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

Objectives of the workshop

- 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

The Abdus Salam International Centre for Theoretical Physics

PHYSWARE 2012

A Collaborative Workshop on Low-Cost Equipment and Appropriate Technologies that Promote Undergraduate Level, Hands-on Physics Education throughout the Developing World

Directors: Pratibha Jolly, Priscilla Laws, Elena Sassi, Dean Zollman
ICTP Co-ordinator: Joe Niemela
Local Organizers: Pratibha Jolly, Mallika Verma

26 November - 7 December 2012

Miranda House, University of Delhi, Delhi, India

Co-sponsors:

PRELIMINARY PROGRAMME

WEEK 1	
Monday, 26 November 2012	
BLOCK 1	
09.30 to 11.00	**OPENING SESSION**
09.00 to 09.30	Registration and Logistics
09.30 to 10.00	Opening Ceremony
10.00 to 11.00	Introduction of Participants
11.00 to 11.30	Coffee Break
BLOCK 2	
11.30 to 12.00	**INTRODUCTION TO PHYSWARE**
12.00 to 13.00	**OVERVIEW ON RESEARCH IN PHYSICS EDUCATION: IMPLICATIONS FOR TEACHING OF PHYSICS**
13.00 to 14.00	Lunch
BLOCK 3	
14.00 to 15.30	**ACTION RESEARCH AND TEACHING ELECTRICITY AND MAGNETISM**
15.30 to 16.00	Coffee Break
BLOCK 4	
16.00 to 18.00	**ACTIVITY 1**
19.00 to 21.00	**DINNER RECEPTION**

Tuesday, 27 November 2012	
BLOCK 1	
09.00 to 10.00	**DISCUSSION: TEACHING vs ACTIVE LEARNING**
10.00 to 11.00	**ACTIVITY 2**
11.00 to 11.30	Coffee Break
BLOCK 2	
11.30 to 13.00	**ACTIVITY 3**
13.00 to 14.00	Lunch
BLOCK 3	
14.00 to 15.30	**ACTIVITY 4**
15.30 to 16.00	Coffee Break
BLOCK 4	
16.00 to 18.00	**ACTIVITY 5**
18.00 to 19.30	**POSTER PREPARATION**
19.30 to 20.30	Dinner

Wednesday, 28 November 2012	
BLOCK 1	
09.00 to 10.00	**DISCUSSION: STUDENT'S LEARNING DIFFICULTIES WITH ELECTRICITY AND MAGNETISM**
10.00 to 11.00	**ACTIVITY 6**
11.00 to 11.30	Coffee Break
BLOCK 2	
11.30 to 13.00	**ACTIVITY 7**
13.00 to 14.00	Lunch
BLOCK 3	
14.00 to 15.30	**ACTIVITY 8**
15.30 to 16.00	Coffee Break
BLOCK 4	
16.00 to 18.00	**ACTIVITY 9**
18.00 to 19.30	**POSTER PRESENTATIONS**
19.30 to 20.30	Dinner

Thursday, 29 November 2012	
BLOCK 1	
09.00 to 10.00	**DISCUSSION: INTERACTIVE LECTURE DEMONSTRATIONS IN LARGE (OR SMALL) CLASSROOMS WITH LOW-COST EQUIPMENT/TECHNOLOGY**
10.00 to 11.00	**ACTIVITY 10**
11.00 to 11.30	Coffee Break
BLOCK 2	
11.30 to 13.00	**ORGANIZATION OF GROUP (OR INDIVIDUAL) PROJECTS: LOW COST ACTIVE LEARNING**
13.00 to 14.00	Lunch
BLOCK 3	
14.00 to 15.30	**PROJECT PLANNING: GROUP DISCUSSIONS**
15.30 to 16.00	Coffee Break
BLOCK 4	
16.00 to 19.30	**WORK ON PROJECTS**
19.30 to 20.30	Dinner

Friday, 30 November 2012	
BLOCK 1	
09.00 to 11.00	**WORK ON PROJECTS**
11.00 to 11.30	Coffee Break
BLOCK 2	
11.30 to 13.00	**WORK ON PROJECTS**
13.00 to 14.00	Lunch
BLOCK 3	
14.00 to 15.30	**WORK ON PROJECTS**
15.30 to 16.00	Coffee Break
BLOCK 4	
16.00 to 19.00	**PROJECT PRESENTATIONS**
20.00 to 21.00	Dinner

Saturday, 01 December 2012	
09.00 to 12.00	Visit to National Science Centre, Pragati Maidan
13.00 to 14.00	Lunch
17.00 onwards	Delhi Sight Seeing Tour (Optional)

Sunday, 02 December 2012
Sight Seeing Tour (Optional)

Program for Week-2

ICTP International Centre for Theoretical Physics

IUPAP

PHYSWARE 2012

A COLLABORATIVE WORKSHOP ON LOW-COST EQUIPMENT AND APPROPRIATE TECHNOLOGIES THAT PROMOTE UNDERGRADUATE LEVEL HANDS-ON PHYSIC EDUCATION THROUGHOUT THE DEVELOPING WORLD

Directors: Pratibha Jolly, Priscilla Laws, Elena Sassi, Dean Zollman
ICTP Co-ordinator: Joe Niemela, ICTP, Trieste
Local Organizers: Pratibha Jolly, Mallika Verma

27 November to 7 December 2012
Miranda House, University of Delhi, Delhi, India
https://sites.google.com/site/2012physware

PROGRAMME: WEEK 2

WEEK 2	
Monday, 03 December 2012	
BLOCK 1	
09.00 to 10.00	**DISCUSSION: MAGNETISM** BEMA Questions 20-23
10.00 to 11.00	**ACTIVITY 1: MOTION OF CHARGES IN A MAGNETIC FIELD** Exploring what you can do with wires, magnets and batteries
11.00 to 11.30	Coffee Break
BLOCK 2	
11.30 to 12.15	**ACTIVITY 2: MOTION OF CHARGES IN MAGNETIC FIELDS** ILD & RTP Lab 9, Investigation 3
12.15 to 13.00	**ACTIVITY 3: e/m ON LINE**
13.00 to 14.00	Lunch
BLOCK 3	
14.00 to 14.30	**ACTIVITY 4: MOTION OF WIRES IN MAGNETIC FIELDS** RTP Lab 9, Investigation 4 Visualizations
14.30 to 15.30	**ACTIVITY 5: MAGNETIC FIELD AROUND A CURRENT CARRYING WIRE** RTP Lab 10, Investigation 1 Visualizations
15.30 to 16.00	Coffee Break
BLOCK 4	
16.00 to 17.00	**ACTIVITY 6: MOTION OF MAGNETS AND COILS** Dropping a Magnet in a Tube Dropping a Coil on a Magnet
17.00 to 17.30	**ACTIVITY 7: BUILD YOUR OWN SIMPLE MOTOR**
17.30 to 18.00	**DISCUSSION: OBSERVATIONS VS VISUALIZATIONS**
	Dinner (In individual Guest Houses)

Tuesday, 04 December 2012	
BLOCK 1	
09.00 to 09.30	**DISCUSSION & FEEDBACK**
09.30 to 11.00	**ACTIVITY 8: 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 BEMA 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 17.00	**FARADAY'S LAW** A Pen 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	***INVITED TALK*** **OBSERVATION OF A NEW BOSON AT THE WORLD'S HIGHEST ENERGY ACCELERATOR** Professor Kirti Ranjan, Department of Physics, University of Delhi
10.00 to 11.00	**ACTIVITY 10: EDDY 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 Poynting Vector
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 18.00	**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

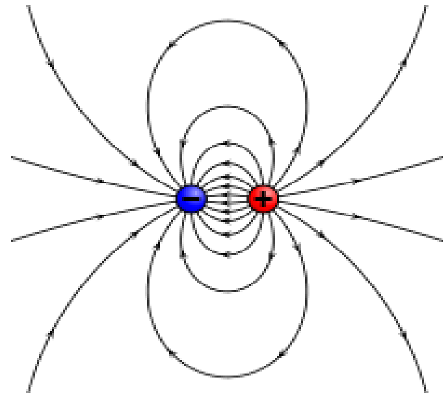
- Motion of charges in a magnetic field (Activity done using wires, magnets and batteries).
- Motion of wires in magnetic fields. (Activity of online e/m experiment).
- Magnetic filed around a current carrying wire (Visualizations).
- Motions of magnets and coils. (Dropping a magnet in a tube).
- Electromagnetic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

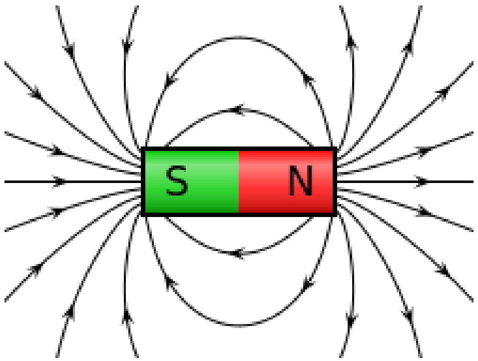
Understanding magnetic dipole

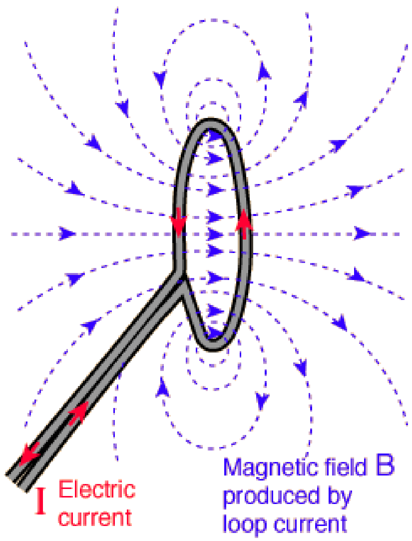
- Mathematically,

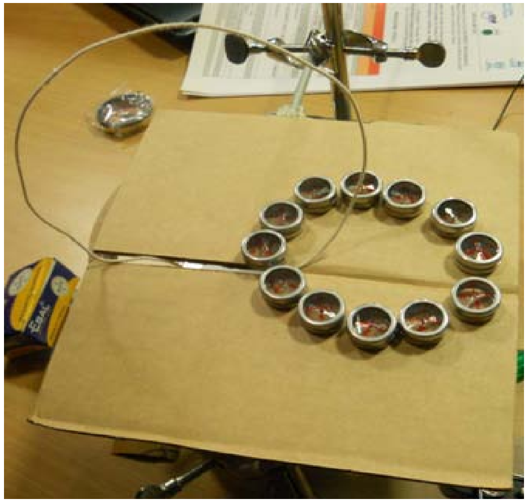
$$\nabla \cdot \mathbf{B} = 0$$

- **Learning outcomes:**
  Helps to understand the magnetic field directions









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

Setup # 1, 4/12/2012

Demonstrating Faraday's Law of Induction

- Mathematically,

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

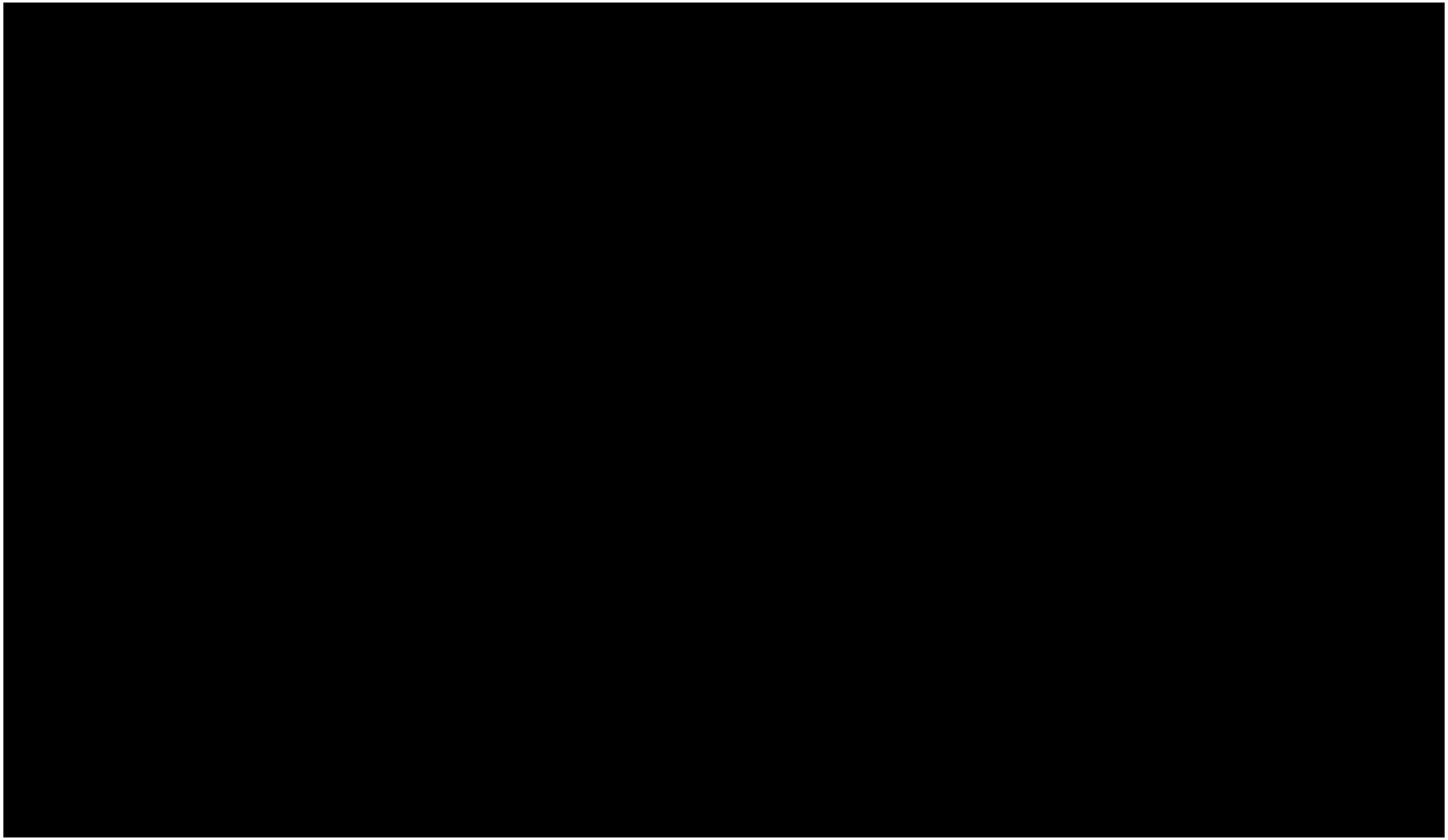
✓ **Learning outcomes:**

- 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

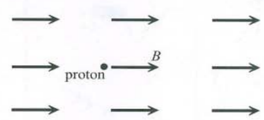


BEMA Questions

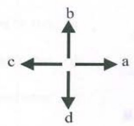
A Brief E&M Assessment

Ruth Chabay and Bruce Sherwood
Department of Physics
North Carolina State University

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:



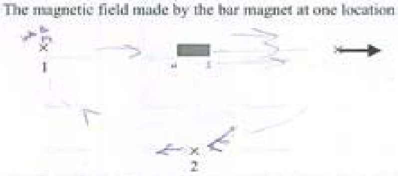
e: out of page ⊙
f: into page ⊗
g: zero magnitude
h: None of the above

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

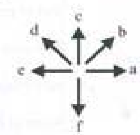
A Brief E&M Assessment

Ruth Chabay and Bruce Sherwood
Department of Physics
North Carolina State University

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

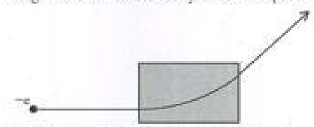


g: out of page ⊙
h: into page ⊗
i: zero magnitude
j: none of the above

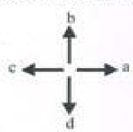
▶ Q21: What is the direction (a - j) of the magnetic field of the bar magnet at location 1 (marked with ×)?

▶ 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:

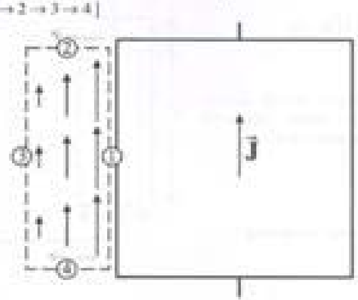


e: out of page ⊙
f: into page ⊗
g: none of the above

▶ Q23: What is a possible direction (a - g) of the magnetic field in the region where the field is non-zero?

BEMA Questions for energy flow

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 $\oint \vec{E} \cdot d\vec{\ell}$ 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?*

Positive

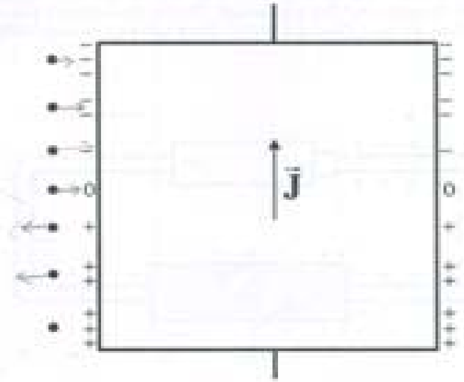
Is the contribution to the line integral from the parts of the loop that are **perpendicular** to the surface (2 & 4 only) *positive, negative or zero?*

Zero

Indicate in the diagram the direction of the perpendicular component of the electric field $\vec{E}^{\perp}$ 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 $\vec{E}^{\perp}$ 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 $\vec{J} = \sigma\vec{E}$ remains finite as $\sigma \rightarrow \infty$?]

BEMA Questions for energy flow

08 - Energy Flow NAME____________________

A. A steady uniform current density $\vec{J}$ 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 σ 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 $\vec{E}$ and the magnetic field $\vec{B}$ at the point shown **inside** the resistor (circular dot).

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

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

Describe in words how energy is flowing into the resistor.

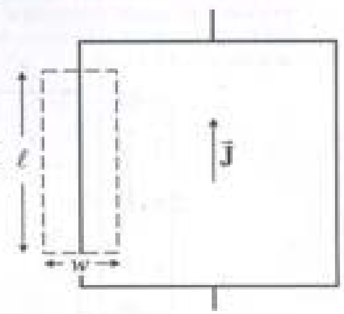
It is flowing in radial

08 - Energy Flow NAME____________________

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

Recall Faraday's Law:

$$\oint \vec{E}\cdot d\vec{\ell} = -\frac{d}{dt}\iint \vec{B}\cdot d\vec{a}$$

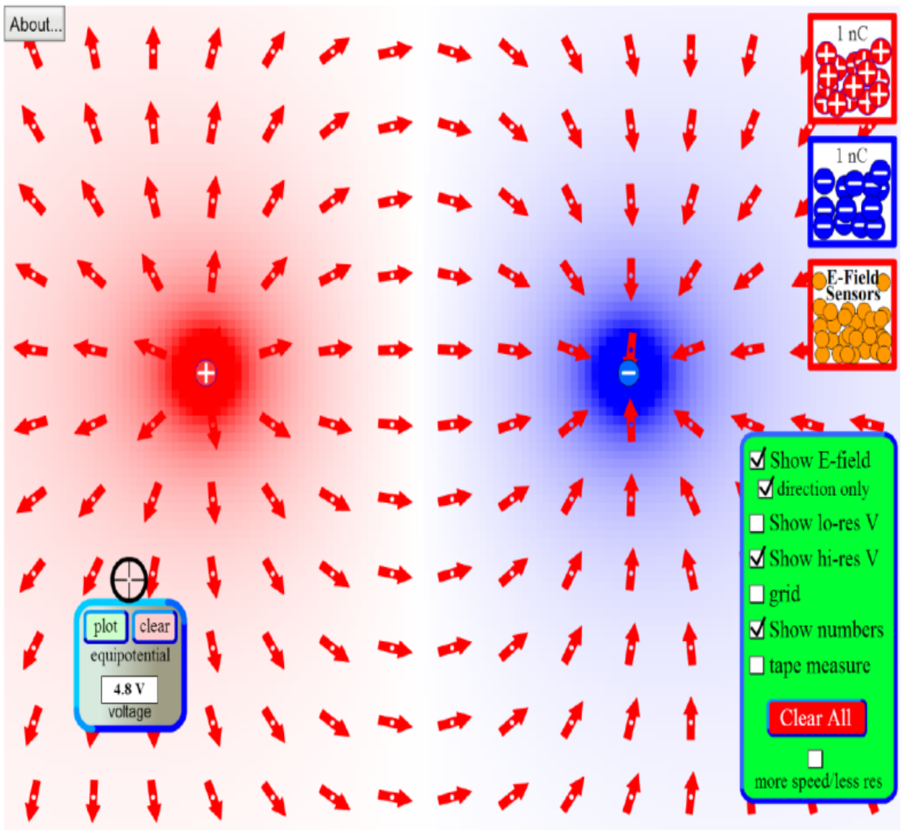


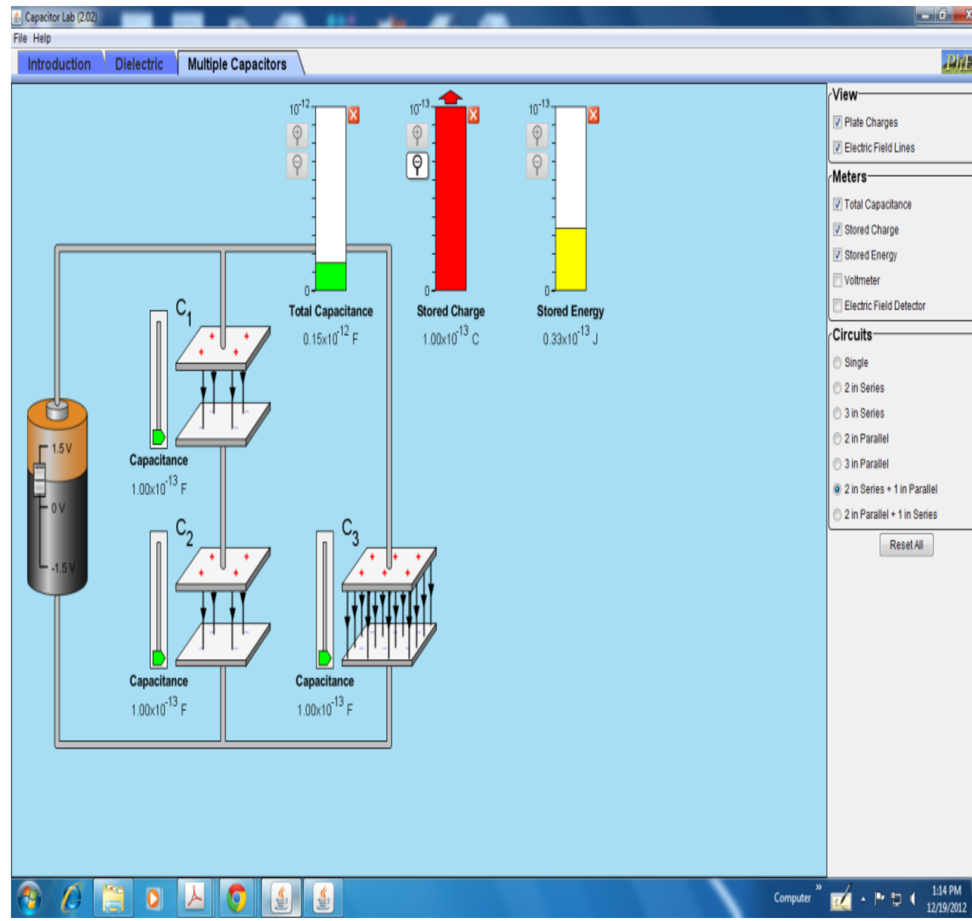
Is the line integral of the electric field along this closed Amperian loop *positive*, *negative* or *zero*?

Briefly explain your reasoning.

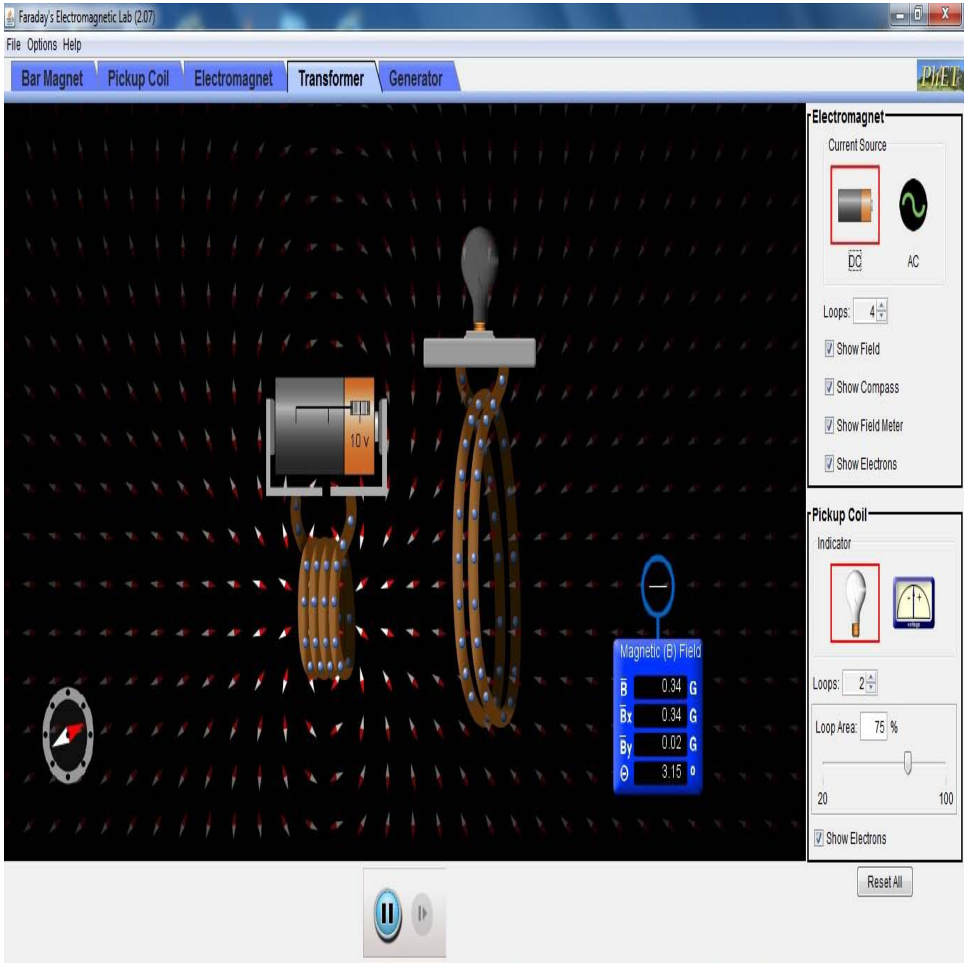
Imagine we let $w \to 0$ while keeping the loop centered on the wall of the resistor. In this situation, is the *parallel* component of the electric field outside the resistor *zero* or *nonzero*? Briefly explain your reasoning.

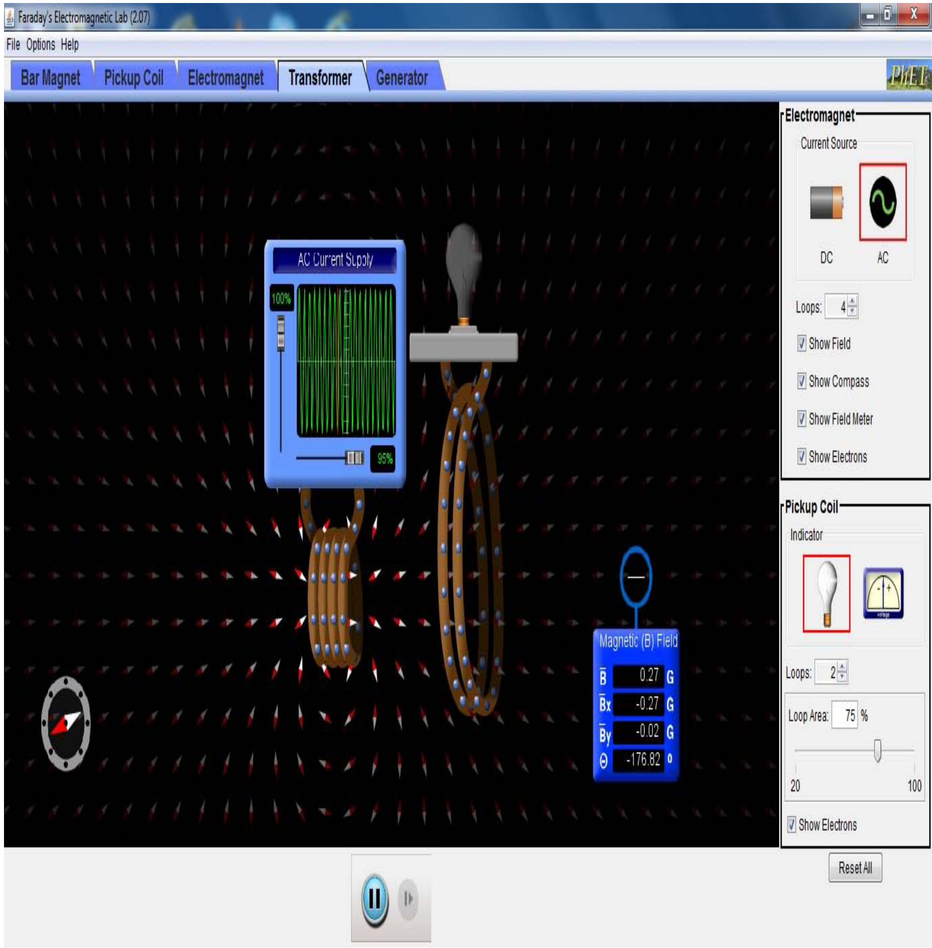
Phet simulations





Phet simulations

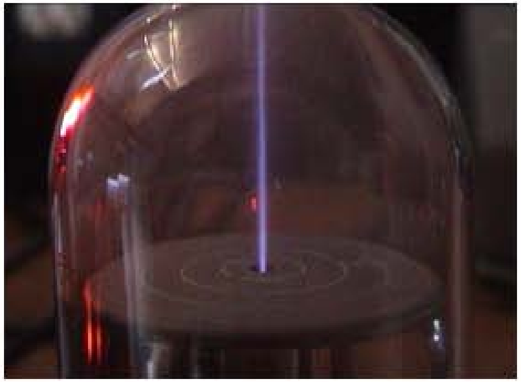




Virtual experiment of e/m ratio

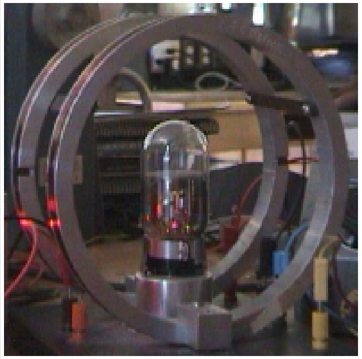
Vacuum tube.

Vacuum tube power supply.



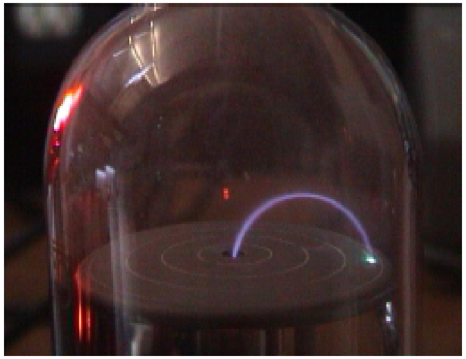
Undeflected electron beam.

Digital multi-meter (DMM).

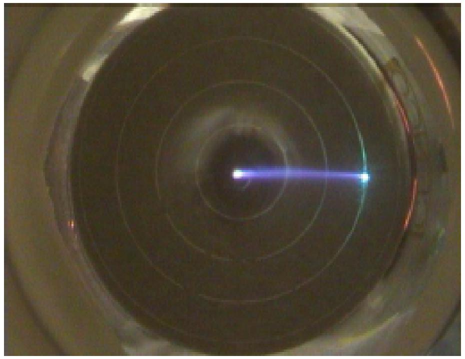


Helmholtz coils.

Current source.



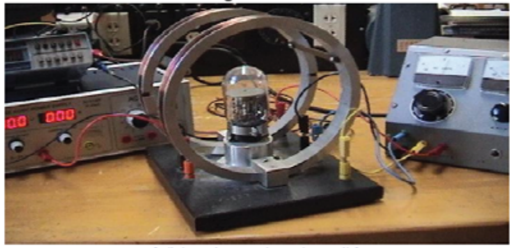
An electron beam bent due to an external magnetic field.



A top-down view of the beam impacting the surface plate.

Virtual experiment on e/m ratio

Figure 10.



[Click on image to enlarge it.]

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.

   Number of turns, N [0.052 Mb]

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

   The coil diameter is measured. [0:33, 6.16 Mb]

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.

   The anode voltage is set. [0:11, 2.22 Mb]
   The DMM displays the anode voltage. [0.047 Mb]

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.

   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 0.50 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 t the Helmholtz coils. **Take great care in measuring the electron deflection and its radius c curvature.** A small error in your deflection measurement, say ± 0.05 cm, can cause a 10% error in your final calculation of the electron's mass. This measurement is especially sensitiv 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 e/m. You can accomplish this in two ways:
   A. Determine the e/m ratio using measurements from each trial and then find the average ratio. (Students with little previous laboratory experience my need to use this method.)

Virtual experiment on e/m ratio

B. Or you may graph the appropriate data along the x- and y-axes and then analyze the resulting curve. The graph may be drawn by hand or created by a spread shee application like MS Excel, for example. (For additional help, see our tutorials on Plotting experimental data, Creating a graph, and Using MS Excel.)

10. In 1913, Robert Millikan determined from his Nobel Prize-winning oil-drop experiments thc the charge of an electron has a value of 1.60×10^{-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 accepte 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 th data into the form below and then clicking The Send Button.

Data Sheet

Exercise 1 Data Sheet

Your name:		
Your e-mail address:		
Number of coils, N		
Helmholtz coil diameter		Choose units ...
Helmholtz coil radius, R		Choose units ...
Filament current		Choose units ...
Anode voltage, V		Choose units ...

Current, I (A)	Magnetic Field, B (T)	Radius of Curvature, r (m)

Quantity plotted on x-axis	Choose quantity	
Quantity plotted on y-axis	Choose quantity	
Slope of your graph		Choose units ...
Experimental value of e/m		Choose units ...
Accepted value of e	1.60×10^{-19} C	
Experimental value of m		Choose units ...
Accepted value of m	9.109×10^{-31} kg	
Percent error		%

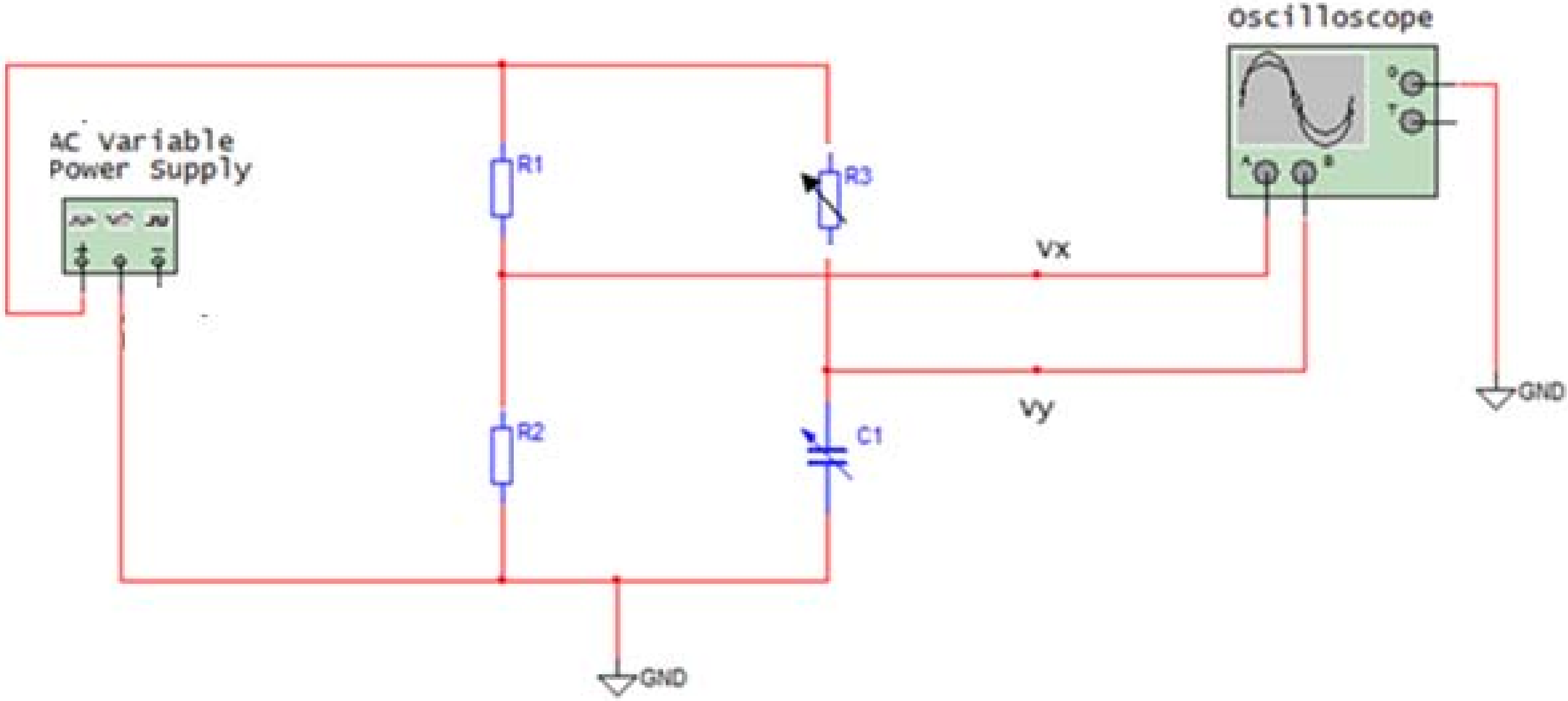
Concept of phase and superposition explored and verified through Lissajous patterns

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

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

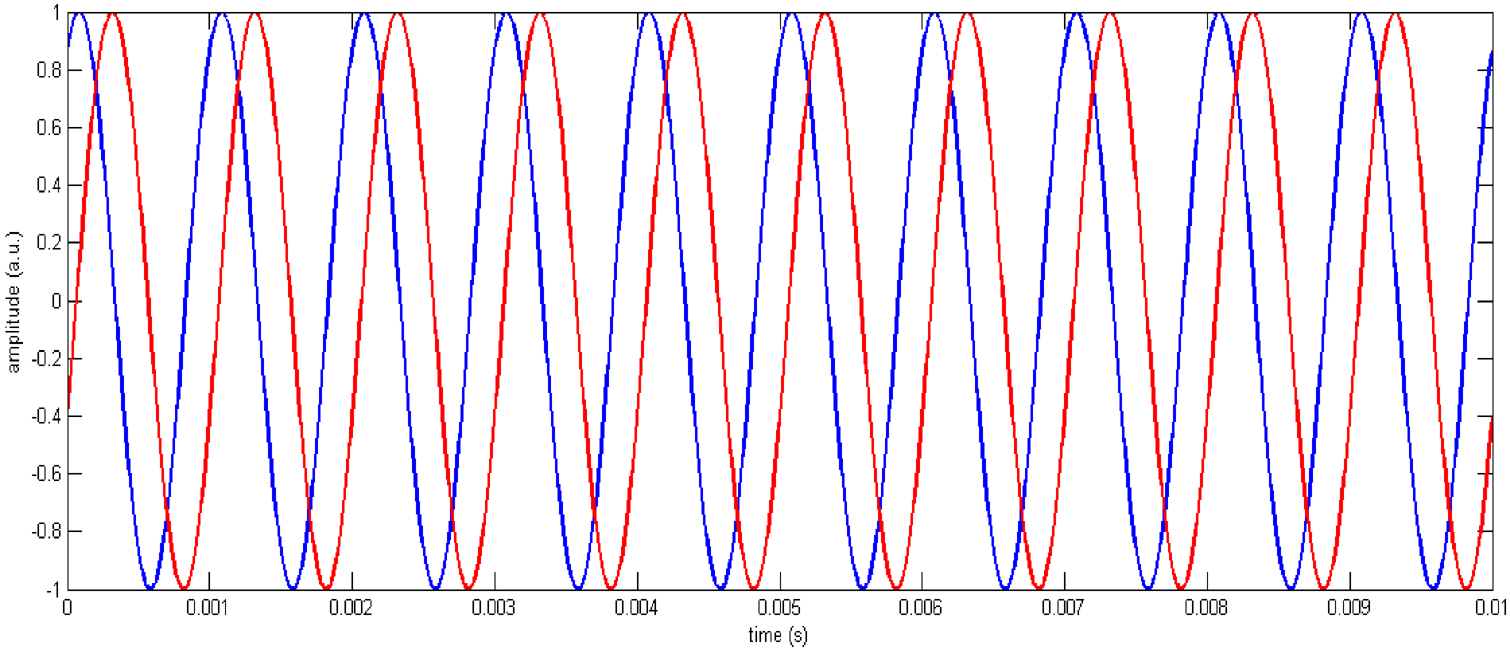
$$V_y = \frac{V}{R_3 + 1/i\omega C}\bullet\frac{1}{i\omega C} = \frac{V}{1+i\omega R_3 C} = V\frac{1-i\omega R_3 C}{1+(\omega R_3 C)^2}$$

$$= \left(\frac{V}{1+(\omega R_3 C)^2}\right)\sqrt{1+(\omega R_3 C)^2}\angle \tan^{-1}(-\omega R_3 C)$$

Representation of two phasors

$$V_x = a\sin(\omega t + \varphi_0)$$

$$V_y = b\sin(\omega t + \varphi_0 + \tan^{-1}(-\omega R_3 C))$$



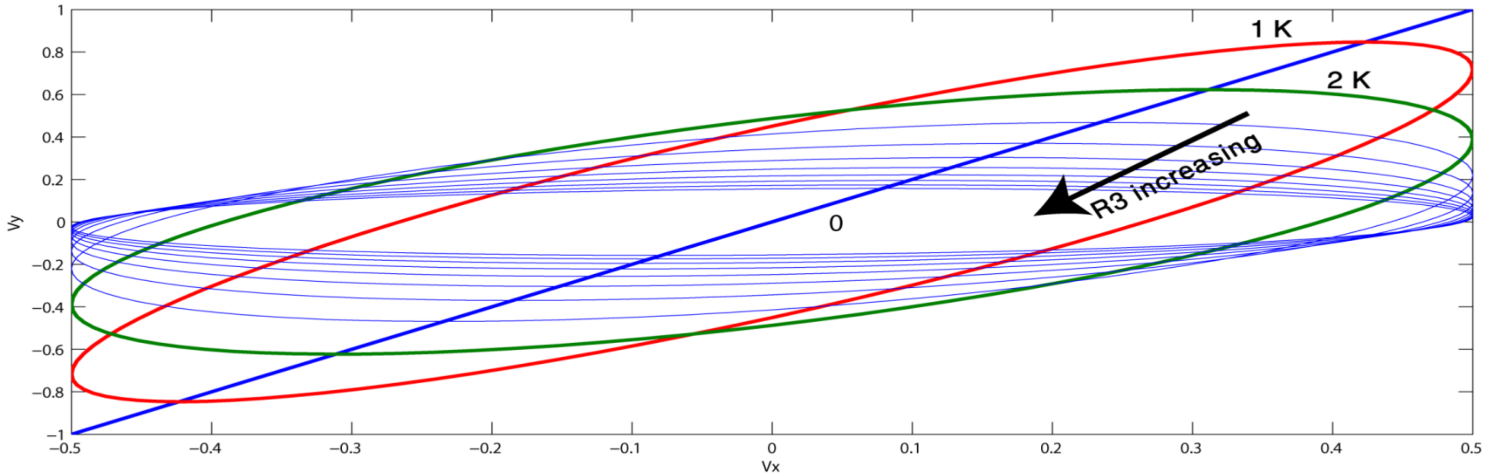
Parametric plots from the waves

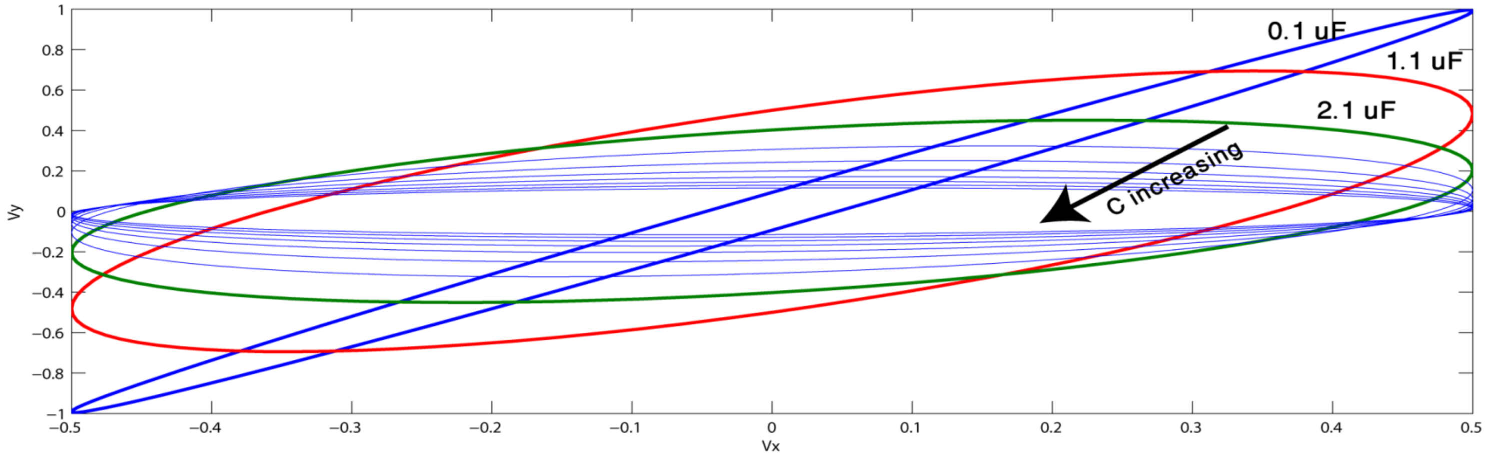
$$x = a\sin(\omega t)$$

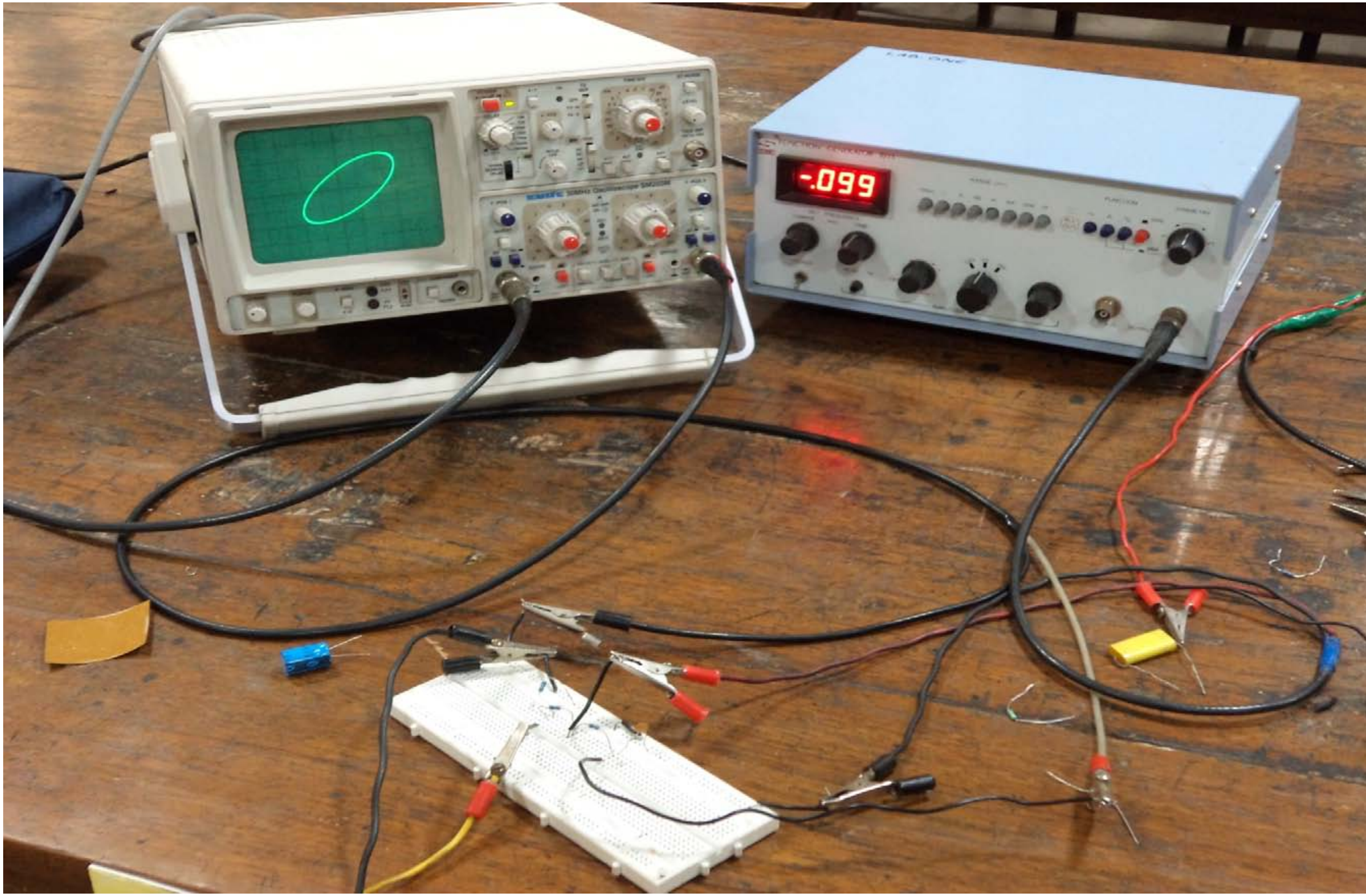
$$y = b\sin(\omega t + \theta)$$

$$\frac{y^2}{b^2} + \frac{x^2}{a^2} - \frac{2xy}{ab}\cos\theta = \sin^2\theta$$

Lissajous patterns



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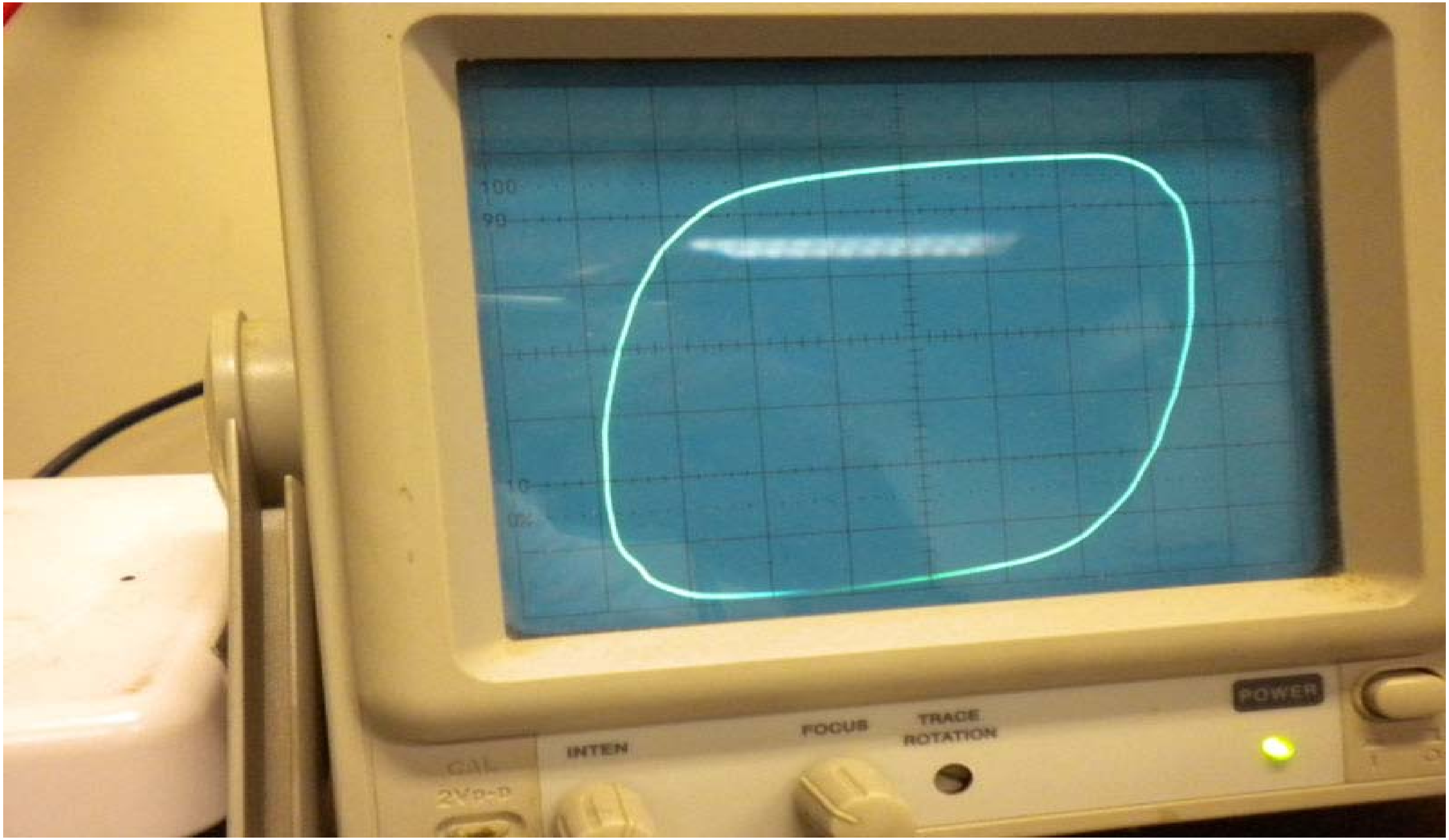
Further explorations

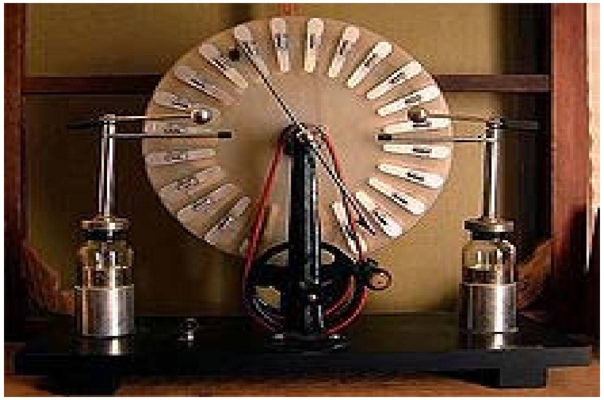


Electrostatic lines of force

Aziz Fatima
Imrana Ashraf
Nazia Sadiq
Amrozia Shaheen
PAKISTAN

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



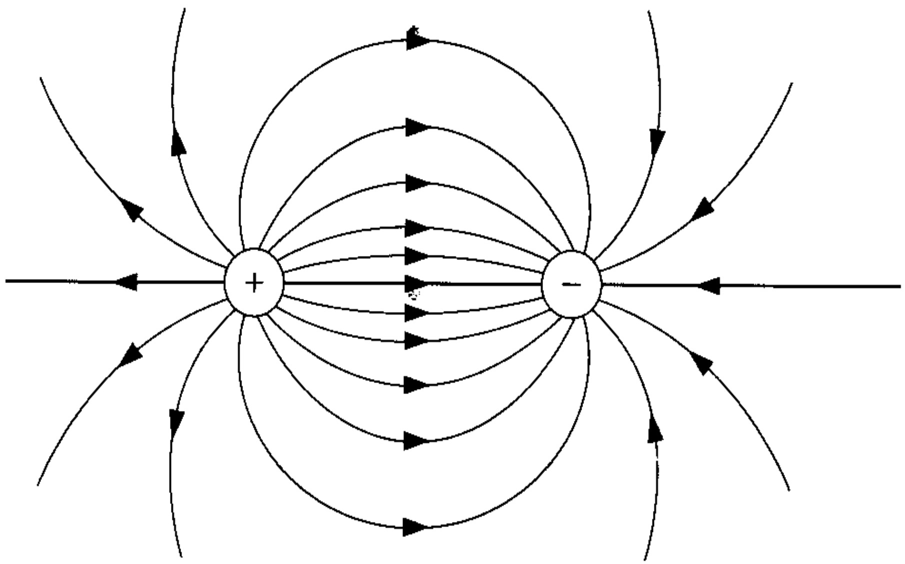

Johnson's
baby
oil

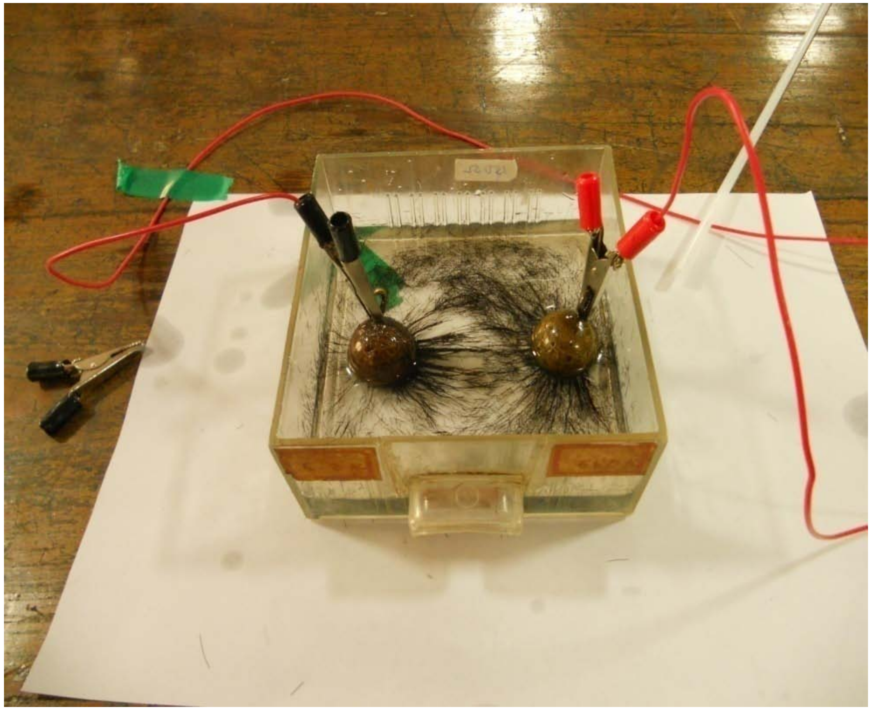
ROAD MAP TO ELECTRIC FIELD LINES

- 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

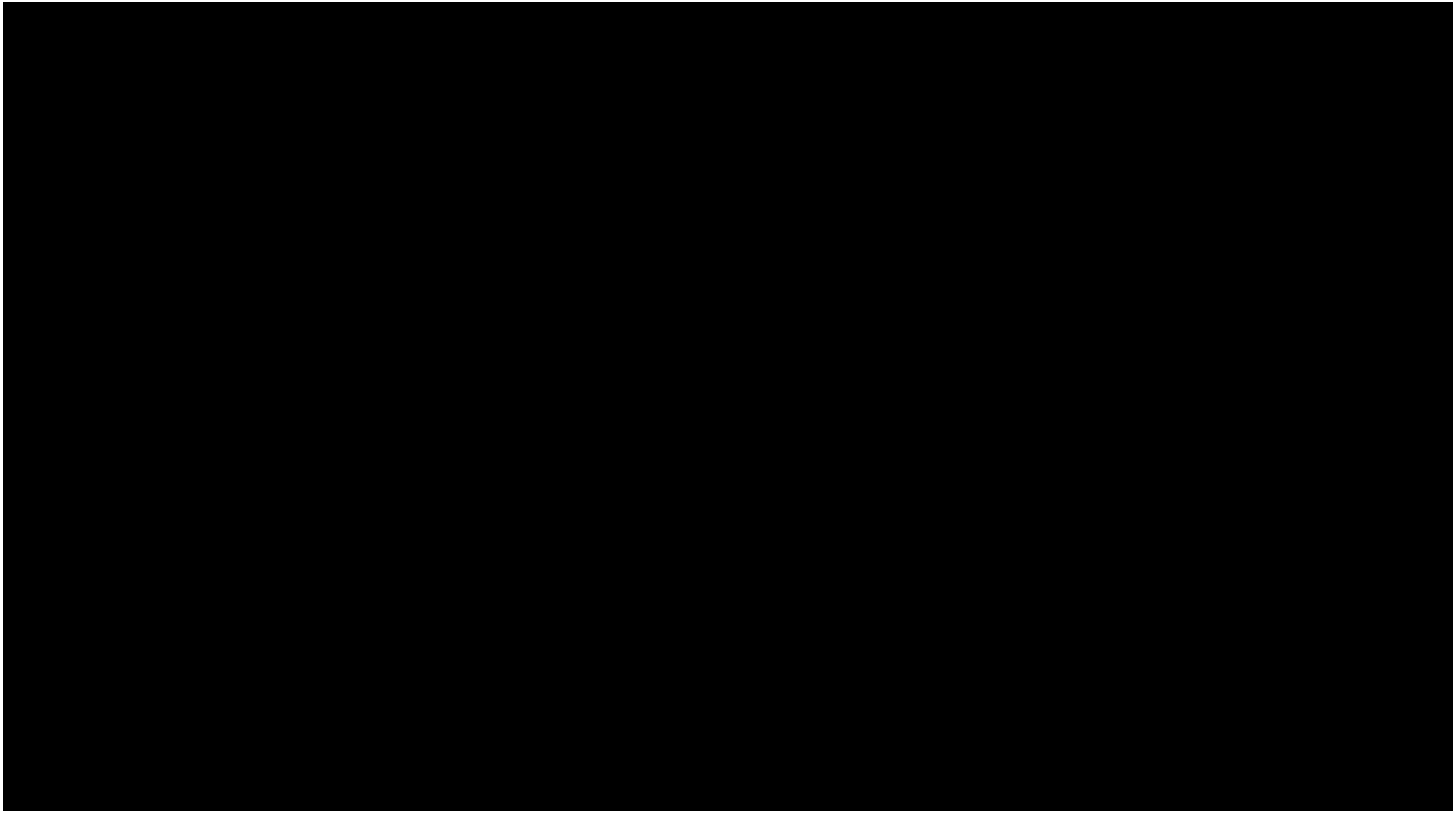
HAVE FUN

EQUAL AND OPPOSITE CHARGE DISTRIBUTION





Field Demonstration for Opposite Charges



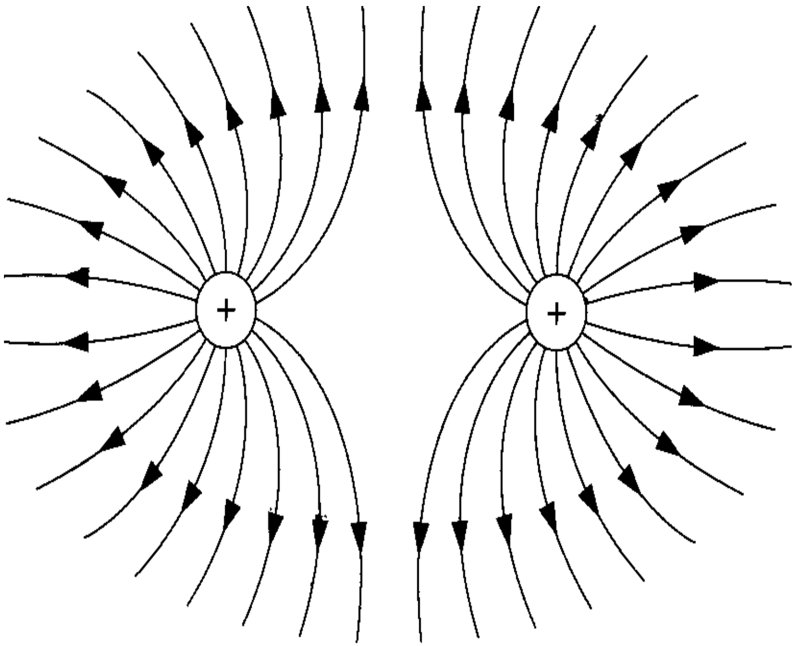
CONCLUSION

EQUAL AND OPPOSITE CHARGE ATTRACT EACH OTHER

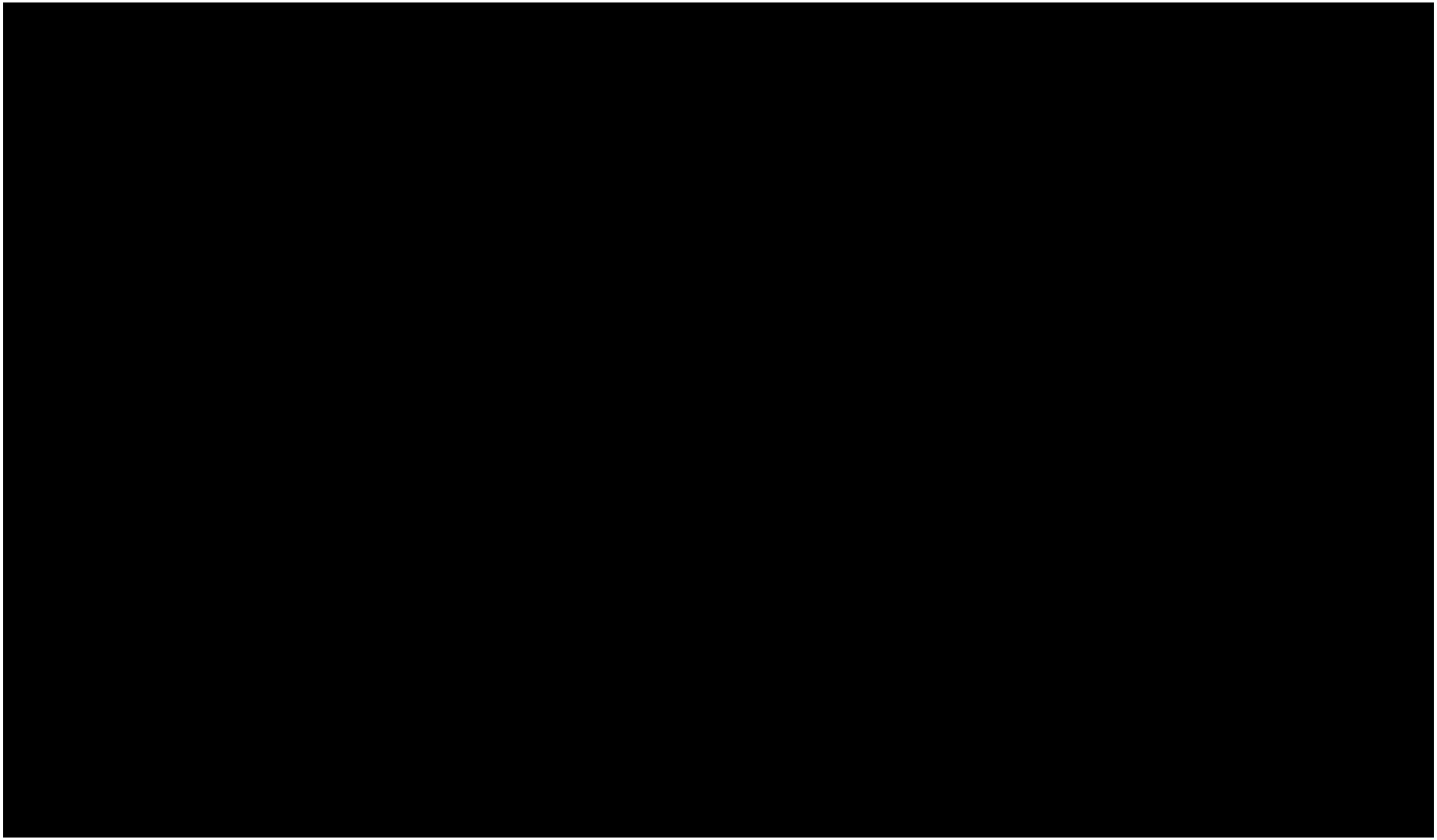
SAME CHARGES

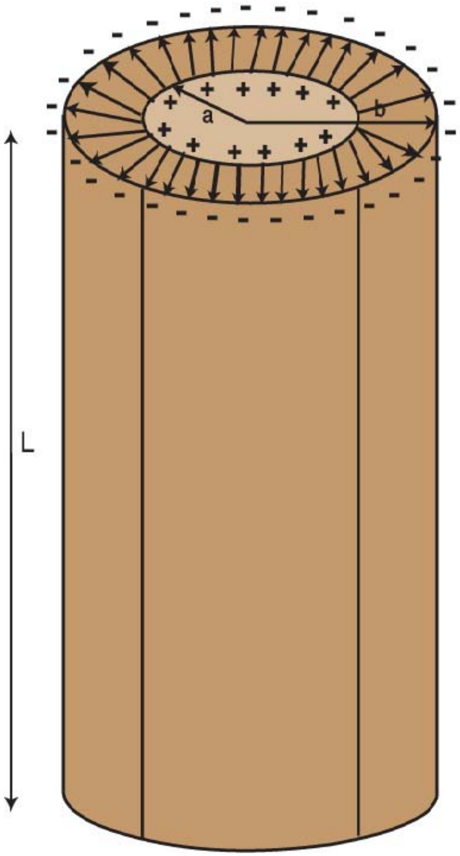
- CONNECT BOTH BALLS WITH SAME TERMINAL OF WIMSHRUT MECHINE
- MAKE WIMSHRUT TO WORK
- SEE THE MOVEMENT OF HAIR ON OIL
- IT IS LIKE THIS WE THINK?

TWO EQUAL AND OPPOSITE CHARGED DISTRIBUTION

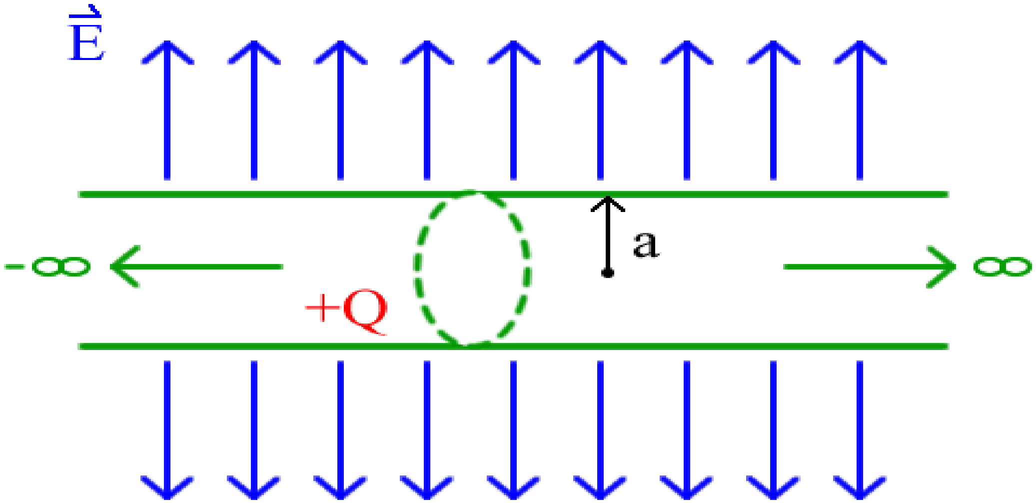


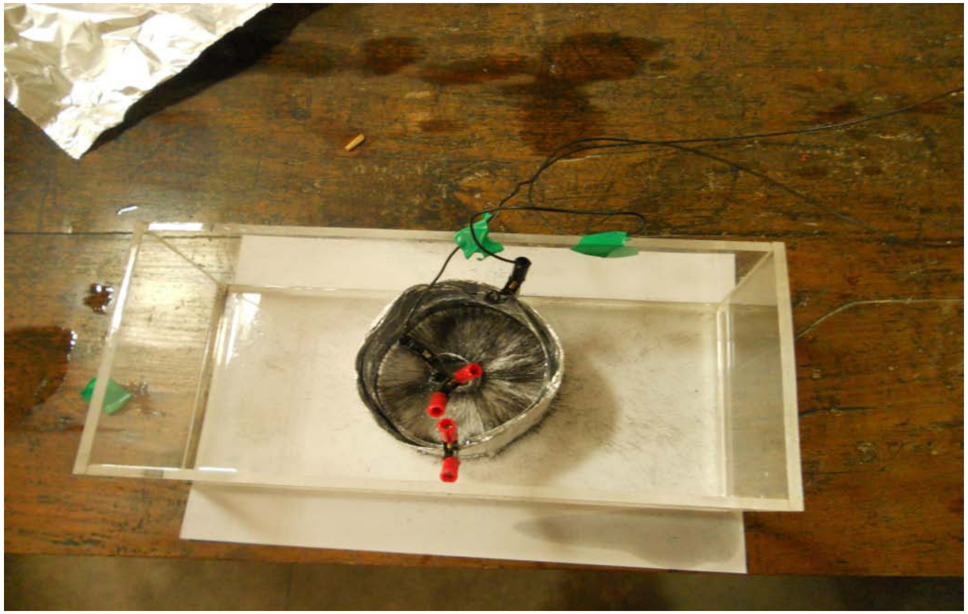
Field Demonstration for Like Charges



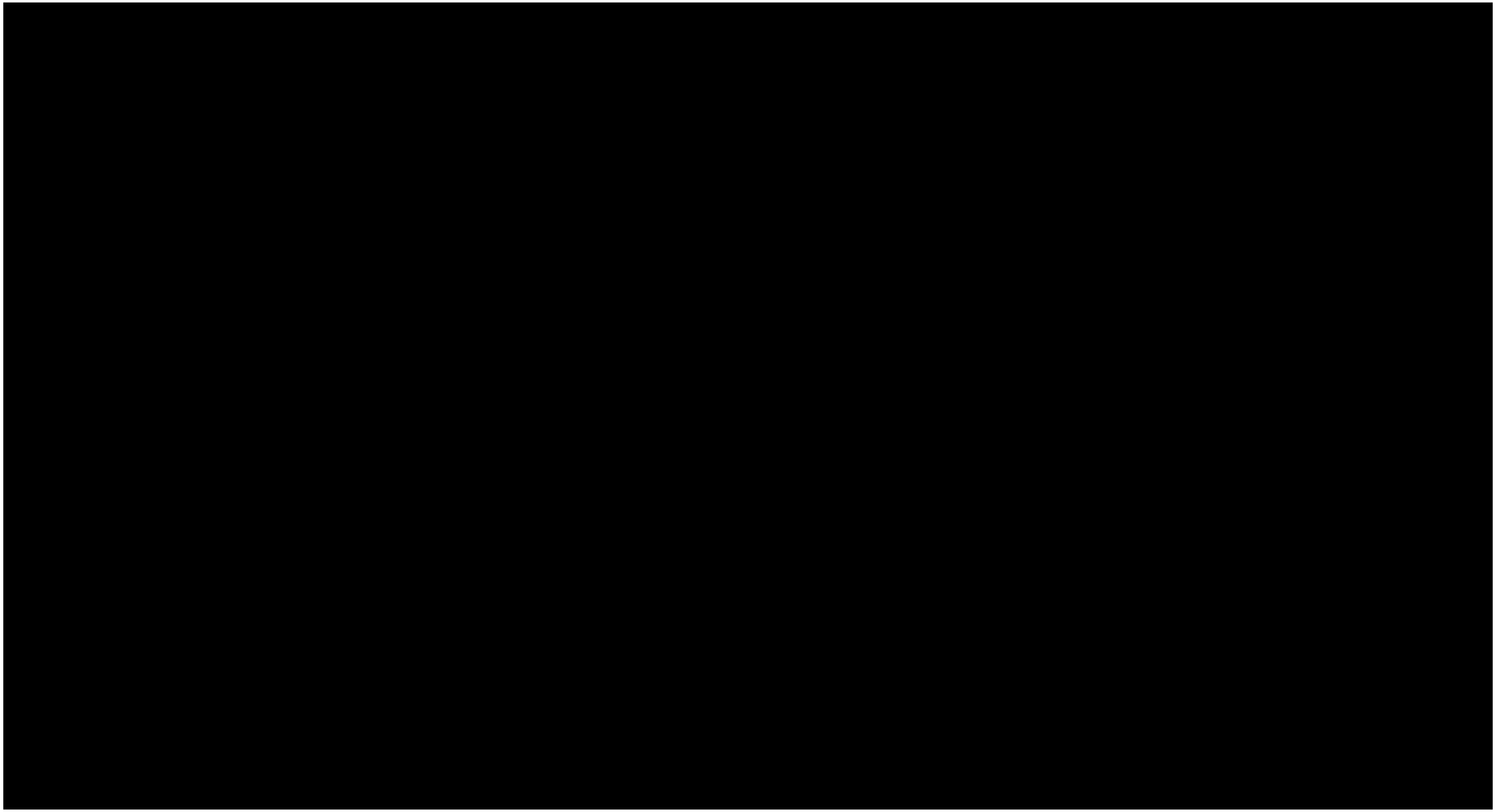


Coaxial Cylinder

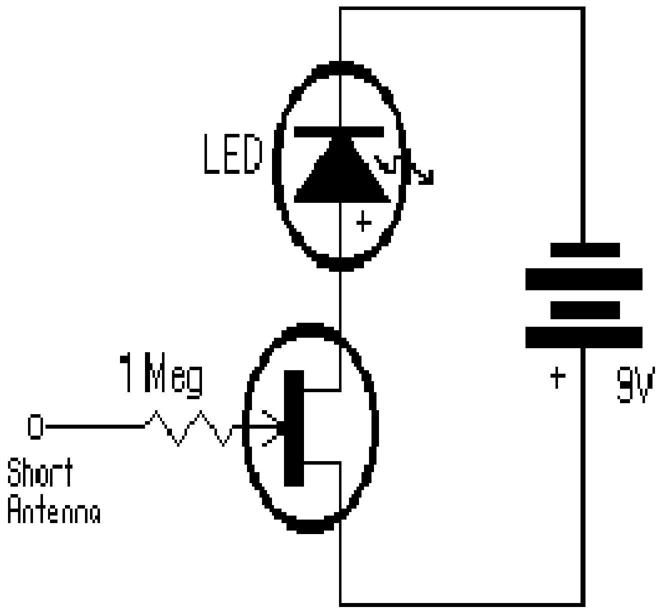


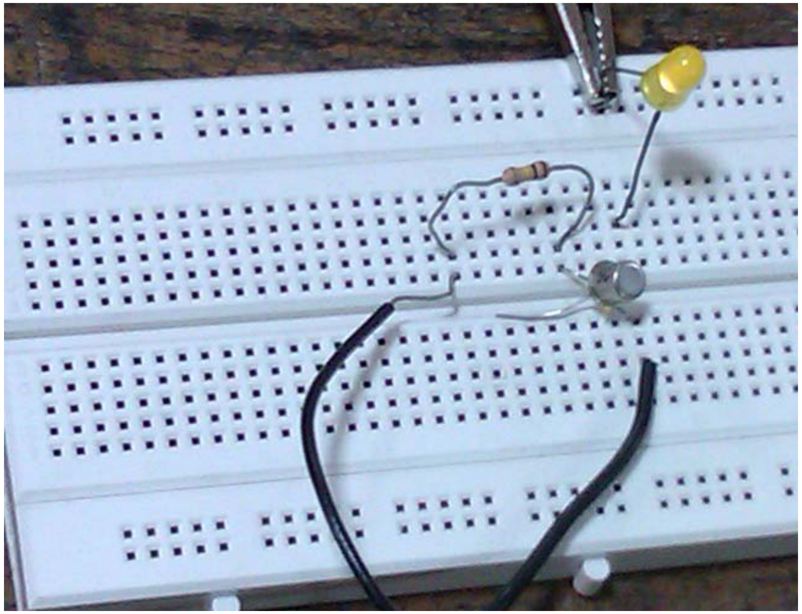


Field Demonstration for Cylindrical Charge Distribution



A SIMPLE TRANSISTORIZED ELECTRIC FIELD DETECTOR





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

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{S}$$

Kanchan, James,
Murthy, Sabieh

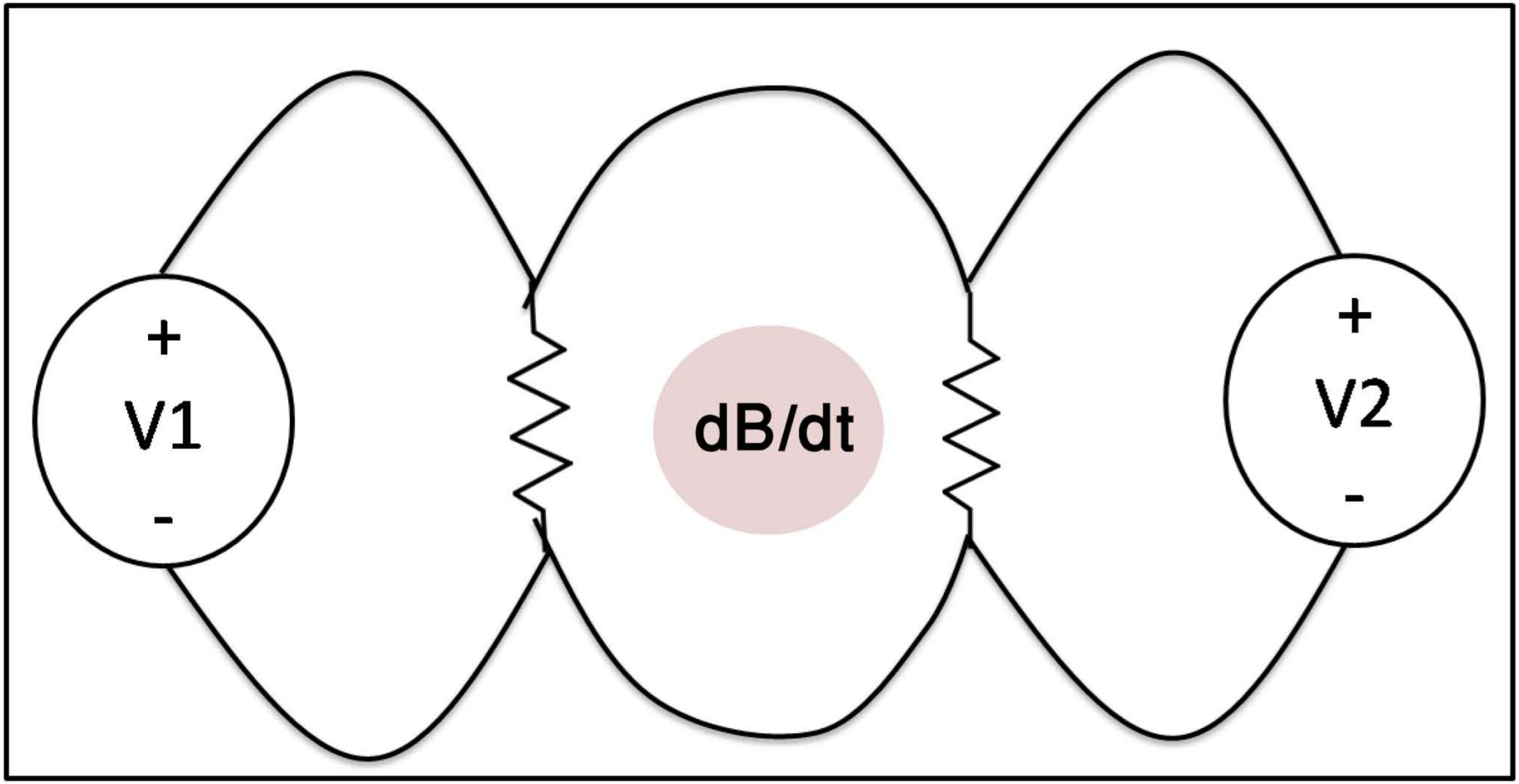
Learning pointers

- Circuit laws are generally taught as being a distinct entity from Maxwell's equations. Can we wed the two?

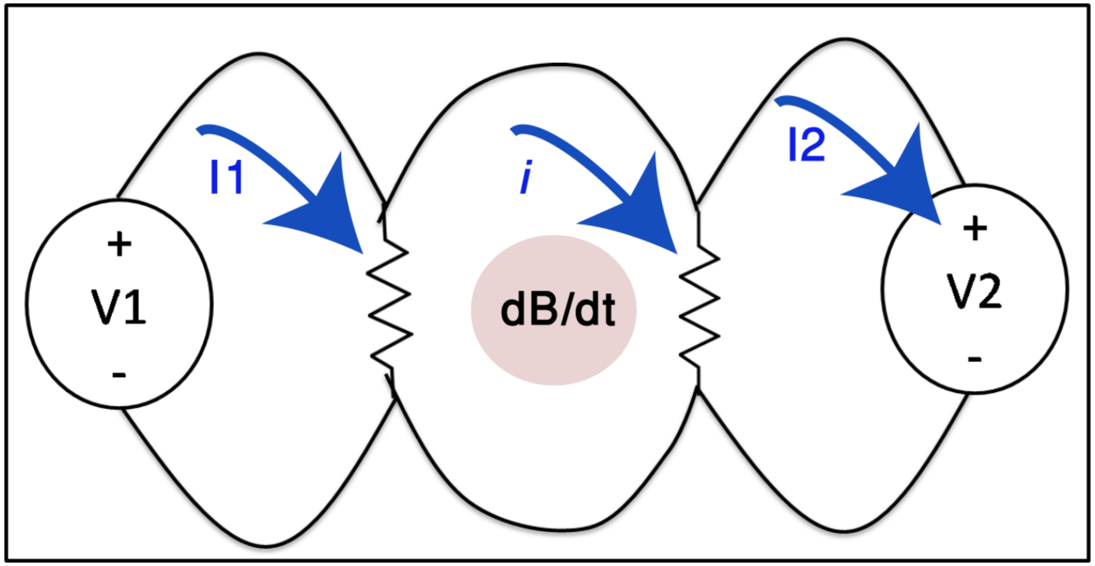
- Demonstrate the changing magnetic flux can act as a battery inside a circuit

- Concept of paths, loops and areas pierced by changing flux

Proposed activity one



Connection of Faraday's law with Kirchoff's voltage law



$$\oint \vec{E} \cdot d\vec{l} = 0$$

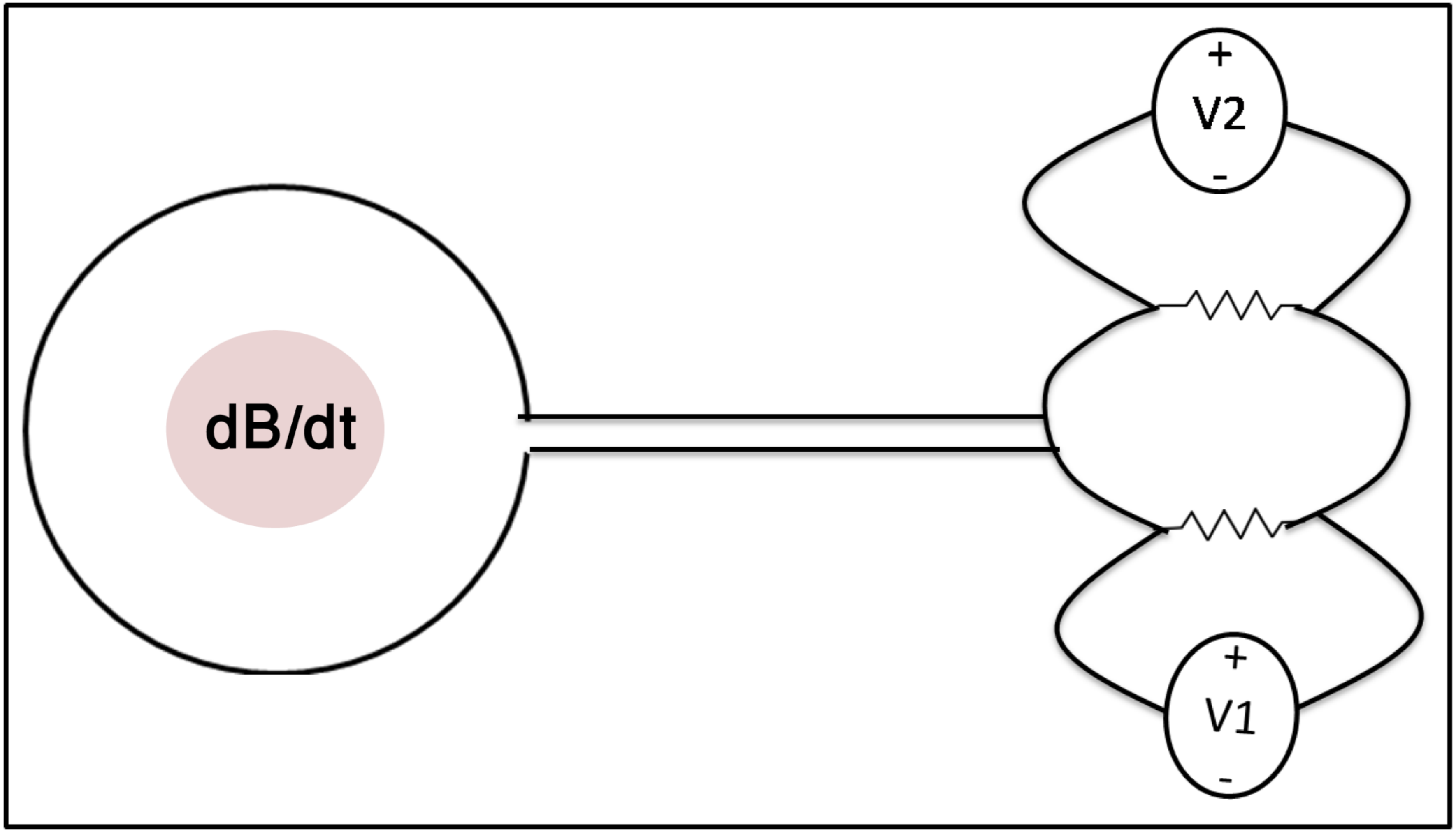
$$\sum V = 0$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{S}$$

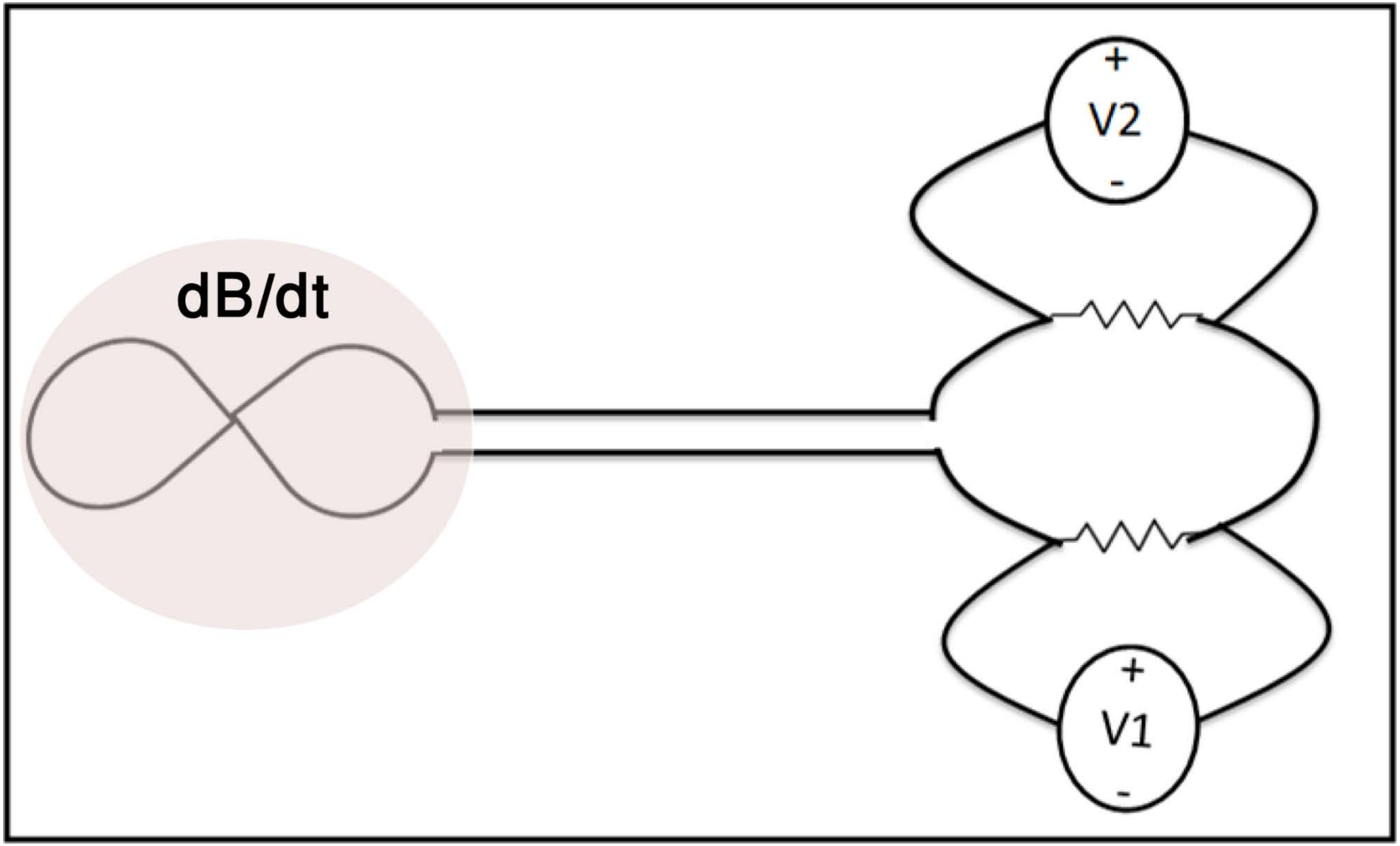
$$-V_1 + V_2 = -\frac{d}{dt}\int \vec{B} \cdot d\vec{S}$$

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

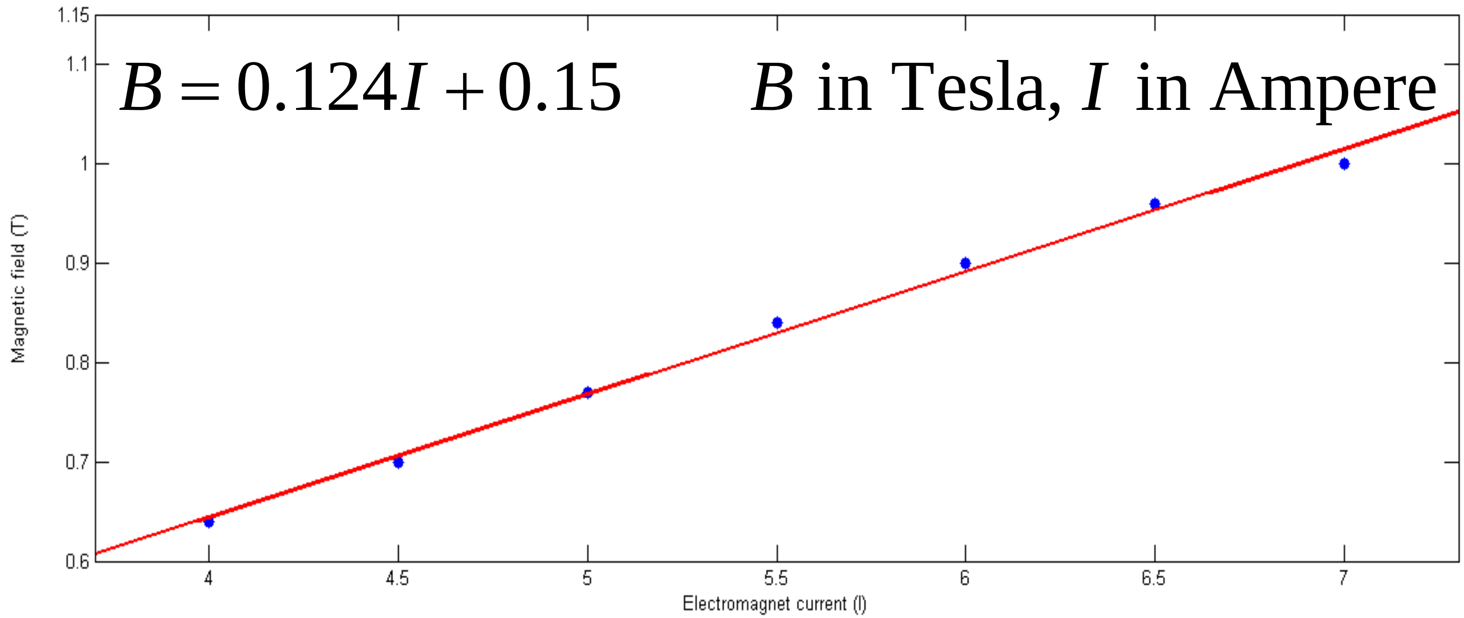
Proposed activity two

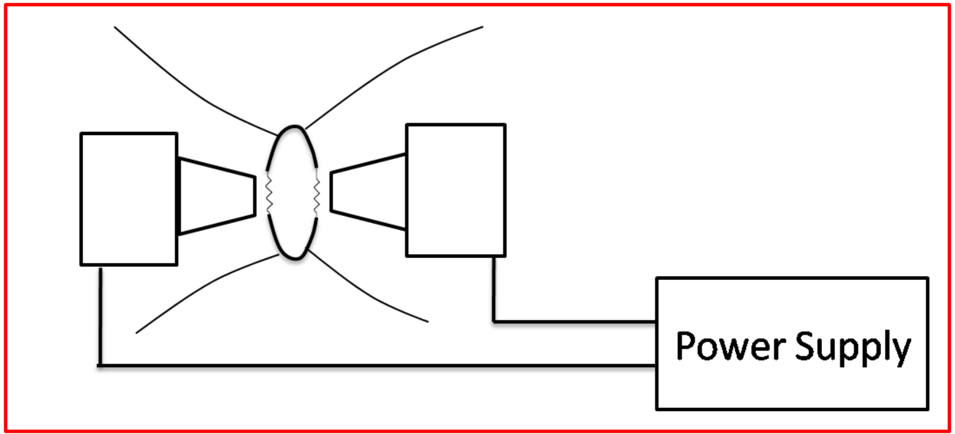


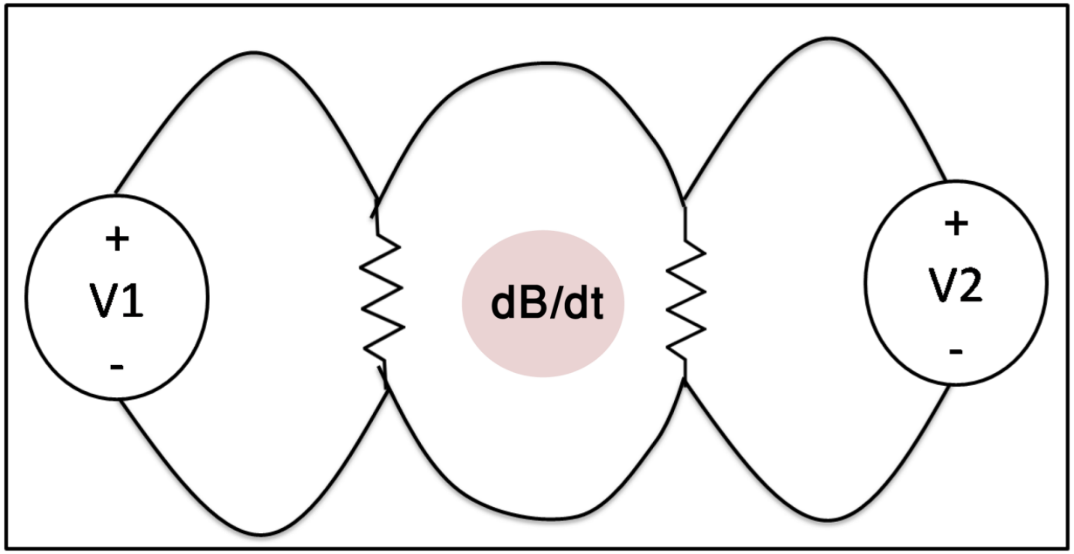
Proposed activity three

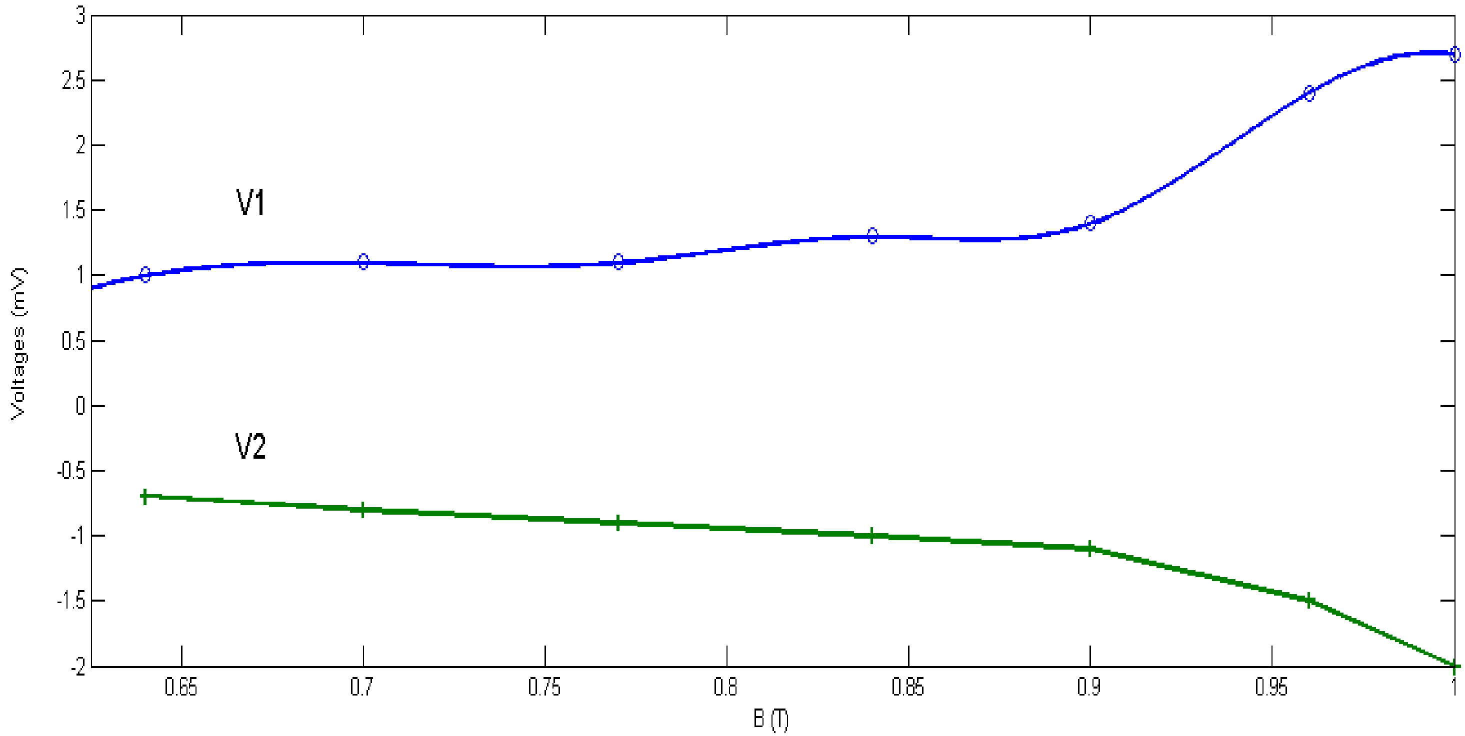


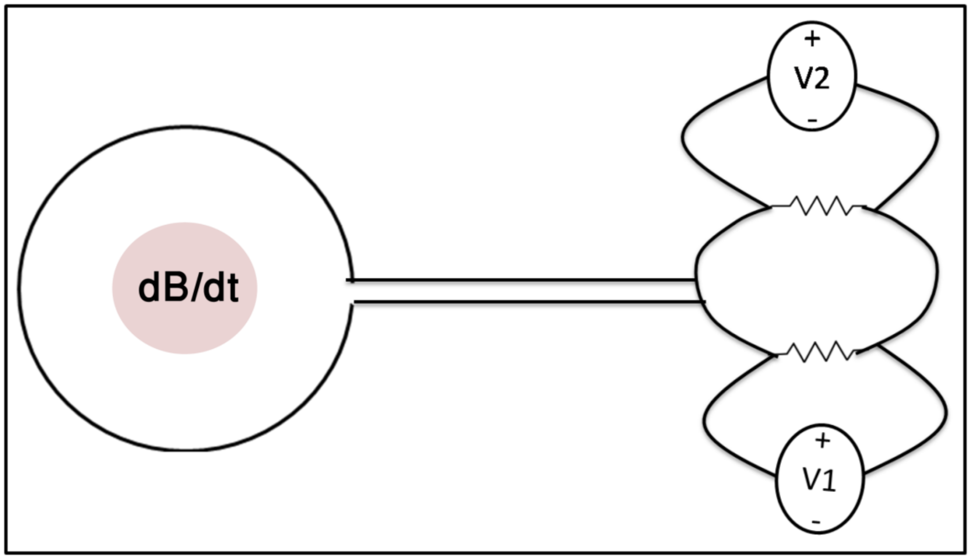
Calibrate the electromagnet

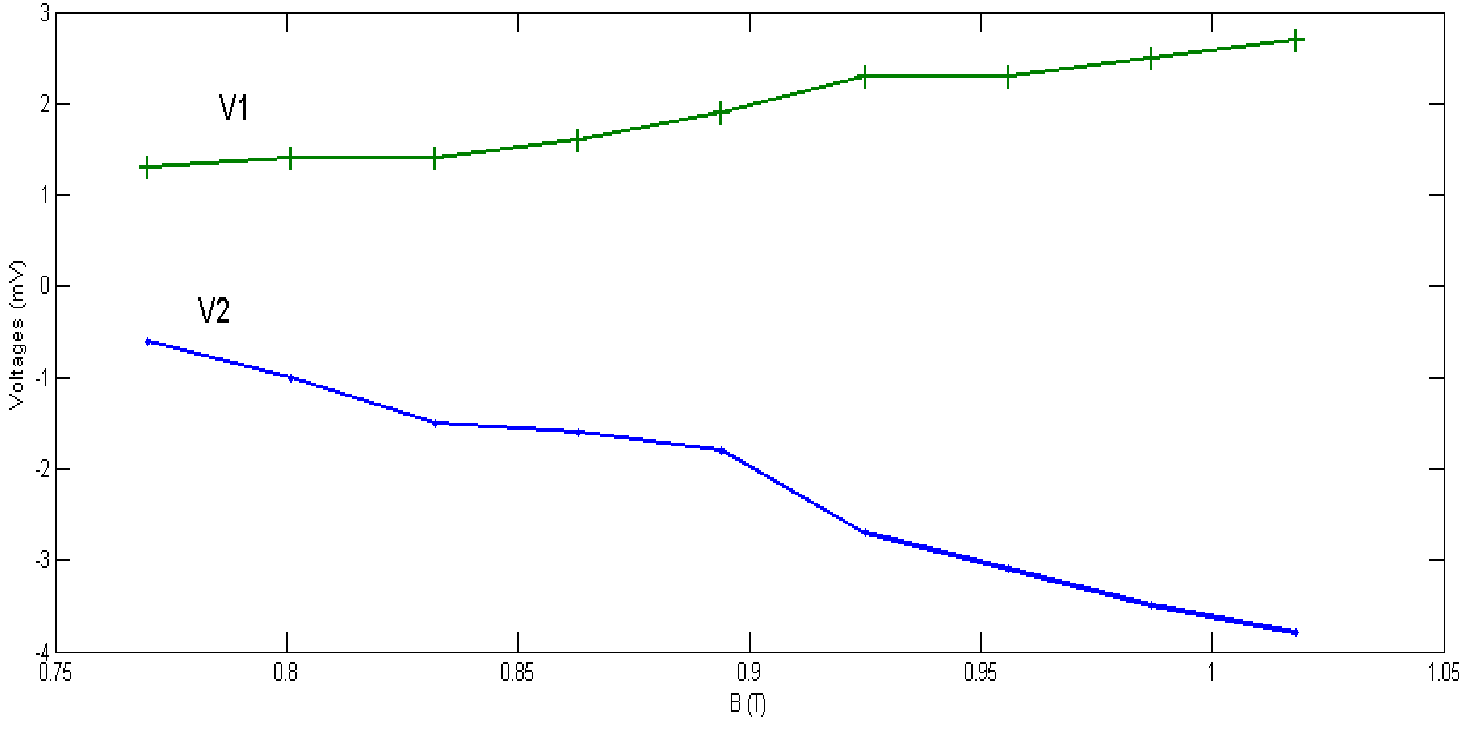





+
V1
-
dB/dt
+
V2
-


V1
V2
Voltages (mV)
B (T)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1


dB/dt
V2
+
-
V1
+
-

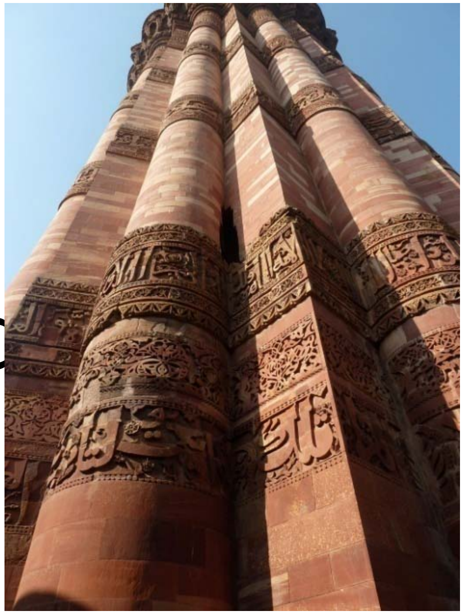

3
2
1
0
-1
-2
-3
-4
Voltages (mV)
0.75
0.8
0.85
0.9
0.95
1
1.05
B (T)
V1
V2

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

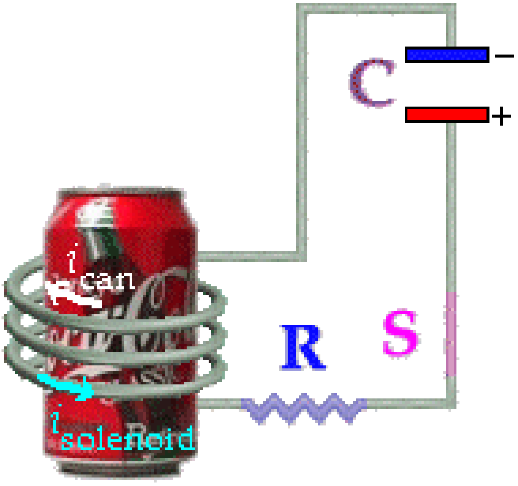


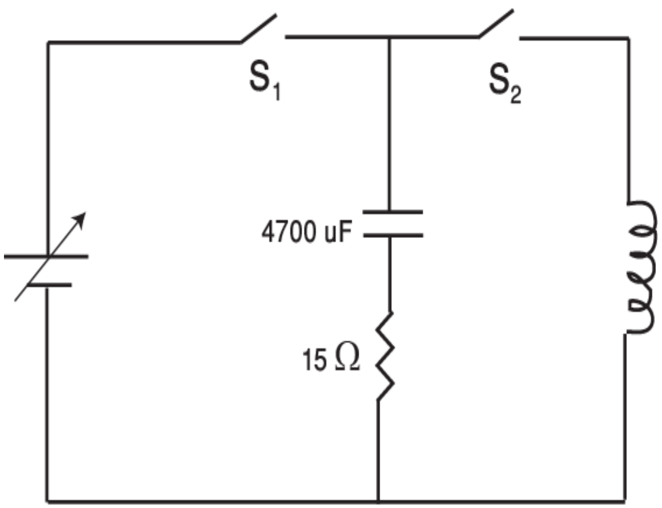
Setup # 1: Crushing cans with Lenz's law

Imrana Ashraf
Aziz Fatima Husnain
Nazia Sadiq
Amrozia Shaheen

Crushing can experiment

- The switch S1 is closed to charge a and S2 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!

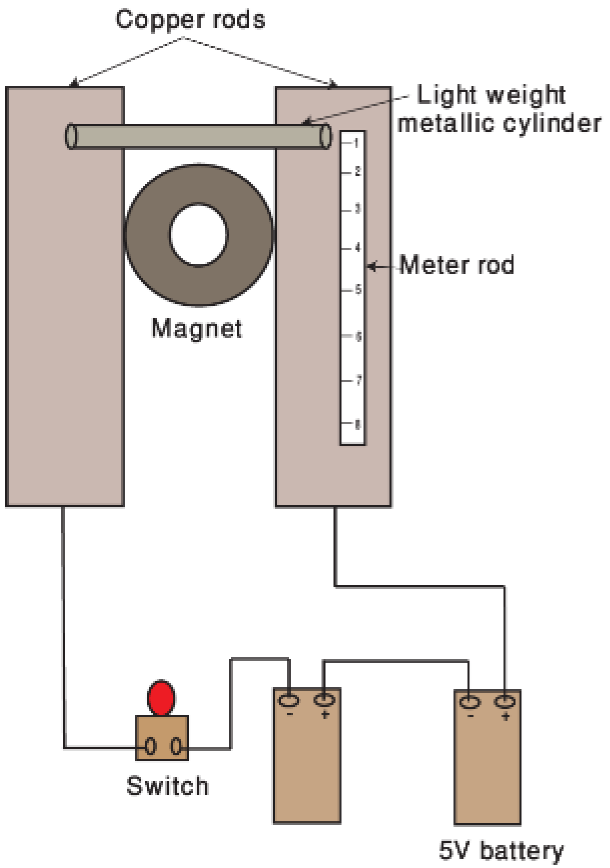
Setup # 2: Motional EMF and Faraday's law

Imrana Ashraf
Aziz Fatima Husnain
Nazia Sadiq
Amrozia Shaheen

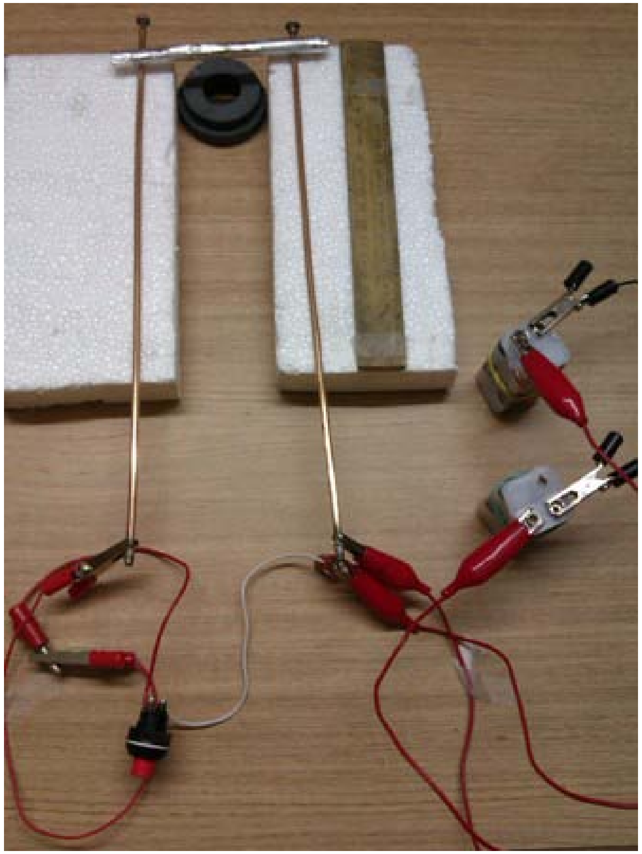
Apparatus: [Low-cost approach]

- 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,

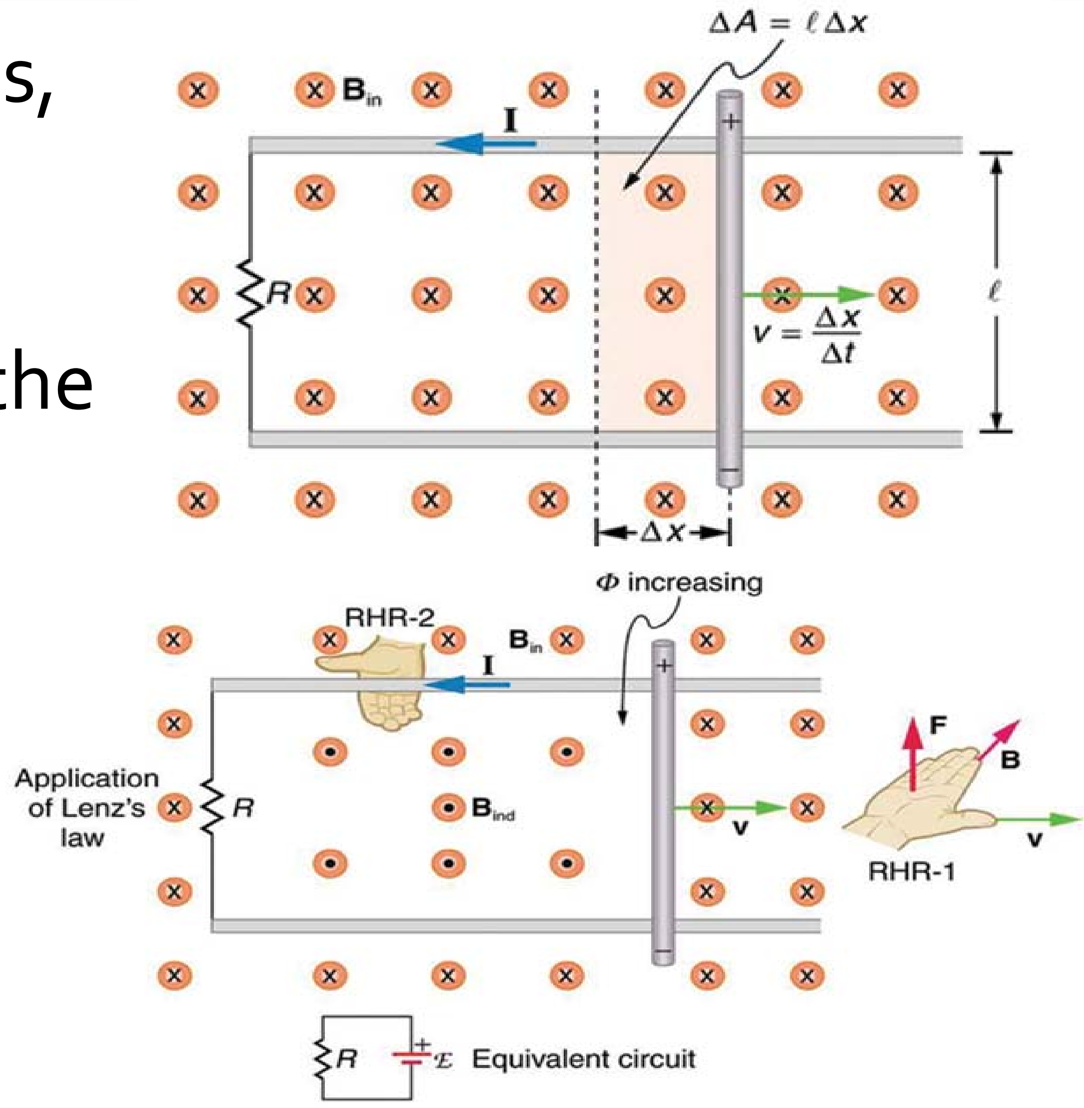
$$\vec{F}_B = q\vec{v} \times \vec{B}$$

- From Faraday's law the induced emf is,

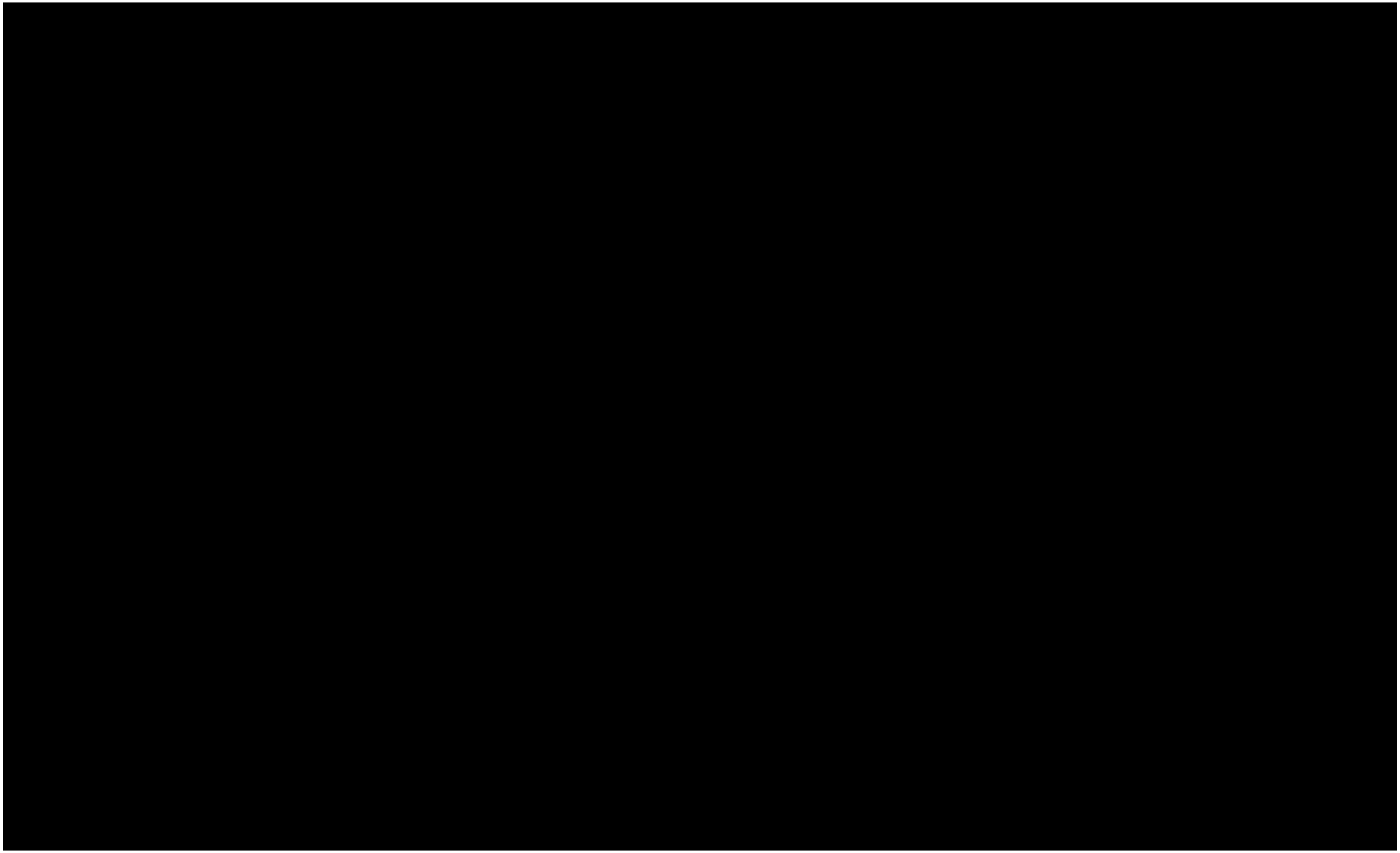
$$\Phi_B = B\,l\,x.$$

$$d\Phi_B = B\,l\,dx = B\,l\,v\,dt.$$

$$\mathcal{E} = \frac{d\Phi_B}{dt} = B\,l\,v.$$



Demonstration of the Experiment:



Some more exercises:

- Quantitative analysis of speed of the moving conductor simply using a meter scale and a stop watch.
- 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.

Questionnaire for Students:

- 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