

Innovation of Electromagnetic Induction Video Teaching Driven by Technology Integration and Discipline Competition

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Abstract: In traditional electromagnetic induction teaching, there exist problems such as the difficulty in understanding abstract concepts, significant limitations of experimental demonstrations, and low student engagement. To address the issue, this paper proposes an innovative video-assisted teaching model jointly driven by technology integration and discipline competitions. The abstract principles of electromagnetic induction are converted into easily understandable video content by utilizing technologies such as digital modeling, dynamic simulation, and visual presentation. Meanwhile, under the guidance of discipline competitions, instructional tasks featuring exploration and practicality are designed to foster students' transition from passive viewing to active innovation and application. Practice has shown that the teaching model contributes to deepening students' understanding of electromagnetic induction and enhancing their experimental design and innovation capabilities. It offers a reference for the reform of college physics.

Keywords: College Physics, Electromagnetic Induction, Video-Assisted Teaching, Technology Integration, Discipline Competitions

1. Introduction

Electromagnetic induction is central to the electromagnetism module in college physics and serves as the theoretical foundation for subsequent specialized courses in electrical engineering/automation, electronic information engineering, communication engineering, and other related fields^[1-4]. Due to the abstract nature of concepts such as magnetic flux variation and motional electromotive force, students often tend to memorize formulas rather than cultivate a deep grasp of the underlying principles. In traditional teaching, instructors often derive formulas on the board and describe physical phenomena through simple demonstrations. However, restricted by experimental precision and the time and space available in the classroom, students often find it difficult to directly observe the dynamic processes of physical phenomena, which hinders their capacity to transfer knowledge and apply it in practice.

With the acceleration of digital transformation in education, video-assisted instruction has emerged as a key approach to addressing the challenges in teaching abstract concepts, owing to its merits of repeatable viewing, visual representation, and scenario-based simulation^[5-7]. Currently, most instructional videos on electromagnetic induction predominantly adopt a one-way communication format, combining teacher explanations with experimental demonstrations. These videos lack in-depth technological integration and precise alignment with instructional objectives, thereby restricting their ability to stimulate students' active thinking and innovative awareness. Meanwhile, the teaching process remains isolated from discipline competitions and engineering practice, hindering students from converting theoretical knowledge into practical problem-solving skills. This isolation runs counter to the educational principle of promoting learning and innovation through competitions.

Thus, this paper puts forward an innovative video-assisted teaching model for electromagnetic induction, which is driven by technology integration and discipline competitions. On the one hand, the integration of digital modeling, dynamic simulation, and video production technologies facilitates the development of microlecture resources, which is featured by the visualization of principles, the simulation of experiments, and the contextualization of applications. On the other hand, under the

guidance of discipline-based competition tasks, it offers a practice platform oriented towards real problems for physics teaching, transforming students from knowledge recipients into innovative practitioners. This paper elaborates on the practical pathway and core logic of the proposed video-assisted teaching model for electromagnetic induction, providing a new paradigm for the reform of video instruction on abstract concepts in science and engineering.

2. Structure and Mathematical Model

The principle of electromagnetic induction, which reveals the law governing the interconversion between electricity and magnetism, forms the theoretical core of electromagnetic technology applications. On the basis of this principle, technologies that employ electromagnetic force to propel objects are classified as electromagnetic launch(EML) technologies. Electromagnetic catapult systems exemplify a typical application direction of this technology, realizing precise launch via the optimization of magnetic field and energy regulation.

2.1 Major components of the electromagnetic catapult system

Electromagnetic catapult systems are generally composed of several key components: a coil array, guide rails, a moving carrier, and a power supply system, as shown in Figure 1. The coil array is made up of a series of electromagnetic coils arranged in a straight line. When an electric current passes through these coils, a varying magnetic field is produced, which interacts with the moving carrier to generate the thrust necessary for launching. The guide rails are typically two parallel metal conductors along which the moving carrier accelerates. The moving carrier is connected to the aircraft or payload, contacts the guide rails and transmits electromagnetic force. The power supply system provides the high-current electrical energy required to energize the coil array and control the acceleration process.

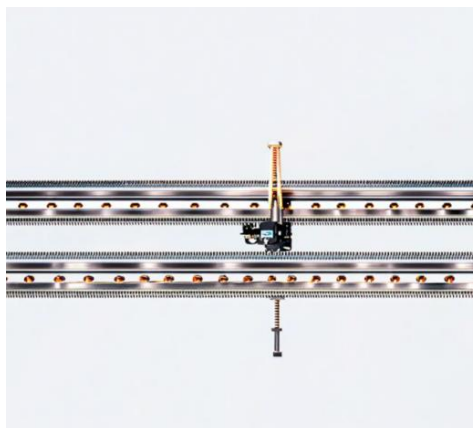


Figure 1: Schematic diagram of the electromagnetic catapult system.

2.2 Operational process of the electromagnetic catapult system

The operational process of an electromagnetic catapult system consists of three distinct phases: initiation, acceleration, and termination. In the initiation phase, the power supply system energizes the first coil, thereby generating a strong magnetic field. In the acceleration phase, as the moving carrier enters the region of the first coil, the generated magnetic field induces a current in the carrier. This current then interacts with the external magnetic field to produce a forward Ampere force, which in turn accelerates the carrier. As the carrier progresses, the power supply system sequentially energizes the subsequent coils, keeping the carrier in a changing magnetic field to enable continuous acceleration until the desired velocity is attained. In the termination phase, the carrier exits the last coil, the acceleration process comes to an end, and the carrier proceeds in flight.

2.3 Mathematical formulation of the electromagnetic catapult system

To better understand and simulate the electromagnetic catapult process, a simplified mathematical model is established. Let m represent the mass of the carrier, v_0 denote the initial velocity, $B(t)$ be the magnetic field generated by the coil, $I(t)$ stand for the current in the carrier, R indicate the contact

resistance between the carrier and the rail, and F signify the Ampere force acting on the carrier.

In accordance with Faraday's law of electromagnetic induction, the electromagnetic force in the coil can be expressed as:

$$\varepsilon = -N \frac{d\Phi}{dt} \quad (1)$$

Where N represents the number of turns in the coil, and Φ is the magnetic flux passing through each turn.

The current I in the carrier is determined by Ohm's law:

$$I = \frac{\varepsilon}{R} \quad (2)$$

According to the Ampere force formula, the force F exerted on the carrier is expressed as:

$$F = BIl \quad (3)$$

Where l represents the effective length of the carrier in contact with the rail.

The acceleration a of the carrier is derived from Newton's second law, that is:

$$a = \frac{F}{m} = \frac{BIl}{m} \quad (4)$$

3. Construction and Presentation of the Simulation Model

The core components, including the coil array, the rails, the moving carrier, and the power supply system, were modeled using solidworks. Subsequently, a simplified physical simulation model of the electromagnetic launch system was constructed, as illustrated in Figure 2.



Figure 2: 2D electromagnetic induction simulation model.

In SolidWorks, a basic cylinder was first created to serve as the main structure of the coil. Subsequently, the coil was formed by generating multiple layers of tightly wound windings via the spiral sweep feature. A specific spacing was maintained between each layer of the coil to guarantee the passage of current, as illustrated in Figure 3. Finally, a rectangular magnet was attached to one side of the coil to represent the external magnetic field source, as shown in Figure 4.



Figure 3: 3D solid model of the coil.

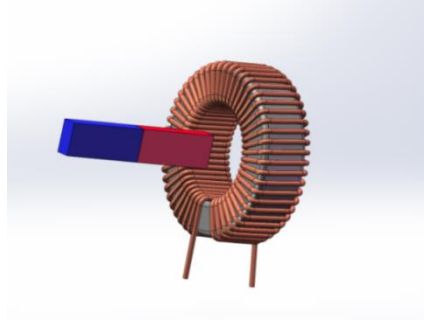


Figure 4: Rectangular magnet as the external magnetic field source.

To clearly demonstrate the principle of electromagnetic induction launch, a multi-coil model was developed, as shown in Figure 5. Each coil is tightly wound to form a continuous annular structure. A magnet is placed at one end of the coil to simulate the variation of the magnetic field. The entire model is made of copper to ensure superior electrical and thermal conductivity.

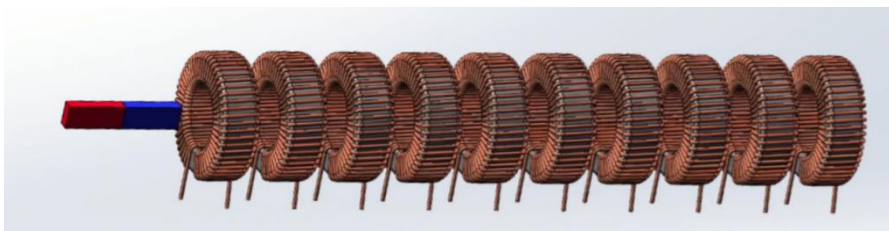


Figure 5: 3D electromagnetic induction simulation basic model.

During the electromagnetic induction launch process, a time-varying magnetic field induces an electromotive force in the closed-loop coil, as depicted in Figure 6. To simulate this process, different magnetic field magnitudes and directions were set in SolidWorks to observe the changes in current within the coil. This configuration can be realized by adjusting the position and polarity of the magnet.

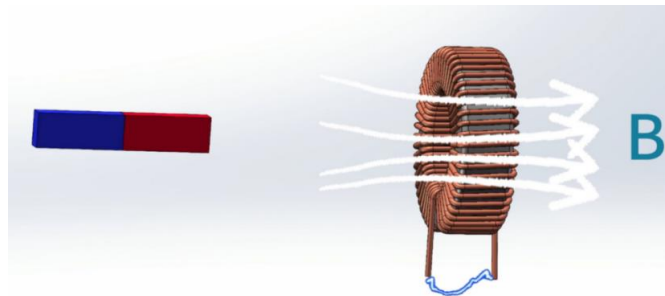


Figure 6: Physical simulation of the actual magnetic field variation in a single coil.

The dynamic simulation function of SolidWorks was used to offer a more intuitive visualization of the electromagnetic induction launch process, as shown in Figure 7. By defining a time sequence, the variation of the coil current with respect to the magnetic field can be observed. This helps the audience in understanding the fundamental principle of electromagnetic induction launch and the effect of various parameters (e.g., magnetic field strength and the number of coils) on the launch performance.

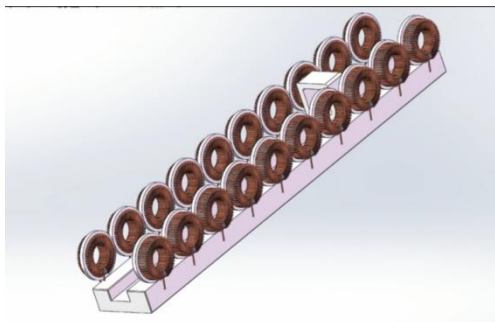


Figure 7: Dynamic simulation of the launch process.

Ultimately, a set of dynamic simulation results was obtained, which shows the variation of the coil current over time. These results can be presented in the form of an animation, making it easier for the audience to understand the electromagnetic induction launch process, as illustrated in Figure 8. Furthermore, the variation trends of key parameters, such as current and magnetic field strength, can be presented in multiple ways, for example, by adjusting the brightness of the coil in the animation.

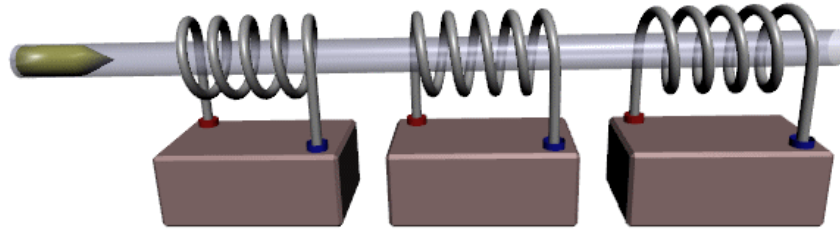


Figure 8: Animated model of electromagnetic launch.

4. Video Design and production

4.1 Video content design

Based on relevant physics knowledge such as electromagnetic induction, students are guided to grasp the essential principles of electromagnetic launch technology and further connect these concepts with practical application technologies. By depicting the present and envisioning the future, the video motivates students to pursue exploration in sciences and technologies. Finally, it highlights two major achievements of China in the field of electromagnetic launch, inspiring students' national pride.

The video is divided into three sections. First, in the “Embarkation” section, it commences with a striking demonstration of electromagnetic phenomena, which serves as an introduction to the subsequent exploration. Second, in the “Unveiling the principles” section, via 3D modeling and animations, the scientific principles underlying electromagnetic induction launch are elucidated in a clear and accessible manner. Finally, in the “Exploration” section, the video integrates simulation experiment footage with real-world application cases. This approach illustrates the current applications and achievements of electromagnetic induction launch technology, while provoking contemplation about future potential.

4.2 Video production

SolidWorks software was employed to model core components such as the coil, establishing a 3D model foundation for the video, as shown in Figure 9. All modeling materials were hand-drawn and original. Subsequently, SolidWorks and AE were utilized to implement the animation transitions and visualize key demonstration processes, such as the acceleration process and the propulsion principle, as illustrated in Figure 10.

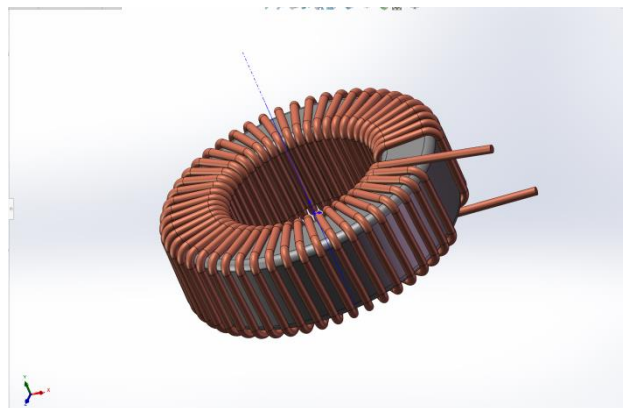


Figure 9: Coil modeling using SolidWorks.

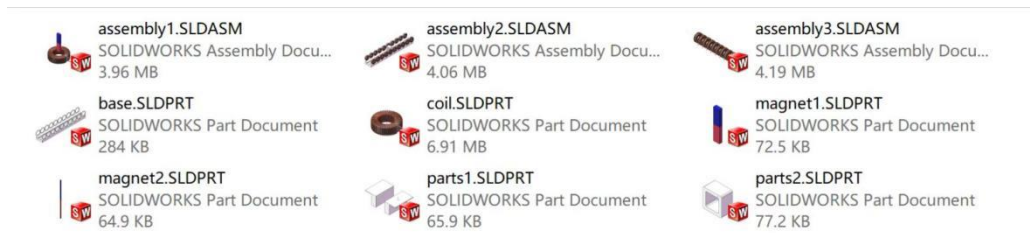


Figure 10: Animation example of SolidWorks modeling.

Through engaging multimedia and three-dimensional modeling, this video vividly elucidates the working principle and real-world applications of electromagnetic induction. Taking the electromagnetic catapult technology of China's Fujian aircraft carrier as a practical case, the video design integrates 3D models and animations to visualize the abstract concept of electromagnetic induction. SolidWorks modeling software was utilized as the primary tool in the video production, enabling the construction of key components including the coil array, guide rails, moving carrier, etc. This further facilitated the exploration of the working mechanism of electromagnetic induction launch. Moreover, by adjusting the magnetic field strength and position, the dynamic acceleration process under the influence of the induced current and the Ampere force is demonstrated in a clear and dynamic manner.

5. Participation in Competitions and Achievements

In conjunction with the 10th Chinese Undergraduate Physics Experiment Competition (Innovation) held in 2024, students were instructed to select topics from auxiliary teaching videos for college physics courses. Focusing on the principle of electromagnetic induction launch, a competition team was established to produce a demonstration video that meets the competition's requirements. The project "Exploring the Electromagnetic Universe: Electromagnetic Induction Launch" won the Third Prize at the national level.

The competition video produced not only reinforces the comprehension of the electromagnetic induction principle but also stimulates students' interest in exploration through the micro-lecture format, rendering complex theories accessible and easy to understand. Meanwhile, it demonstrates students' innovative capabilities in digital modeling, dynamic simulation and video production, offering new insights for exploring the integration of physics knowledge and technological applications. All participating students stated that they deepened their understanding of the principle of electromagnetic induction by making the competition video, which reflects the role of "technology integration + discipline competition" mode in improving teaching quality.

6. Conclusions

This paper takes the video teaching of electromagnetic induction as a starting point to develop an innovative video-assisted teaching model driven by technology integration and discipline competitions. Specifically, "technology integration" is adopted to reduce the difficulty in grasping abstract concepts, whereas "disciplinary competitions" serve to promote the transformation of knowledge into practical skills, thereby forming a closed loop of "resource development-practical application- capability enhancement." Furthermore, the underlying logic of the proposed model, namely "principle decomposition-simulation modeling-competition-oriented design", exhibits strong generalizability and can be readily extended to other domains of college physics, such as mechanics, thermodynamics, and optics. This provides a standardized framework for the development of comparable teaching resources, thus contributing to the establishment of a high-quality microlecture resource library for college physics. Practice has proven that the videos developed based on this model have attained remarkable results in discipline competitions. Therefore, this model possesses significant promotional value and application value, as it effectively enhances students' knowledge acquisition and innovative practical abilities. It also offers replicable and scalable experiences for the reform of abstract concept teaching in college physics.

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