utilizes permanent magnets to generate repulsive forces, enabling levitation without direct contact between the train and the track. A DC motor and propeller are incorporated to provide horizontal motion. The research employs a qualitative experimental approach focusing on design, construction, and functional testing. The results indicate that the miniature successfully demonstrates levitation and motion, offering a clear visualization of magnetic force and motion principles. This learning media has strong potential to improve students' conceptual understanding, engagement, and interest in STEM-based education.

**Keywords:** *Electromagnetism, Learning Media, Magnetic Levitation, Maglev Train Miniature, Physics Education, Propulsion System, STEM Education*

## 1 Introduction

The rapid development of transportation technology has become a key factor in enhancing mobility, efficiency, and sustainability in modern society. Increasing population growth and urbanization have intensified the demand for faster and more efficient transportation systems. One of the most significant innovations in this field is the magnetic levitation (maglev) train, which operates using magnetic forces to lift and move the train without direct contact with the track. This technology eliminates mechanical friction, allowing for higher speeds and improved energy efficiency compared to conventional rail systems. According to Zhang and Wang (2021), maglev trains represent a breakthrough in high-speed transportation due to their advanced engineering design and reduced operational losses.

Maglev technology is fundamentally based on the principles of electromagnetism, where magnetic forces are used to achieve levitation and propulsion. Unlike traditional trains that rely on wheels, maglev systems use repulsive and attractive magnetic forces to suspend the train above the track. This absence of contact significantly reduces wear and maintenance costs while increasing system reliability. Wang and Liu (2020) reported that maglev trains are capable of reaching speeds exceeding 600 km/h, making them among the fastest transportation systems in the world. Additionally, the smooth and quiet operation enhances passenger comfort and reduces noise pollution, which is beneficial for urban environments.

Despite the technological advantages of maglev systems, the level of public understanding, especially among students, remains relatively low. The concepts involved, such as magnetic force, levitation, and electromagnetic interaction, are often difficult to visualize using conventional teaching methods. This limitation creates a gap between theoretical knowledge and practical understanding. According to Hidayat

### How to Cite

Putri, R. N., Sahal, M., & Zulhelmi. (2026). Design and Development of a Simple Maglev Train Miniature as a Physics Learning Media. *Journal of Frontier Research in Science and Engineering (JoFRISE)*, 4 (1), 17-24

and Sari (2022), the use of learning media and physical teaching aids can significantly improve students' comprehension of complex scientific concepts. Therefore, there is a strong need for innovative and interactive learning tools that can make abstract concepts more concrete and understandable.

In physics education, hands-on learning approaches have proven to be highly effective in improving students' engagement and conceptual understanding. Learning tools that incorporate real-world applications can make lessons more meaningful and relevant (Febi & Sianturi, 2025). One effective strategy is the use of miniature models that simulate real technological systems. These models allow students to directly observe and experiment with physical phenomena, thereby strengthening their understanding. Supriyadi (2023) emphasized that project-based learning enhances students' active participation and helps them develop critical thinking skills through direct involvement in the learning process.

The development of a simple maglev train miniature is closely aligned with the concept of STEM (Science, Technology, Engineering, and Mathematics) education. STEM education focuses on integrating multiple disciplines to solve real-world problems and prepare students for future technological challenges. The National Science Foundation (2020) states that STEM-based learning is essential for developing innovation, creativity, and problem-solving skills. By involving students in the design and construction of a maglev model, they gain not only theoretical knowledge but also practical engineering experience that is highly relevant in today's technological era.

In Indonesia, the integration of modern technology into educational practices is strongly encouraged to improve the quality of learning and prepare students for global competition. The Ministry of Education and Culture (2021) emphasizes the importance of incorporating technological innovation into the curriculum. However, many schools still face limitations in providing advanced learning media, particularly for complex topics such as maglev technology. This challenge highlights the importance of developing simple, cost-effective, and accessible educational tools that can be widely implemented across different educational settings (Dier, 2025).

The proposed maglev miniature in this study utilizes permanent magnets to generate repulsive forces between the train and the track, enabling levitation without the need for complex electromagnetic control systems. This design simplifies the construction process while maintaining the fundamental principles of magnetic levitation. In addition, a DC motor combined with a propeller is used to provide horizontal propulsion, allowing the train to move along the track. This approach makes the system practical, affordable, and suitable for classroom demonstrations, especially in resource-limited environments (Pratiwi et al., 2025).

Previous research has demonstrated that the use of physical models in science education can significantly improve students' analytical and problem-solving abilities. Prabowo and Rahmawati (2023) found that students who engage in hands-on learning activities tend to have a deeper understanding of scientific concepts compared to those who rely solely on theoretical instruction. Furthermore, such learning experiences foster curiosity and motivation, which are essential for effective learning. By constructing and testing the maglev miniature, students can actively explore the relationship between theory and application.

Another important consideration in this study is the affordability and accessibility of the learning media. Many advanced educational tools are expensive and not available in all schools, particularly in developing regions. By using readily available materials such as neodymium magnets, DC motors, and simple structural components, the maglev miniature can be constructed at a relatively low cost. This ensures that the model can be widely adopted and used as an effective teaching aid in various educational contexts, including schools with limited resources.

In addition to its educational value, the maglev miniature also introduces students to real-world engineering challenges. Issues such as stability, alignment, and propulsion must be carefully addressed during the design and construction process. These challenges encourage students to think critically and creatively to find solutions. Such experiences are crucial in developing engineering thinking and preparing students for future careers in science and technology fields.

Finally, this study aims to design and develop a simple maglev train miniature that can function effectively as a physics learning medium. The objectives include designing the system, constructing the model, and evaluating its functionality. Through this approach, the study seeks to bridge the gap between theoretical knowledge and practical application. The results are expected to contribute to the improvement of physics education by providing an innovative, interactive, and accessible learning tool that enhances students' understanding of modern transportation technology

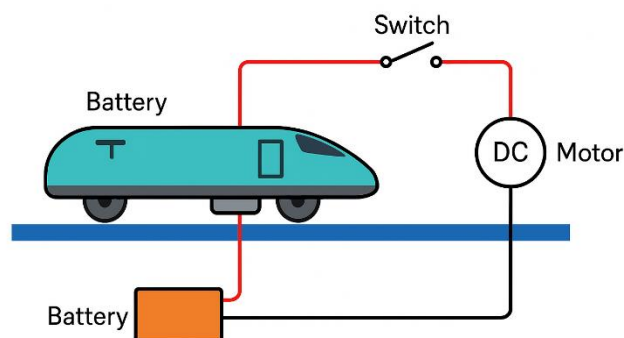
## 2 Research Methodology

This study adopted a design-based experimental research approach to develop and evaluate a simple magnetic levitation (maglev) train miniature as an interactive physics learning medium. The methodology integrates engineering design processes with educational experimentation, aiming to bridge theoretical concepts of electromagnetism with practical implementation. The research was conducted at the Physics Education Laboratory, Faculty of Teacher Training and Education, Universitas Riau, from March to June 2025.

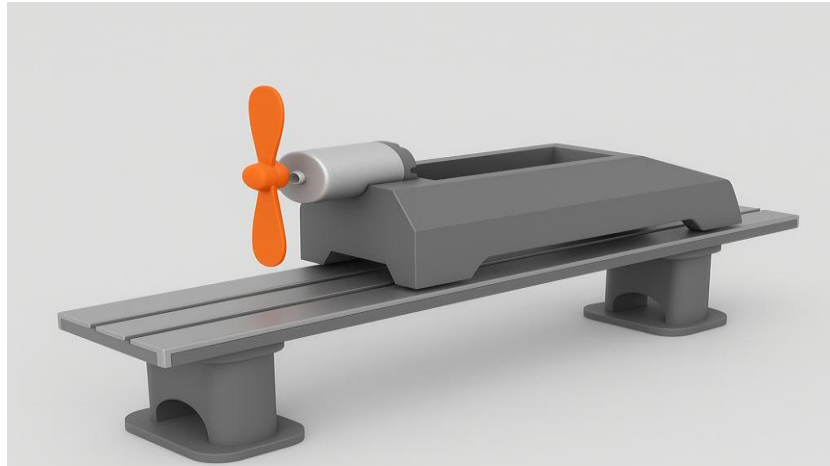
The research procedure consisted of five main stages: (1) conceptual analysis and literature review, (2) system design and modeling, (3) prototype construction, (4) functional testing and validation, and (5) data analysis and evaluation. The initial stage involved an extensive review of literature related to magnetic levitation systems, permanent magnet interactions, and simplified propulsion mechanisms. This step was essential to identify feasible design strategies that could be implemented using low-cost and easily accessible materials while maintaining scientific accuracy.

In the design stage, a conceptual model of the maglev miniature was developed using SketchUp software to visualize both 2D and 3D configurations. The system architecture consisted of three primary subsystems: the levitation subsystem, propulsion subsystem, and guiding subsystem. The levitation subsystem utilized neodymium permanent magnets arranged in a repulsive configuration, where identical magnetic poles faced each other between the train base and the track surface. This arrangement generated a magnetic force sufficient to counteract gravitational force, enabling vertical lift. The propulsion subsystem employed a DC motor coupled with a propeller to generate horizontal thrust, while the guiding subsystem ensured directional stability along the track.

Below are 2D and 3D design drawings of a miniature Maglev train shown to provide an idea of the structure and arrangement of components.



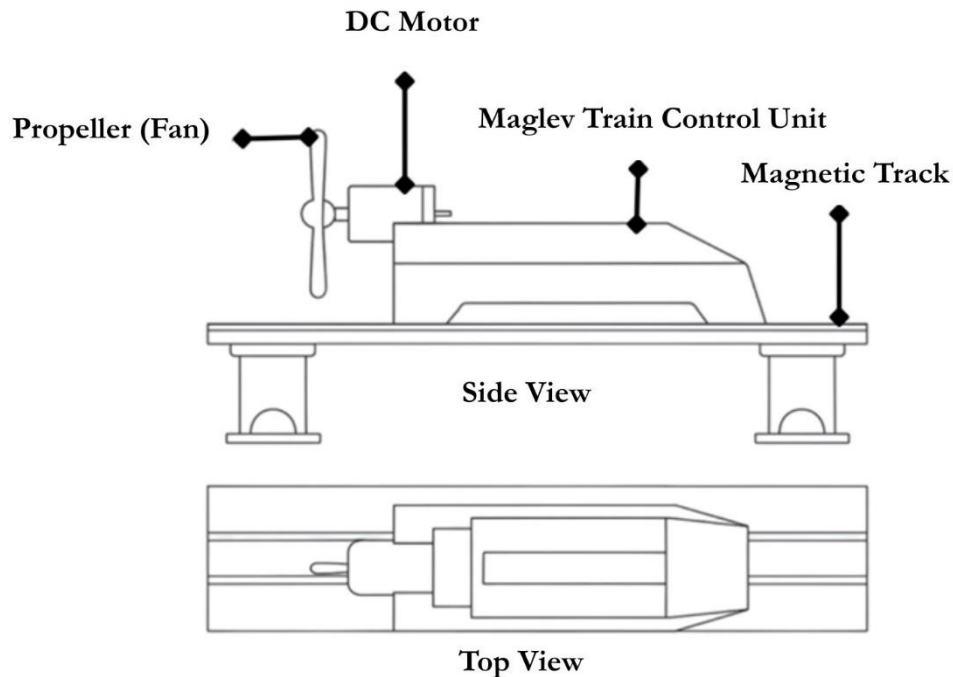
**Figure 2.** Maglev Train Electrical Circuit Design



**Figure 2.** 3D Maglev Train Design

### *Experimental Setup and Prototype Construction*

The materials and components used in this study included neodymium magnets (50×10 mm), a DC motor, a propeller, two 4.5 V batteries, an electrical switch, jumper wires, a one-meter track board, supporting pipes, and lightweight plywood for the train body. The selection of materials was based on considerations of availability, cost-efficiency, and safety for classroom implementation. The use of permanent magnets instead of electromagnets significantly simplified the system by eliminating the need for active control and continuous power supply for levitation.



**Figure 3.** Dimensional Maglev Train Design

The prototype construction phase was carried out through a systematic fabrication process. The track was prepared by embedding magnets along its surface with uniform polarity orientation to ensure consistent repulsive interaction. The train body was constructed using lightweight plywood to minimize mass and enhance levitation efficiency. Magnets were then mounted on the underside of the train with identical polarity relative to the track magnets. The propulsion system was installed by attaching a DC motor

and propeller to the rear section of the train, followed by wiring the electrical circuit using batteries and a switch. Special attention was given to alignment precision to maintain system stability during operation.

Functional testing was conducted to evaluate the performance of the developed prototype. The evaluation focused on three key parameters: levitation capability, propulsion efficiency, and directional stability. The prototype was tested on a one-meter track to observe its ability to levitate and move continuously. Key observations included levitation height, travel time, motion consistency, and system stability. Data were collected through direct observation and repeated trials to ensure reliability.

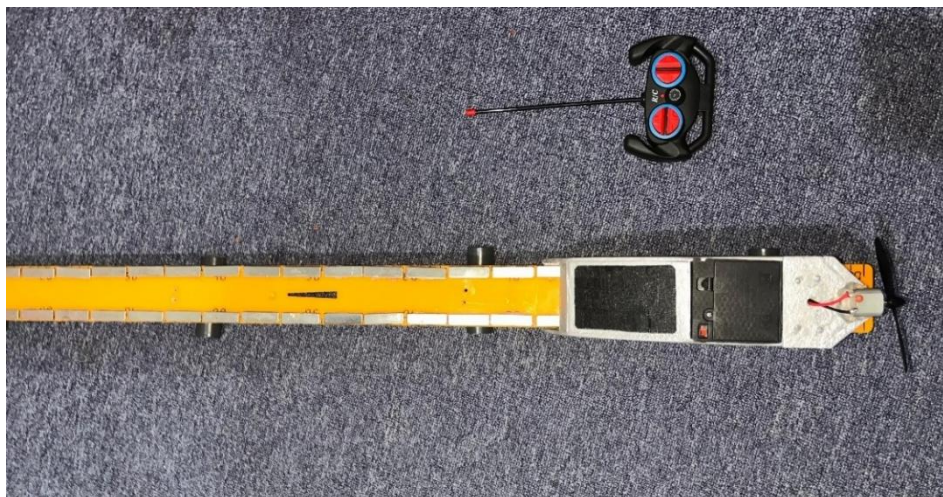
The data analysis stage involved qualitative interpretation supported by basic quantitative measurements such as distance and time. The motion performance was analyzed by calculating average velocity, while system functionality was assessed based on success indicators for each subsystem. An iterative evaluation approach was applied, where any detected instability or malfunction was followed by design refinement and retesting.

Overall, this methodology emphasizes an integrative approach combining physics principles, engineering design, and educational application. The resulting maglev miniature not only serves as a functional prototype but also as an effective pedagogical tool that facilitates experiential learning. This approach ensures that students can directly observe and interact with magnetic levitation phenomena, thereby enhancing conceptual understanding and engagement in physics learning.

### 3 Results and Discussion

#### *Results of System Development*

The developed maglev miniature successfully demonstrated both levitation and motion along the track. The train body, constructed from lightweight plywood, was equipped with three neodymium magnets attached to its base. The track consisted of a one-meter board embedded with magnets arranged in the same polarity as those on the train. This configuration produced a repulsive magnetic force that allowed the train to levitate approximately 1 cm above the track surface. The results of the tool design seen from above, from the side and from behind can be seen in Figure 4, Figure 5 and Figure 6.



**Figure 4.** Design of a Simple Maglev Train Miniature as a Learning Medium Top View



**Figure 5.** Design of a Simple Maglev Train Miniature as a Learning Medium Side View



**Figure 6.** Simple Maglev Train Miniature Design as a Learning Medium, Rear View

The propulsion system utilized a 4.5 V DC motor connected to a propeller, which generated thrust to move the train forward. The system was powered by two batteries connected through a switch, allowing controlled operation. During testing, the train was able to travel the entire one-meter track within approximately 4 seconds, demonstrating effective motion.

**Table 1.** Presents The Functional Evaluation Of The System Components.

No	System Component	Result
1	Propulsion System	Successful
2	Levitation System	Successful
3	Guiding System	Successful

The results indicate that all major components functioned as expected, confirming the feasibility of the design as a learning medium.

### *Discussion of Magnetic Levitation System*

The levitation system in this study relies on permanent magnet repulsion. Unlike electromagnetic suspension (EMS) or electrodynamic suspension (EDS), this system does not require active control or external power for levitation. This makes it significantly simpler and more cost-effective. However, the system also has limitations, particularly in terms of stability. Without active control, maintaining consistent levitation height can be challenging. Minor misalignments in magnet placement can lead to instability or derailment. To address this, a guiding system was implemented to maintain alignment and reduce lateral movement.

### *Discussion of Propulsion System*

The propulsion system uses a DC motor and propeller instead of a linear motor, which is commonly used in real maglev systems. This choice was made to simplify the design and reduce costs. While this method is less efficient and produces lower speeds, it effectively demonstrates the concept of thrust-based motion. The use of a propeller introduces air resistance and energy loss, which are not present in real maglev systems. However, for educational purposes, this approach provides a clear and observable mechanism for motion.

### *Comparison with Real Maglev Systems*

Real maglev systems use advanced electromagnetic control and linear motors to achieve high speeds and stability. In contrast, this miniature uses permanent magnets and a simple propulsion system. While the performance is limited, the model effectively captures the fundamental principles of maglev technology. This comparison highlights the trade-off between complexity and educational value. The simplified model prioritizes accessibility and ease of understanding, making it suitable for classroom use.

## **4 Conclusion**

This study successfully designed and developed a simple maglev train miniature as a physics learning medium. The system utilizes permanent magnets to achieve levitation and a DC motor with a propeller for propulsion. The results demonstrate that the miniature can levitate approximately 1 cm above the track and travel a one-meter distance within 4 seconds, confirming its functional effectiveness.

The developed model provides a clear and practical demonstration of key physics concepts, including magnetic force, levitation, and motion. Its simplicity, affordability, and accessibility make it suitable for educational use, particularly in schools with limited resources. The hands-on nature of the model enhances student engagement and supports the development of critical thinking and problem-solving skills.

Although the system has limitations in terms of stability and speed, it effectively fulfills its purpose as a learning medium. Future improvements can further enhance its performance and expand its educational applications. Overall, this study contributes to the development of innovative teaching tools that bridge the gap between theory and practice in physics education.

## **Reference**

- Anderson, M. (2021). The future of eco-friendly transportation. *Journal of Sustainable Transport*, 15(4), 233–245.
- Chen, L., et al. (2021). Testing and performance analysis of magnetic levitation systems. *International Journal of Engineering Research and Applications*.
- Dier, M. (2025). Analysis of Electric Field Distribution Patterns of Dipoles in Various Vacuum Mediums and Dielectric Materials. 3, 14–19
- Febi, T., & Sianturi, A. (2025). Analysis of Electric Potential Distribution in a System without Charge Using Laplace's Equation Approach ; Literature Review. 3, 20–25

- Hellinger, R., & Mnich, M. (2012). Magnetically levitated trains: The future of railroad transportation? *IEEE Transactions on Industrial Electronics*, 59(11), 4120–4127.
- Huang, J. (2020). Advances in maglev technology. *International Journal of Transportation Engineering*, 8(2), 112–119.
- Kawasaki, T. (2019). *Electromagnetic levitation: Applications in medicine and engineering*. Wiley.
- Kumar, R. (2022). Challenges in the implementation of maglev systems. *Asian Journal of Transportation Research*, 9(3), 98–105.
- Prabowo, R. (2019). Prinsip kerja dan aplikasi kereta maglev di Indonesia. *Jurnal Transportasi*, 7(1), 23–30.
- Pratiwi, W., Wahyu, N., Yani, I., Dwi, R., Putri, A., & Desri, D. E. (2025). Transformation Of Electronic Communication Systems Into Optical Communication Systems. 3, 1–6.
- Wang, L., & Chen, S. (2018). STEM education: The future of learning. *Journal of STEM Education Research*, 4(1), 34–40.
- Zhang, L., & Wang, J. (2021). Advances in electromagnetic levitation technology. *Journal of Applied Physics*, 129(4), 045001.