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## Teaching of Faraday's and Lenz theory of electromagnetic induction using java based Faraday's laws of stimulations.

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### Abstract

I have used Faraday's lab simulation software freely available on website <http://phet.colorado.edu> to teach faraday's and Lenz's theory of electromagnetic induction. I had taken the sample of 30 students and 30 questions. Student's response to all questions before and after simulation was noted to study effect of simulation lab work. The response of students to conceptual and application oriented questions was totally changed. They realize their mistakes in understanding of EMI phenomenon. Teaching with faraday's lab simulation creates the interest and curiosity about EMI among students. It makes the study Easy and reduces the real lab work. It is difficult for high school teachers to realize every concept of EMI in real lab experiments due to limited resources. This simulation helps the students to learn the EMI phenomenon by their own.

**Keywords:** Physics education, electromagnetic induction, faraday's lab simulation

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### I. INTRODUCTION

School teachers teach the Faraday's and Lenz's theory of electromagnetic induction using equations, graphs, diagrams, examples and numerical. Many students face considerable difficulties in understandings the phenomenon using equations. Student use equations to calculate some variables and numbers as a solution. It is very difficult for students to see the importance of each variable and constants in a given equations. However physical equations have deeper meanings. Equations represent the relation between various observations and measurements. By using simulation based experi-

ments; student can see the important of each variable of equation. Such simulation based teaching changes the students view about equations. Students can imagine lot of things just from equations. Simulation base teaching enhances the visualizations power of students for physical phenomenon. Student can solve the practical problems after simulation based teaching. In this work we investigate the effectiveness of a role of web based computer simulation teaching in electromagnetic induction [1, 2, 3].

## II. METHOD

**The student sample:** Sample for this study included the 30 students of plane science of higher secondary level. All students are of same rank. Simulation based teaching is new thing for them [4, 5, 6].

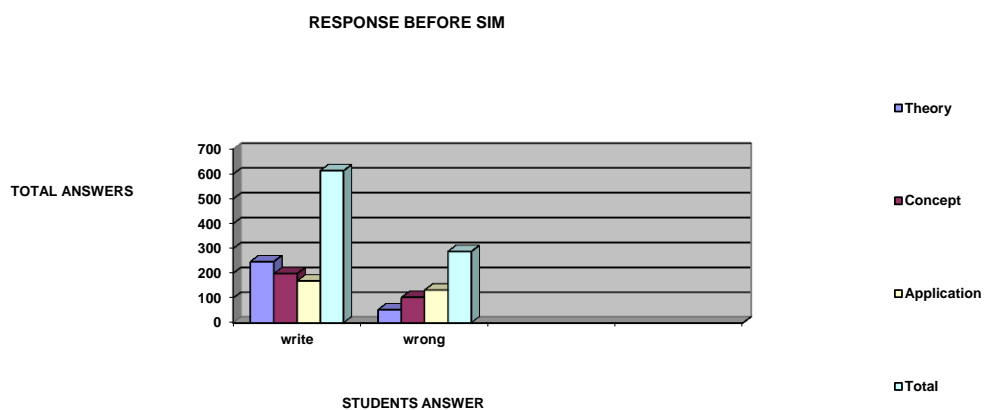
**Treatments:** Theory based lecture on the faraday's law of electromagnetic induction and its applications was given to students for six hours; one hour daily for six days. Lecture contents are given in Appendix A. During lecture care was taken that on student should remain absent in any of six lectures. On the seventh day multiple choice question tests was taken to check their understanding of theory of EMI. Questions were selected from various section text books [7]. Test includes total 30 questions. It includes equal number of theory, conceptual, application based questions. Time allotted to each question is of 2 minutes. After test

Question papers were collected back from students. Students response to this test is given in following table I and response is shown in the figure I

**TABLE I.** Student's response in the form of write and wrong answers before Faraday's simulation lab work

Question type	Answers given by all 30 students	
	Write answers	Wrong answers
Theory based	247	53
Concept based	198	102
Application based	168	132
Total Answers	613	287

**FIGURE I.**



On the same day Faradays lab simulation is played on LCD projector in classroom. The information about each experiment of simulation was given to the students. Demonstration of every experiment was given to the students. After it students were

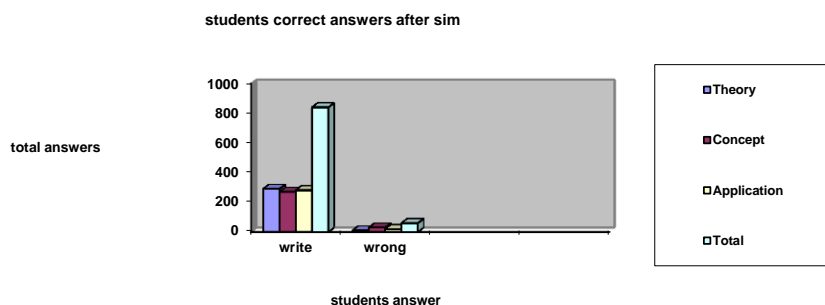
divided into five groups and they were allowed to do the experiment with the faraday's lab simulation software in computer lab due to limited sources. Same multiple choice question test was again taken just after faradays lab simulation experiments. Now answers given by students were

evaluated and are given in following table II and response is shown in figure II.

**TABLE II** Students response in the form of write and wrong answers after Faraday’s simulation lab work

Question type	Answers given by all 30 students	
	Write answers	Wrong answers
Theory based	290	10
Concept based	270	30
Application based	281	19
Total Answers	841	59

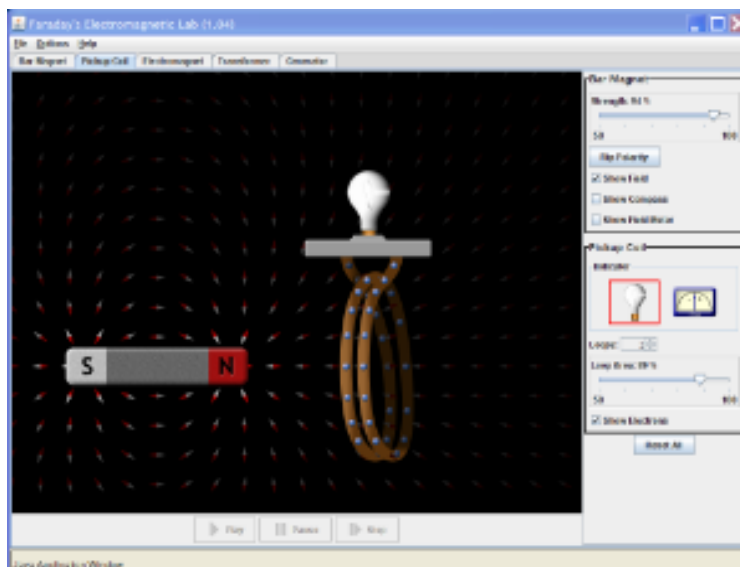
**FIGURE II**



### III. FARADAY’S EMI LAB SIMULATION EXPERIMENTS

Five experiments of EMI LAB SIM are performed by students using carefully design instructions. Snap shot of simulation is given in figure III.

Figure III Snap shot of Faraday’s Lab Sim



The experiments are;

**III A Bar magnet; compass and field meter experiment:** It describes the strength, direction of magnetic field of bar magnet at different positions near it. This part of simulation is related with the following equations

$$B = \frac{\mu_0 M}{4\pi r^3} \sqrt{3\cos^2\theta + 1}$$

$$\text{and } \alpha = \tan^{-1} \frac{1}{2} \tan\theta$$

Instructions

1. Here you will find a compass and a bar magnet. What do the two have in common?
2. Slowly move the compass around the bar magnet. What observations do you make? How can you explain what you are witnessing?
3. Increase and decrease the strength of the bar magnet (use slider) and continue to slowly move the compass around the bar magnet. What effect does changing the magnet's field strength appear to have on the compass?
4. Place the compass next to the South Pole of the bar magnet and press the Flip Polarity button. What happens to the magnet and the compass?
5. Click See Inside Magnet. What do you see?
6. Click Show Field Meter and move the meter around. In what position does B have the greatest magnitude? When does it get weaker?
7. Where is  $B_x$  positive? Where is it negative? Where is  $B_y$  positive? Where is it negative?
8. Place the meter at a location to the left and underneath the bar magnet. What are the  $B_x$ ,  $B_y$  and B Values? Verify the mathematical relationship between the three.

**IIIB. Bar magnet coil experiment:** It describes the Lenz's Faraday's law of EMI. It describes the equation

$$e = - \frac{d\phi}{dt}$$

Instructions

1. Here you have a bar magnet and a coil of wire attached to an incandescent light bulb. Does the

coil or the bar magnet appear to be creating the magnetic field? How can you verify this?

2. Click the Show Electrons box off and back on. What does it do, visually?
3. Move the bar magnet around the outside of the coil/bulb apparatus. What do you observe happening to the coil/bulb?
4. What could possibly explain WHY this is occurring?
5. Now, move the bar magnet back and forth inside the coil of wire. Thoroughly describe and explain your observations.
6. Increase and decrease the strength of the bar magnet (slider) and repeat. What effect does changing the magnet's strength have?
7. Set the bar magnet strength at 75% and continue to move the magnet. Decrease the number of loops to 1, and then increase it to 3. What effect does this have?
8. Replace the incandescent bulb with the Voltage meter and return loop # to 3. What happens when you move the bar magnet back-n-forth through the loop? Does this appear to be creating a Direct Current or an Alternating Current? How do you know?
9. What effect does changing the bar magnet strength or the number of loops seem to have on the voltage? What combination gives you the greatest?

**IIIC Electromagnet experiment:** It describes the Biot-Savart law and magnetic field produced by bar magnet. It is based upon the equation

$$B = \mu_0 NI$$

Instructions:

1. Here you will find a compass and a power supply (battery) connected to a coil of wire. What effect does the battery appear to be having on the wire?
2. How can you confirm that the battery is, indeed, a DC power supply...and not just trust the label by the picture?

3. What appears to be creating the magnetic field being represented here? How can moving the compass around confirm that?

Why do you suppose the magnetic field surrounding the compass is not being represented by the simulation in this instance?

4. Does changing the number of loops appear to have an effect on the rate of motion of the electrons in the wire? Explain.

5. Gradually decrease the voltage of the battery from 10 V to 5 V. What effects does that appear to have on things?

6. What happens when the voltage is 0 V?

7. You may have noticed that you can continue to slide the voltage bar to the left. What does that do? Explain. (Slide bar back-n-forth a couple times to confirm).

8. Press the Show Field Meter button. Set the voltage to 10 V. What is the strength of the magnetic field inside the coil?

9. Decrease the voltage to 5 V. What effect did that have on the field strength? What kind of relationship do the two appear to have?

10. Replace the battery with an AC Current Supply. What effect does this have on the wire, the compass and the magnetic field meter?

**IIID. Transformer experiment:** It is based upon principle of mutual induction and describes the following equations.

$$e_s = -M \frac{dI_p}{dt}$$

and

$$\frac{e_s}{e_p} = \frac{n_s}{n_p}$$

Instructions:

1. Connect the D.C. source in the first coil and fixed its voltage. Note whether emf get induced in the secondary coil or not. Change the d.c. voltage continuously and note its effect on emf induced in secondary coil.
2. Replace DC supply of primary coil by AC source. Change the amplitude, frequency of

AC source and observe its effect on the emf induced in secondary coil.

3. Note the effect on induced emf if number of loops and area of secondary coil is changed

**IIIE. AC generation experiment:** In this simulation rotating bar magnet induces emf in the fixed coil. By changing the area, number of turns of coil and rotational speed of bar magnet student can change the magnitude of induce emf. It is based upon following equations.

$$e = - \frac{d}{dt} [n A B \cos(\omega t)]$$

Instructions:

1. Here you will find a water faucet, a compass, a bar magnet on a wheel (turbine), and a coil of wire connected to an incandescent bulb. Move the compass around a little and determine what it is reacting to at this time.
2. Turn the faucet on, just enough to get about 10 RPM on the turbine. What effect does this have on the compass and the wire/bulb?
3. Increase the rotation to about 20, 50, even 100 RPM. What effect does that appear to have on the compass, the wire and the bulb?
4. Increase and decrease the number of loops. What effect does this have?
5. Increase and decrease the bar magnet's strength. What effect does this have?
6. Replace the bulb with a Voltage Meter. What effect does increasing the RPMs have on the amount of voltage?
7. Does the rotating magnet appear to create a Direct or Alternating Current? Explain.
8. What effect does the number of loops appear to have on the voltage?
9. The moving of this magnet has created an electric current in the coil, which is being utilized by the bulb! Do you know what we call such a device? What is it?
10. If we could reverse this process, what would we call the device? What would one do to make that work? Can you get the simulation to do it?

Students can study the importance of each variable in every equation of EMI using above simulations and instructions.

#### IV. OUTCOMES OF THE STUDY

After faraday's simulation lab exercise students thinking and approach towards conceptual and application based question is changed. Maximum student had given correct answers to all questions which were not before. Response to theory based questions was near about same. This happens due to experiment performed by students using simulation. It is possible to do the experiment easily, without any risk only due to simulations. Experiments done by students had removed the understanding difficulties of the EMI theory.

#### V. CONCLUSIONS

Physics lab simulations are effective tools to describe each difficult concept of physics. Faraday's lab simulation is an easy way to enhance students understanding of faraday's theory of electromagnetic induction.

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#### APPENDIX A Lecture contents

1. Introduction of EMI phenomenon using Magnet-coil and coil-coil experiment
2. concept of Magnetic flux. Farady's law of EMI And problem of conservation of Energy.
3. Lenz's law of EMI.
4. Proof of Lenz's law of EMI.
5. Eddy current
6. Phenomenon of Self and Mutual induction. Concept of back emf.
7. Transformer construction; working and power losses.
8. AC generation by Rotating coil experiment