Physware 2012: A collaborative workshop on low-cost equipment and appropriate technologies that promote undergraduate-level, hands-on physics education throughout the developing world

Amrozia Shaheen
Physware series of workshops is an initiative launched to ‘Educate the educators’ for improving physics education in developing countries.

1st workshop held at ICTP from 16 to 27 February, 2009. The main focus was on ‘Mechanics’.

To explore active learning material at the undergraduate level using low-cost equipment that can easily be adapted throughout developing countries.

To provide an exposure to appropriate technologies and computer-based tool to enhance conceptual understanding.
### Program for Week-1

#### Tuesday, 27 November 2012

<table>
<thead>
<tr>
<th>BLOCK 1</th>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>09:00 to 10:00</td>
<td>DISCUSSION:</td>
<td>TEACHING vs ACTIVE LEARNING</td>
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<tr>
<td>10:00 to 11:00</td>
<td>ACTIVITY 2</td>
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<tr>
<td>11:00 to 11:30</td>
<td>Coffee Break</td>
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<td>11:30 to 13:00</td>
<td>ACTIVITY 3</td>
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<td>13:00 to 14:00</td>
<td>Lunch</td>
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<td>14:00 to 15:30</td>
<td>ACTIVITY 4</td>
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<td>15:30 to 16:00</td>
<td>Coffee Break</td>
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<td>16:00 to 18:00</td>
<td>ACTIVITY 5</td>
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<tr>
<td>18:00 to 19:30</td>
<td>POSTER PREPARATION</td>
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<tr>
<td>19:30 to 20:30</td>
<td>Dinner</td>
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#### Thursday, 29 November 2012

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<tr>
<th>BLOCK 1</th>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>09:00 to 10:00</td>
<td>DISCUSSION:</td>
<td>INTERACTIVE LECTURE DEMONSTRATIONS</td>
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<td>IN LARGE (OR SMALL) CLASSROOMS WITH</td>
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<td>LOW-COST EQUIPMENT/TECHNOLOGY</td>
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<td>10:00 to 11:00</td>
<td>ACTIVITY 10</td>
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<td>11:00 to 11:30</td>
<td>Coffee Break</td>
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<tr>
<td>11:30 to 13:00</td>
<td>ORGANIZATION</td>
<td>OF GROUP (OR INDIVIDUAL) PROJECTS:</td>
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<td>LOW COST ACTIVE LEARNING</td>
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<td>12:00 to 14:00</td>
<td>Lunch</td>
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<tr>
<td>14:00 to 15:30</td>
<td>PROJECT PLANNING: GROUP DISCUSSIONS</td>
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<tr>
<td>15:30 to 16:00</td>
<td>Coffee Break</td>
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<tr>
<td>16:00 to 19:30</td>
<td>WORK ON PROJECTS</td>
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<tr>
<td>19:30 to 20:30</td>
<td>Dinner</td>
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#### Friday, 30 November 2012

<table>
<thead>
<tr>
<th>BLOCK 1</th>
<th>Time</th>
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<tbody>
<tr>
<td>09:00 to 11:00</td>
<td>WORK ON PROJECTS</td>
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<tr>
<td>11:00 to 11:30</td>
<td>Coffee Break</td>
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<tr>
<td>11:30 to 13:00</td>
<td>WORK ON PROJECTS</td>
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<tr>
<td>13:00 to 14:00</td>
<td>Lunch</td>
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<tr>
<td>14:00 to 15:30</td>
<td>WORK ON PROJECTS</td>
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<tr>
<td>15:30 to 16:00</td>
<td>Coffee Break</td>
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<tr>
<td>16:00 to 19:00</td>
<td>PROJECT PRESENTATIONS</td>
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<tr>
<td>20:00 to 21:00</td>
<td>Dinner</td>
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#### Saturday, 01 December 2012

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>09:00 to 12:00</td>
<td>Visit to National Science Centre, Pragati Maidan</td>
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<td>13:00 to 14:00</td>
<td>Lunch</td>
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<tr>
<td>17:00 onwards</td>
<td>Delhi Sight Seeing Tour (Optional)</td>
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**Sight Seeing Tour (Optional)**
Program for Week-2

Tuesday, 04 December 2012

**BLOCK 1**
09.00 to 09.30  DISCUSSION & FEEDBACK
09.30 to 11.00  ACTIVITY 1: ELECTROMAGNETIC INDUCTION
                RTP Lab 10, Investigation 4, Visualizations
11.00 to 11.30  Coffee Break

**BLOCK 2**
11.30 to 13.00  FARADAY’S LAW
                Interactive Demo
                Video Analysis: Motion of magnets through coils
                BEMAP Q 31
13.00 to 14.00  Lunch

**BLOCK 3**
14.00 to 15.30  ACTIVITY 9: MAGNETIC RESONANCE IMAGING ANALOGY
15.30 to 16.00  Coffee Break

**BLOCK 4**
16.00 to 17.30  FARADAY’S LAW
                A Fun and Paper Tutorial for Advanced students
17.00 to 18.00  ALEXANDER GRAHAM BELL & MEDICAL IMAGING
                Interactive Lecture

Dinner (In individual Guest Houses)

Wednesday, 05 December 2012

**BLOCK 1**
09.00 to 10.00  INTRODUCTORY TALK
                DISCOVERY OF A NEW BOSON AT THE WORLD'S HIGHEST
                ENERGY ACCELERATOR
                Professor Kiran Ranjan, Department of Physics, University of Delhi
10.00 to 11.00  ACTIVITY 10: RIDDLY CURRENTS
11.00 to 11.30  Coffee Break

**BLOCK 2**
11.30 to 13.00  ACTIVITY 11: ENERGY FLOW IN A SIMPLE CIRCUIT
                Pen and Paper Tutorial for Advanced students: A use of the Joule's Law
13.00 to 14.00  Lunch

**BLOCK 3**
14.00 to 15.30  ACTIVITY 12: ELECTROMAGNETIC WAVES
15.30 to 16.00  Coffee Break

**BLOCK 4**
16.00 to 18.00  PROJECT WORK
                Each group picks a topic for the project and makes requests for equipment.
18.00 to 19.00  CULTURAL PROGRAMME
                Dinner (In individual Guest Houses)

Thursday, 06 December 2012

**BLOCK 1**
09.00 to 11.00  FEEDBACK & INTRODUCTION TO WEEK 2 PROJECTS
                Each group reports its topic.
11.00 to 11.30  Coffee Break

**BLOCK 2**
11.30 to 13.00  PROJECT WORK
13.00 to 14.00  Lunch

**BLOCK 3**
14.00 to 15.30  PROJECT WORK
15.30 to 16.00  Coffee Break

**BLOCK 4**
16.00 to 17.30  PROJECT WORK
19.30 to 20.30  BANQUET

Friday, 07 December 2012

**BLOCK 1**
09.00 to 11.00  PROJECT PRESENTATIONS
11.00 to 11.30  Coffee Break

**BLOCK 2**
11.30 to 13.00  PROJECT PRESENTATIONS
13.00 to 14.00  Lunch

**BLOCK 3**
14.00 to 14.45  DISCUSSION: CHANGING THE WAY OF TEACHING IN YOUR
                DEPARTMENT
14.45 to 15.30  FEEDBACK, GENERAL DISCUSSION AND CLOSURE
                Certificate Distribution
                Lottery on materials and equipment (must be present to win)
15.30 to 16.00  Coffee Break

**BLOCK 4**
16.00 to 17.00  FREE TIME
19.30 to 20.30  Dinner (In individual Guest Houses)
Topics covered in week-1

- Electrostatics: Verifications of Coulomb’s law (video analysis).
- Electric field hockey, Rutherford scattering (simulations).
- Exploring Gauss law and Faraday’s pail (Lab investigations & BEMA).
- Representations of electric fields and electric potentials (lab investigations).
- Basic DC circuits (lab investigations, activities & BEMA questions).
- Basic capacitors circuits (lab investigations).
Topics targeted in week-2

- Motion of charges in a magnetic field (Activity done using wires, magnets and batteries).
- Motion of wires in magnetic fields. (Activity of online e/m experiment).
- Magnetic filed around a current carrying wire (Visualizations).
- Motions of magnets and coils. (Dropping a magnet in a tube).
- Electromagnetic induction (visualizations).
- Faraday’s law (Demo, video analysis & BEMA).
- Magnetic resonance imaging analogy.
- Electromagnetic waves.
Understanding magnetic dipole

- Mathematically,

\[ \nabla \cdot \mathbf{B} = 0 \]

- Learning outcomes:
  Helps to understand the magnetic field directions

Aziz Fatima Hasnain, Imrana Ashraf, Nazia Sadiq, Amrozia Shaheen

Setup #1, 4/12/2012
- Mathematically,

\[ \mathcal{E} = -N \frac{\Delta \Phi_B}{\Delta t} \]

**Learning outcomes:**
- Helps to understand Faraday’s Law of Electromagnetic Induction.
- Relate the induced current/EMF with the changing Magnetic Flux.
- Correlate Faraday’s Law with Lenz’s Law as per their statements with the help of polarity (direction) of the induced current, in accordance to the changing magnetic flux.
- Compare different materials on the basis of their magnetic interaction (using pipes made up of different materials creating tunnels for magnet to move and pass through a pick up coil).

Aziz Fatima Hasnain, Imrana Ashraf, Nazia Sadiq, Amrozia Shaheen  
Setup # 2, 5/12/2012
Activity on building a motor
A proton is initially at rest in a region of uniform magnetic field (shown below). There are no other charges present.

Choose from the following possible directions to answer the question below:

[Diagram showing possible directions:]
- a. out of page
- b. into page
- c. zero magnitude
- d. None of the above

Q20: What is the direction (a - d) of the initial magnetic force on the proton?

---

Here is a bar magnet. The magnetic field made by the bar magnet at one location is shown on the diagram:

Choose from the following:

- g. out of page
- h. into page
- i. zero magnitude
- j. None of the above

Q21: What is the direction (a - i) of the magnetic field of the bar magnet at location 1 (marked with ¥)?

Q22: What is the direction (a - j) of the magnetic field of the bar magnet at location 2 (marked with ¥)?

A moving electron travels along the path shown, and passes through a region of magnetic field. There are no other charges present. The magnetic field is zero everywhere except in the gray region.

Choose from the following directions to answer the question below:

[Diagram showing possible directions:]
- c. out of page
- f. into page
- g. None of the above

Q23: What is a possible direction (a - g) of the magnetic field in the region where the field is non-zero?
C. The total electric field must diminish as we move away from the resistor. The arrows inside the dashed region on the left represent the magnitude and direction of the parallel component of the electric field outside the resistor. Consider a line integral of the electric field \( \int E \cdot dl \) in the counter-clockwise direction, \([1 \rightarrow 2 \rightarrow 3 \rightarrow 4]\).

Is the contribution to the line integral from the parts of the loop that are parallel to the surface (1 & 3 only) positive, negative or zero?

Is the contribution to the line integral from the parts of the loop that are perpendicular to the surface (2 & 4 only) positive, negative or zero?

Indicate in the diagram the direction of the perpendicular component of the electric field \( E \) along parts 2 & 4 of the loop. Assume that both parts contribute equally to the line integral.

Is the volume charge density inside the resistor positive, negative or zero? Where are the charges located that are responsible for the perpendicular components of the electric field outside the resistor?

D. Suppose the steady-state surface charge on the resistor is distributed as shown in the diagram. The surface charge density varies smoothly from positive at the bottom to negative to negative at the top.

Sketch the magnitude and direction of just the perpendicular component of the electric field \( E \) at the points indicated just outside and to the left of the resistor (circular dots).

Suppose the resistor were instead an ideal conductor (\( \sigma \rightarrow \infty \)). Would the parallel component of the electric field just outside this ideal conductor be zero or nonzero? [Hint: What happens to the electric field inside the material if the current density \( J = \sigma E \) remains finite as \( \sigma \rightarrow \infty \)?]
A. A steady uniform current density $\mathbf{J}$ flows upwards through a cylindrical resistor (as shown in the diagram at right). The resistor is made from a poorly conducting material with high resistivity $\rho = 1/\sigma$, where $\sigma$ is the conductivity of the material. The bottom wire is connected to the positive terminal of a battery, and the top wire is connected to the negative terminal.

This next diagram shows the same resistor in cross-section.

Indicate the direction of both the electric field $\mathbf{E}$ and the magnetic field $\mathbf{B}$ at the point shown inside the resistor (circular dot).

At this same point, draw an arrow indicating the direction of the Poynting vector:

$$\mathbf{S} = \frac{\mathbf{E} \times \mathbf{B}}{\mu_0}$$

Describe in words how energy is flowing into the resistor.

B. Consider an Amperian loop (dashed lines) with length $\ell$ and width $w$ that straddles the surface of the resistor.

Recall Faraday's Law:

$$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \int \mathbf{B} \cdot d\mathbf{a}$$

Is the line integral of the electric field along this closed Amperian loop positive, negative or zero?

Briefly explain your reasoning.

Imagine we let $w \to 0$ while keeping the loop centered on the wall of the resistor. In this situation, is the parallel component of the electric field outside the resistor zero or non-zero? Briefly explain your reasoning.
Phet simulations
Phet simulations
Virtual experiment of e/m ratio

- Vacuum tube.
- Vacuum tube power supply.
- Undeflected electron beam.
- Digital multi-meter (DMM).

- Helmholtz coils.
- Current source.
- An electron beam bent due to an external magnetic field.
- A top-down view of the beam impacting the surface plate.
Virtual experiment on e/m ratio

Exercise 1: Constant kinetic energy, variable magnetic field.

1. The manufacturer of the Helmholtz coils engraves the number of turns of each coil, \( N \), onto the base of the apparatus. Record this value in the Data Sheet.

2. Measure the diameters of one of the coils and then calculate its radius, \( R \). Record the value of the radius. In the video below, one of the coils has been removed for clarity purposes only.

3. Connect the power supply to the vacuum tube with wire leads being sure to match the colors of the banana jack outlets with those of the vacuum tube apparatus. In the video below, the black wire is connected to ground, red to the anode, blue to the filament. (The yellow wire is connected to the grid, which helps focus the beam, but was not used in this experiment.)

   Also connect a digital multi-meter (DMM) across the vacuum tube’s anode and ground leads. The DMM will be used in step 5 to accurately measure the anode voltage.

   The wire leads are connected to the vacuum tube, [0:32, 6.58 MB]

   The digital multi-meter leads are connected across the anode voltage, [0:16, 2.98 MB]

4. Turn on the power to the vacuum tube power supply and adjust the filament current so that the beam is sufficiently bright. In our example, the filament current is set to 0.6 amps and is held constant throughout this exercise.

   The filament current is set and the beam appears, [0:22, 4.19 MB]

5. Adjust the anode voltage, \( V \), on the power supply to impart a kinetic energy to the electrons. In this exercise the anode voltage is set to an arbitrary value of 38.4 volts. Since we want the electrons to have a fixed kinetic energy, the anode voltage is not adjusted again for the duration of the exercise. You should record the anode voltage in the Data Sheet below.

6. Connect the Helmholtz coil to the variable current source with wire leads. The polarity of the leads is not an issue. What will happen if the leads are inverted?

   Leads from the current source are connected to Helmholtz coils, [0:15, 2.82 MB]

7. In this step we will use the Helmholtz coils to create the magnetic field that is used to deflect the electron beam. To do so, power up the variable current source and apply enough current to the coils so that the resulting magnetic field is strong enough to bend the beam into a circular path. The magnetic field should be large enough to cause the beam to impact the surface plate. Record the value of the current, \( I \). Also calculate the magnetic field strength, \( B \), and record this value in the Data Sheet.

   The anode voltage is set, [0:11, 2.22 MB]

   The DMM displays the anode voltage, [0.047 MB]

   During this step, you must measure the beam’s radius of curvature, \( r \), by carefully noting where the beam impacts the surface plate. Use the concentric circles imprinted on the plate as reference points to help you make the measurements. Recall that the circles are separated by a distance of 0.5 cm, and that the distance between the exit hole and the beam’s impact point is twice that of the beam’s radius of curvature.

   The beam is bent and the first deflection is measured, [0:41, 7.81 MB]

   All deflection measurements are played here, [1:32, 17.3 MB]

8. Repeat step 7, varying the strength of the magnetic field by varying the current applied to the Helmholtz coils. Take great care in measuring the electron deflection and its radius of curvature. A small error in your deflection measurement, say \( \pm 0.05 \) cm, can cause a 10% error in your final calculation of the electron’s mass. This measurement is especially sensitive when \( r \) is small.

   All deflection measurements are played here, [1:32, 17.3 MB]

   The second deflection measurement may be made, [0:08, 1.51 MB]

   The third deflection measurement may be made, [0:08, 1.57 MB]

   The fourth deflection measurement may be made, [0:09, 1.81 MB]

   The fifth deflection measurement may be made, [0:09, 1.87 MB]

   The final deflection measurement may be made, [0:10, 2.01 MB]

   All deflection measurements are played here, [1:32, 17.3 MB]

9. Use the values entered into the Data Sheet below to determine the ratio \( \frac{V}{I} \). You can accomplish this in two ways:
   A. Determine the \( \frac{V}{I} \) ratio using measurements from each trial and then find the average ratio. (Students with little previous laboratory experience may need to use this method.)
Virtual experiment on e/m ratio

CUPOL: Electron Charge to Mass Ratio

10. In 1913, Robert Millikan determined from his Nobel Prize-winning oil-drop experiments that the charge of an electron has a value of $1.60 \times 10^{-19}$ C. Use your experimental results and Millikan's value to determine the electron mass, $m$. 

11. Calculate the percent error between your value for the electron’s mass and the accepted value of $m = 9.109 \times 10^{-31}$ kg.

12. For safe keeping, you may e-mail the data directly to yourself or to your TA by entering the data into the form below and then clicking The Send Button.

**Data Sheet**

**Exercise 1 Data Sheet**

- Your name:
- Your e-mail address:

<table>
<thead>
<tr>
<th>Number of coils, $N$</th>
<th>Helmholtz coil diameter</th>
<th>Helmholtz coil radius, $R$</th>
<th>Filament current</th>
<th>Anode voltage, $V$</th>
<th>Choose units…</th>
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<table>
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<tr>
<th>Current, $I$ (A)</th>
<th>Magnetic Field, $B$ (T)</th>
<th>Radius of Curvature, $r$ (m)</th>
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- Choose quantity…
- Choose quantity…
- Choose units…
- Choose units…
- Choose units…

- Quantity plotted on x-axis
- Quantity plotted on y-axis
- Slope of your graph
- Experimental value of $\frac{e}{m}$
- Accepted value of $e$
- Experimental value of $m$
- Accepted value of $m$
- Percent error
Concept of phase and superposition explored and verified through Lissajous patterns

Kanchan, Babalola, James, Murthy, Sabieh
Learning objectives

• Phasors and phase in passive circuits
• AC circuit analysis using complex numbers
• Working of an oscilloscope
• Simulating electrical behavior
• Nonlinear circuits and chaos (Optional)
Circuit diagram
Circuit analysis

\[ V_x = V \frac{R_2}{R_1 + R_2} = V \frac{R_2}{R_1 + R_2} \angle 0^\circ \]

\[ V_y = \frac{V}{R_3 + \frac{1}{i\omega C}} \cdot \frac{1}{i\omega C} = \frac{V}{1 + i\omega R_3 C} = V \frac{1 - i\omega R_3 C}{1 + (\omega R_3 C)^2} \angle \tan^{-1}(-\omega R_3 C) \]
Representation of two phasors

\[ V_x = a \sin(\omega t + \phi_0) \]

\[ V_y = b \sin(\omega t + \phi_0 + \tan^{-1}(-\omega R_3 C)) \]
Parametric plots from the waves

\[ x = a \sin(\omega t) \]
\[ y = b \sin(\omega t + \theta) \]
\[ \frac{y^2}{b^2} + \frac{x^2}{a^2} - \frac{2xy}{ab} \cos \theta = \sin^2 \theta \]
Lissajous patterns
Further explorations
Electrostatic lines of force
THINGS WE NEED

1. BABY OIL
2. ARTIFICAL HAIR
3. PLEXY GLASS CONTAINER
4. WIMSHURT MACHINE
5. CONNECTING CABLES
6. COPPER BALLS
7. CO-AXIAL CYLINDERS
ROAD MAP TO ELECTRIC FIELD LINES

- PUT BABY OIL IN PLEXY GLASS PLATE
- ATTACH TWO COPPER BALLS WITH CONNECTING WIRES.
- JOIN WITH WIMSHURT MECHINE
- MAKE SMALL CUTINGS OF ARTIFICAL HAIR SPRINKLE ON THE TOP OF OIL
- MAKE WIMSHRUT MECHINE TO WORK

HAVE FUN
EQUAL AND OPPOSITE CHARGE DISTRIBUTION
Field Demonstration for Opposite Charges
CONCLUSION

EQUAL AND OPPOSITE CHARGE ATTRACT EACH OTHER
SAME CHARGES

- Connect both balls with same terminal of Wimshrut machine
- Make Wimshrut to work
- See the movement of hair on oil
- It is like this we think?
TWO EQUAL AND OPPOSITE CHARGED DISTRIBUTION
Field Demonstration for Like Charges
Coaxial Cylinder

\[ \vec{E} \]

\[ -\infty \rightarrow a \rightarrow \infty \]

\[ +Q \]
Field Demonstration for Cylindrical Charge Distribution
We have made it to detect the presence of electric field. When there is any electric field present in a proximity of even 10 meters, this simple tool is capable of detecting very week fields also. This detector can be equipped with a calibrated meter to provide electric field measurement also.
Seeing Kirchoff’s voltage law in light of Faraday’s law

\[ \int \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \int \vec{B} \cdot d\vec{S} \]

Kanchan, James, Murthy, Sabieh
Circuit laws are generally taught as being a distinct entity from Maxwell’s equations. Can we wed the two?

Demonstrate the changing magnetic flux can act as a battery inside a circuit

Concept of paths, loops and areas pierced by changing flux
Proposed activity one

\[ + \quad V1 \quad - \]

\[ dB/dt \]

\[ + \quad V2 \quad - \]
Connection of Faraday’s law with Kirchoff’s voltage law

\[ \int \vec{E} \cdot d\vec{l} = 0 \]

\[ \sum V = 0 \]

\[ \int \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \int \vec{B} \cdot d\vec{S} \]

\[ \sum V = -\frac{d}{dt} \int \vec{B} \cdot d\vec{S} \]

\[ -V_1 + V_2 = -\frac{d}{dt} \int \vec{B} \cdot d\vec{S} \]
Proposed activity two
Proposed activity three

$\frac{dB}{dt}$
Calibrate the electromagnet

\[ B = 0.124I + 0.15 \quad B \text{ in Tesla, } I \text{ in Ampere} \]
Future improvements

• Control over $-\frac{d}{dt} \int \vec{B} \cdot d\vec{S}$

• Precise measurement of voltages, preferably using analog voltmeters or acquiring data

• KCL and KVL are only lumped approximations
Setup #1: Crushing cans with Lenz’s law

Imrana Ashraf
Aziz Fatima Husnain
Nazia Sadiq
Amrozia Shaheen
The switch $S_1$ is closed to charge a and $S_2$ is used to energize the solenoid.

Since the current varies in time, the magnetic field in the solenoid and the magnetic flux defined in the solenoid will vary in time.

The flux passes through the can inside the solenoid, inducing in it a current in opposite direction of the current through the solenoid (Lenz's Law).

The two anti-parallel currents repel each other, and since the solenoid is fixed the can will be crushed.
Proposed Learning outcomes

- To understand Lenz’s law in an interesting way.
- Study of Repulsion between anti-parallel currents and the consequence.

Our Exploration:

- So far now, it is just a proposal by us!
- We have not been successful in crushing the pop cans by the said procedure.
- Analyzing the possibilities and causes of failure has been very interesting however!
Setup # 2: Motional EMF and Faraday’s law

Imrana Ashraf
Aziz Fatima Husnain
Nazia Sadiq
Amrozie Shaheen
Apparatus: [Low-cost approach]

- Copper rods as electric rail
- Light weight metallic cylinder
- Ring magnets
- Battery
- Switch
- Connecting wires
- Thermo pore blocks
Experimental setup

Schematic diagram
Learning Goals

- To understand the concept of Motional EMF generated by a current carrying conductor in an external magnetic field.
- To show the motion of a current carrying conductor in a magnetic field.
- To show the dependence of the speed of a current carrying conductor on magnetic field.
- To show the direction of motion with the changing direction of magnetic field.
- To explore an indirect way of finding the strength of Magnetic field of a magnet.
Motional emf and Faraday’s law

- The magnetic force is,
  \[ \vec{F}_B = q\vec{v} \times \vec{B} \]

- From Faraday’s law the induced emf is,
  \[ \Phi_B = B l x. \]
  \[ d\Phi_B = B l dx = B l v dt. \]
  \[ \mathcal{E} = \frac{d\Phi_B}{dt} = B l v. \]
Demonstration of the Experiment:
Some more exercises:

- Quantitative analysis of speed of the moving conductor simply using a meter scale and a stopwatch.
- Exploring the dependence of the moving conductor’s speed on the strength of magnetic field.
- Dependence of the moving conductor’s speed on the battery voltage.
- Reversing the polarity of the battery and/or flipping the poles of the magnet and observing its effect on the motional emf.
Are induced EMFs and currents different in any way from EMFs and current provided by battery connected to a conducting loop?

Can a charged particle at rest be set in motion by the action of a magnetic field? If so low? Consider both static and time varying fields.
Thank you..

We have many Queries ourselves!

Responses and Feedbacks are welcome..

Imrana Ashraf
Aziz Fatima Husnain
Nazia Sadiq
Amrozia Shaheen
Why was the can not crushed in our setup # 1? During the exploration we have analyzed that the use of smaller value of capacitor and low-inductive solenoid might be the hurdles to the success. Are we really correct?

Instead of creating a strong magnetic field and thus permitting an induced current in the can, the solenoid got extremely hot. Is that because of the coil resistance (in our case it was 17ohms) of the solenoid only?

Instead of metallic can we also tried with an aluminum foil cylinder to shorten the scale of our experiment, but it didn’t work. What had been wrong with it?
Taj Mahal
Taj Mahal