The 3D simulation of Lorentz Force based on augmented reality technology

F Bakri*, D Sumardani and D Muliyati

Physics Education Department, Universitas Negeri Jakarta, Jl. Rawamangun Muka No.1, Jakarta 13220, Indonesia

*fauzi-bakri@unj.ac.id

Abstract. The Lorentz force concept is classified as an abstract to be understood. The direction of the current, the direction of the magnetic field and the direction of the force generated are difficult to understand without real media. This article will describe the Lorentz Force style simulation by utilizing augmented reality technology. The development of Lorentz force media uses 4D stages (define, design, develop, and disseminate). Interactive media based on augmented reality Lorentz force can display the Lorentz style concept by making changes to magnetic field variables and electric currents. The process of developing this media has been guided by pedagogical content knowledge (PCK). Our simulation successfully displays the relationship between the magnetic field and electric current which is directly proportional to the Lorentz force. AR-based Lorentz force simulation has fulfilled the principle of technological pedagogical content knowledge (TPACK).

1. Introduction

The Internet of Things (IoT) performs everything smarter through computation, sensing, and embedded actuation in various digital forms [1]. Augmented reality transforms the perception of space by presenting digital media in the real world [2]. There is growing evidence that the use of simulations in teaching is the primary means to enhance learning, skills, and outcomes, especially for practical skills [3]. Augmented reality is one of the developing technologies that have comprehensive pedagogical potential and is proven to increase student learning interest and has been recognized by educational researchers [4].

Learning simulation using augmented reality is a very massive development. The use of augmented reality simulations is done to develop student skills and improving science laboratory capabilities by presenting engaging augmented reality simulations [3,5]. Besides being used in the world of education, augmented simulations are also widely used to observe things that cannot be done conventionally in the field of medicine, field of trade and simulation in social life [6-9]. Many simulations have been conducted using augmented reality in the world of magnetic physics education such as numerical simulations of two-phase flow to determine the existence of magnetic fields, application of modeling airflow around buildings to accommodate time variability from atmospheric conditions, turbine simulations, observations of cavitation flow and magnetic fields, and electromagnetic simulations [10-14].

To get a complete and complete analysis of the Lorentz force simulation between magnetic fields, a simulation using augmented reality is needed. The simulation will analyze the influence of the magnetic
field, electric current on the Lorentz force that occurs on the drive board. The results of this simulation will be used to regulate the parameters of electric motors in future research.

2. Method
In this simulation, the rotating board will be given a variation of the magnetic field $B$, and a different current strength $i$ in several samples. The swivel board has been wrapped around a wire which gets current direct from a predetermined battery. There are four types of batteries used, namely those that produce 1 ampere, 2 amperes, 3 amperes, and 4 amperes. The battery used is illustrated in figure 1.

![Figure 1](image1.png)

**Figure 1.** The illustration of four Battery as a current source.

The simulation identifies the Lorentz force, $F$ which produces torque to rotate the board. The end of the board is fitted with a wire that will be electrified. The wire will be produced because of the Lorentz direction in accordance with the right-hand rule. Figure 2 shows the illustration of electricity in the wire.

![Figure 2](image2.png)

**Figure 2.** The illustration of swivel board surrounded by wire.

The electric current that occurs in the rotary board is direct current. Therefore, in creating a rotation of 360° a semicircular conductor is needed to maintain the consistency of the direction of the Lorentz force. Illustration of rectifier ring shown in figure 3.
3. Results and discussion

Simulation is done by changing the variable magnetic field B and electric current i. The augmented reality application will display digital objects in the real world. When the augmented reality application is activated, it will enter the camera section to find the target. As long as the target image is not found, the application will show red which indicates the object has not been found. Figure 5 shows the situation when the augmented reality application looks for a target to scan.

This simulation provides a magnetic field of 40 Tesla and four current variations in the first to fourth simulations. Simulation illustrations using a 40 Tesla magnetic field are shown in figure 6 – figure 9.
The Lorentz force produced from the magnetic field $B = 40$ Tesla and the electric current of 1 Ampere, 2 Ampere, 3 Ampere, and 4 Ampere is shown by Eq. (1)-Eq (4) respectively.

$$F = B \cdot i \cdot l$$

$$= 40 \text{T} \cdot 1 \text{A} \cdot 5 \text{m} = 200 \text{N}$$

(1)

$$F = B \cdot i \cdot l$$

$$= 40 \text{T} \cdot 2 \text{A} \cdot 5 \text{m} = 400 \text{N}$$

(2)

$$F = B \cdot i \cdot l$$

$$= 40 \text{T} \cdot 3 \text{A} \cdot 5 \text{m} = 600 \text{N}$$

(3)

$$F = B \cdot i \cdot l$$

$$= 40 \text{T} \cdot 4 \text{A} \cdot 5 \text{m} = 800 \text{N}$$

(4)

This simulation provides a magnetic field of 80 Tesla and four current variations in the next fourth simulations. Simulation illustrations using an 80 Tesla magnetic field are shown in figure 10 - figure 13. The Lorentz force produced from the 80 Tesla magnetic field and the electric current 1Ampere, 2 Ampere, 3 Ampere, and 4 Ampere are shown by Eq. (5) – Eq (8) respectively.

$$F = B \cdot i \cdot l$$

$$= 80 \text{T} \cdot 1 \text{A} \cdot 5 \text{m} = 400 \text{N}$$

(5)
\[ F = B \cdot i \cdot l = 80 T \cdot 2 A \cdot 5 m = 800 N \]  
(6)

\[ F = B \cdot i \cdot l = 80 T \cdot 3 A \cdot 5 m = 1200 N \]  
(7)

\[ F = B \cdot i \cdot l = 80 T \cdot 4 A \cdot 5 m = 1600 N \]  
(8)

Figure 10. The illustration of Lorentz force produced from 80 Tesla and 1 Ampere.

Figure 11. The illustration of Lorentz force produced from 80 Tesla and 2 Ampere.

Figure 12. The illustration of Lorentz force produced from 80 Tesla and 3 Ampere.

Figure 13. The illustration of Lorentz force produced from 80 Tesla and 4 Ampere.

The Lorentz force media based on augmented reality technology can display the strength of the magnetic field, the strength of the current and the length of the wire against the Lorentz force value. Users can vary these values and can change the direction and speed of motor rotation. Users can learn each quantity on the electric motor rotation. This Lorentz force media based on augmented reality technology can become a learning gap in achieving the Lorentz force concept.

4. Summary
In summary, we succeeded in simulating a motor working system that works through the Lorentz force concept. The augmented reality application in this study was made using the interactive interface and using programming to be interactive. This system can be used in analyzing the best results in accelerating the rotation rate of the electric motor. This simulation has implications for the visualization of Lorentz force in the media of physics learning to obtain a better understanding.
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