LAB MANUAL: ELECTROMAGNETISM

Experiment-I

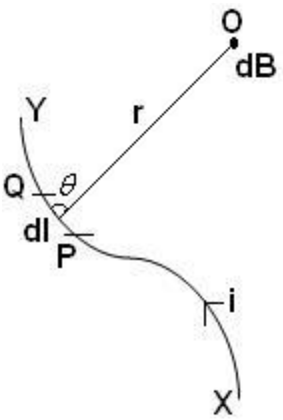
Aim:

To study the variation of magnetic field with distance along the axis of a circular coil carrying current.

Theory:

A current carrying wire generates a magnetic field. According to Biot-Savart's law, the magnetic field at a point due to an element of a conductor carrying current is,

1. Directly proportional to the strength of the current, *i*
2. Directly proportional to the length of the element, *dl*
3. Directly proportional to the Sine of the angle θ between the element and the line joining the element to the point and
4. Inversely proportional to the square of the distance *r* between the element and the point.



Thus, the magnetic field at O is dB, such that,

$$dB \propto \frac{i\,dl\,Sin\,\theta}{r^2}$$

Then,

$$dB = k\frac{i\,dl\,Sin\,\theta}{r^2} \quad dB = k\frac{i\,dl\,Sin\,\theta}{r^2}$$

where,

$$k = \frac{\mu_0}{4\pi}$$ is the proportionality constant and

$$\mu_0 = 4\pi\times10^{-7}\ NA^{-2}$$

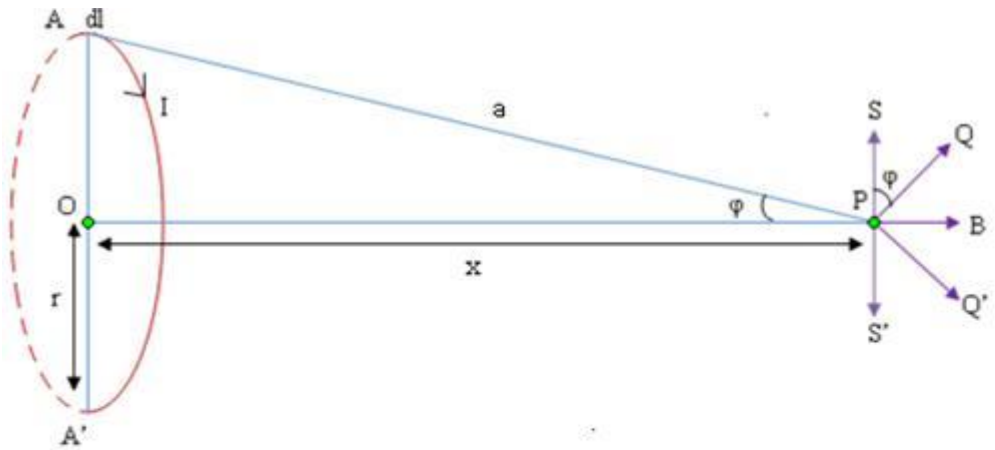
is called the permeability of free space.
Then,

$$dB = \frac{\mu_0}{4\pi}\frac{i\,dl\,Sin\theta}{r^2}$$

In vector form,

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\,d\vec{l}\times\vec{r}}{r^3}$$

Consider a circular coil of radius r, carrying a current I. Consider a point P, which is at a distance x from the centre of the coil. We can consider that the loop is made up of a large number of short elements, generating small magnetic fields. So the total field at P will be the sum of the contributions from all these elements. At the centre of the coil, the field will be uniform. As the location of the point increases from the centre of the coil, the field decreases.



By Biot- Savart's law, the field dB due to a small element dl of the circle, centered at A is given by,

$$dB = \frac{\mu_0}{4\pi}I\frac{dl}{(x^2+r^2)} \qquad (1)$$

This can be resolved into two components, one along the axis OP, and other PS, which is perpendicular to OP. PS is exactly cancelled by the perpendicular component PS' of the field due to a current and centered at A'. So, the total magnetic field at a point which is at a distance x away from the axis of a circular coil of radius r is given by,

$$B_x = \frac{\mu_0 I}{2}\frac{r^2}{(x^2+r^2)^{3/2}}$$

If there are *n* turns in the coil, then

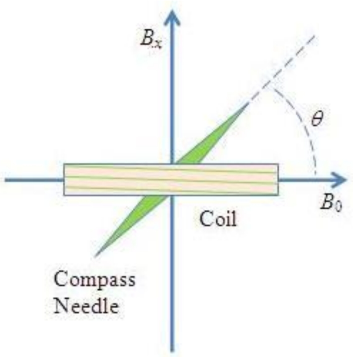
$$B_x = \frac{\mu_0 n I}{2}\frac{r^2}{(x^2+r^2)^{3/2}} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \;(2) \qquad \boldsymbol{B_x} = \frac{\mu_0 \boldsymbol{nI}}{2}\frac{\boldsymbol{r}^2}{(\boldsymbol{x}^2+\boldsymbol{r}^2)^{3/2}}$$

$$B_x = \frac{\mu_0 n I}{2}\frac{r^2}{(x^2+r^2)^{3/2}} \qquad (2)$$

$$B_x = \frac{\mu_0 n I}{2}\frac{r^2}{(x^2+r^2)^{3/2}} \qquad (2)$$

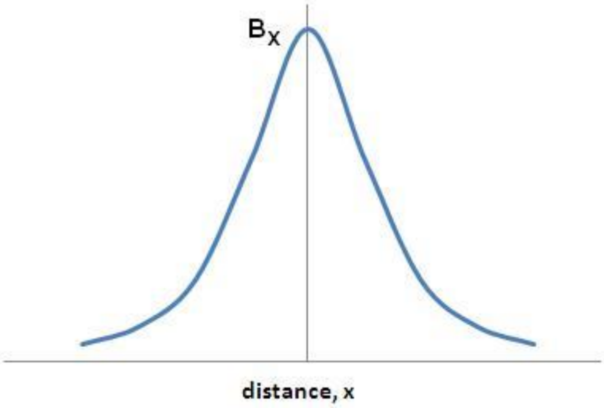
where μ_0 is the absolute permeability of free space.

Since this field B_x from the coil is acting perpendicular to the horizontal intensity of earth's magnetic field, B_0, and the compass needle align at an angle θ with the vector sum of these two fields, we have from the figure



$$B_x = B_0 \tan\theta \qquad (3)$$

The horizontal component of the earth's magnetic field varies greatly over the surface of the earth. For the purpose of this simulation, we will assume its magnitude to be $B_0 = 3.5\text{x}10^{-5}$ T. The variation of magnetic field along the axis of a circular coil is shown here.



Apparatus:

Circular coil, compass box, ammeter, rheostat, commutator, cell, key, connection wires, etc. The purpose of the commutator is to allow the current to be reversed only in the coil, while flowing in the same direction in the rest of the circuit.

Circular coil apparatus:

The apparatus consists of a circular coil C of 5 to 50 turns, having diameter about 10 centimeters. There is a brass frame in which the coil is wound. The frame is fitted to a stand, with its plane vertical. It can be moved along a rectangular wooden board. B is the deflection magnetometer. There is a scale fitted to the wooden board, from which the distance of the centre of the magnetic needle from the centre of the coil can be measured.

Procedure for doing the real lab:

To find the magnetic field:

The connections are made as shown in the diagram and the initial adjustments of the apparatus are made as follows:

- First, the coil is fixed at the middle of the platform and the compass box is placed at the centre of the coil.

- The compass box is rotated till the 90-90 line becomes parallel to the plane of the coil.
- Then the apparatus as a whole is rotated till the aluminium pointer reads 0-0.
- Close the circuit.
- Adjust the rheostat until the deflection lies between 30 and 60 degrees. Note down the deflection of the compass needle and the current.
- Then current through the coil is reversed using the commutator and again the deflection and current are noted.
- Average the magnitude of the two deflections and calculate the magnetic field at the centre of the coil from the equation.
- Without changing the current or the number of turns, place the compass box at a particular distance from the centre of the coil. Note the deflection. Again reverse the current and average the magnitudes of the two deflections. Note the average, and the distance.
- The same procedure is repeated with the compass box at the same distance on the other side of the arm, keeping number of turns and current constant.
- Take the average of the two values of θ measured on opposite sides of the coil.
- Then calculate the magnetic field B_x from the coil using equation (3).
- Repeat for various distances.
- Draw graph of B_x on the vertical axis *vs*. distance x on thehorizontal axis.

To plot the graph between distance and magnetic field intensity:

B_0= 3.5x10^{-5} T.

Current, I = ……… A

No: of turns of the coil, n = …..

Radius of the circular coil, r = ….. cm.

Distance from the centre, x (cm)	Deflection with compass box on left side				Deflection with compass box on right side				Mean θ (degrees)	B_x(T)	$B_0 = \frac{B_x}{\tan\theta}$ (T)
	Direct		Reversed		Direct		Reversed				
	θ_1	θ_2	θ_3	θ_4	θ_1	θ_2	θ_3	θ_4			

Then plot the graph.

Check out this video to see how to do an experiment in an original lab,

https://www.youtube.com/watch?v=v2B0QyW8XJ0

Procedure for doing the simulator:

First, the preliminary adjustment should be done in order to make the apparatus in the magnetic meridian.

- First, preliminary adjustments should be done in order to properly align the apparatus with the earth's magnetic field. The button Initial Adjustment is provided for this purpose. The experimental apparatus will be fully active only after the initial adjustments are done.

- On clicking the initial adjustment button, a zoomed view of the compass box will be displayed in the simulator. Two sliders Rotate Compass box and Rotate apparatus are provided.

- Using the slider Rotate Compass box, the compass box can be rotated and its 90-90 reading parallel to the plane of the coil. Fine adjustments can be made, if necessary, with the left-right arrow keys.

- When the 90-90 alignment is exact, the slider Rotate apparatus will be active. Using this, rotate the whole apparatus and make the aluminium pointer to read 0-0. Fine adjustments can be made with left-right arrow keys.

- Using the Show normal button in the simulator, go back to the experimental set up.

- Make the connections as shown in the circuit diagram. The user can drag the connection wires from the terminals of each components when a hand symbol appears there.

- Close the circuit using the button Insert key.

- Zoom compass box enables the user to view the reading of the pointer.

- Number of turns of the coil: The user can select the number of turns of the coil using this combo box.

- Reverse current: Enables the user to reverse the direction of current through the circuit.

- Using the slider Radius of the coil, the user can change the radius of the coil.

- The slider along with the compass box can be moved along the arm of the apparatus using the slider Compass box position. The user can vary the distance x of the compass box from the centre of the coil.

- Adjust Rheostat slider can be used to adjust the current throuh the circuit.

- Show result button displays the result after doing the experiment.

- A Reset button is provided to reset the experimental set up. (Warning! all wires will be disconnected and the apparatus will be returned to its starting position.)

- The experiment can be repeated for different number of turns and radius of the coil and for different currents.

Link for virtual lab,

http://emv-au.vlabs.ac.in/electricity-magnetism/Circular_Coil/experiment.html

Result

Flux density due to earths horizontal field at the place=..........T

Experiment-II

Aim:

To find the temperature coefficient of resistance of a given coil

Theory:

A Carey foster bridge is principally same as a meter bridge, which consists of four resistances P, Q, R and X that are connected to each other as shown in figure 1.

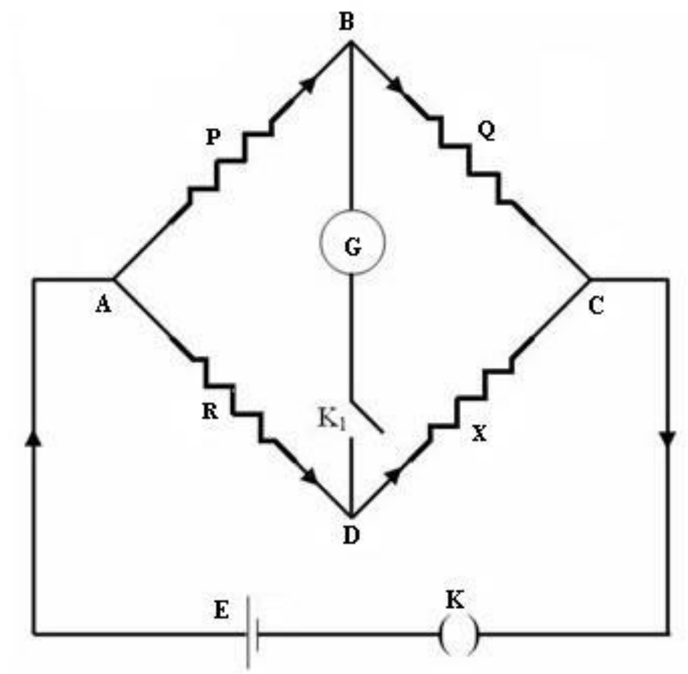
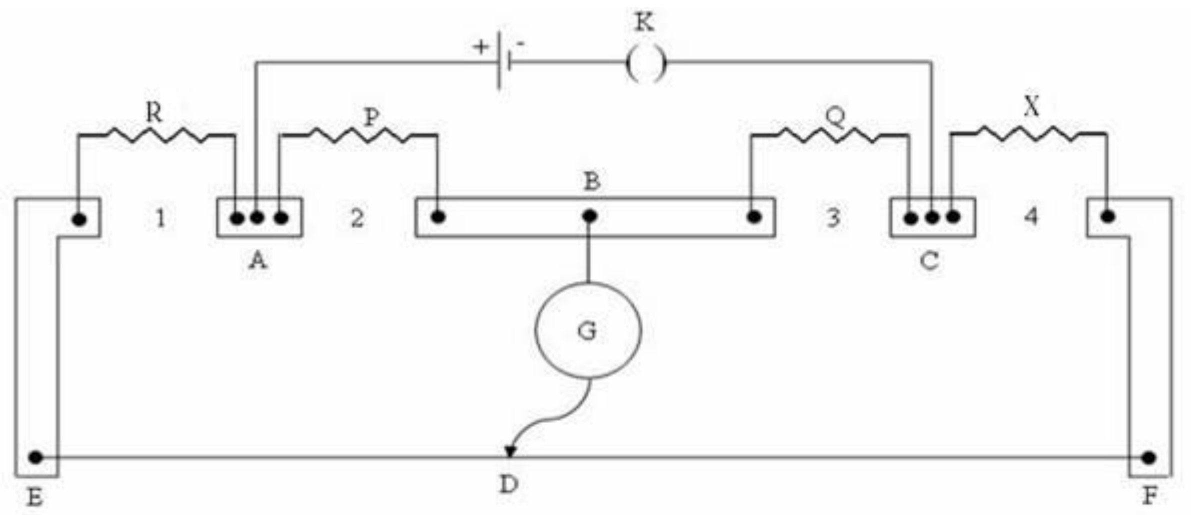


Figure 1: Wheatstone's bridge

In this circuit G is the galvanometer and E is a lead accumulator and *K*1and *K* are the galvanometer key and accumulator key respectively. If the values of the resistances are adjusted so that no current flows through the galvanometer, and if any of three resistances P,Q,R and X are known, the unknown resistance can be determined using the relationship,

$$\frac{P}{Q} = \frac{R}{X}$$

The Carey foster bridge is used to measure the difference between two nearly equal resistances and knowing the value of one, the other can be calculated. In this bridge, the end resistances are eliminated in calculation. Which is an advantage and hence it can conveniently used to measure a given resistance.



Let *P* and *Q* be the equal resistances connected in the inner gaps 2 and 3, the standard resistance R is connected in gap 1 and the unknown resistance X is connected in the gap 4.Let l_1 be the balancing length ED measured from the end *E*. By whetstone's principle,

$$\frac{P}{Q} = \frac{R + a + l_1\rho}{X + b + (100 - l_1)\rho}$$ ....

.... (1)

Where, a and b are the end corrections at the ends E and F, and is the resistance per unit length of the bridge wire.
If the experiment is repeated with X and R interchanged and if l_2 is the balancing length measured from the end E,

$$\frac{P}{Q} = \frac{X + a + l_2\,\rho}{R + b + (100 - l_2)\rho}$$

$$\frac{P}{Q} = \frac{X + a + l_2\,\rho}{R + b + (100 - l_2)\rho} \text{..................} (2)$$

...............................(2)

From equation (1) & (2)

$$X = R + \rho(l_1 - l_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots$$

(3)

Let l_1' and l_2 ' are the balancing lengths when the above experiment is done with a standard resistance *r* (say 0.1) in the place of R and a thick copper strip of zero resistance in place of X

From equation (3),

$$0 = r + \rho(l_1' - l_2')$$

Or
$$\rho = \frac{r}{l_1' - l_2'}$$

If *X1* and *X2* are the resistance of a coil at temperatures $t_1{}^o c$ and $t_2{}^o c$, the temperature coefficient of resistances is given by the equation,

$$\alpha = \frac{X_2 - X_1}{X_1 t_2 - X_2 t_1}$$

Also, if X_0 and X_{100} are the resistance of the coil at 0^oc and 100^oc,

$$\alpha = \frac{X_{100} - X_0}{X_0 \times 100}$$

Apparatus:

carey foster bridge, unknown low resistor, Resistance box, Lead accumulator, jockey, one way key, Galvanometer, connecting wires etc. .

PROCEDURE:

1. Hook up the slide-wire from of the bridge as shown above. For X, use the copper wire filament immersed in the oil bath. The whole tube is than placed in a deionized water bath. For R_G, use the provided resistance, and use the decade resistance box for *R*. Before closing any switches, have the circuit approved by your instructor.

2. Start with the contact key (C) in the middle of the slide wire, such that L_1 is equal to L_2. Set R so that the galvanometer shows no deflection.

NOTE:

· Do not let the deflection of galvanometer go off scale. that will damage the instrument.

· Do not slide the key along the wire while it is pressed down. This will scrape the wire, causing it to become non-uniform

3. There should only be one point along the slide-wire at which the galvanometer shows no deflection. This is called the balance point. Repeat step 3 until you are sure you've found the balance point to within a millimeter or so.

4. Record the values of R, L_1, L_2, and the water bath temperature in your data table on the worksheet of the write-up. DO NOT CHANGE THE VALUE OF R THROUGHOUT THE REST OF THE EXPERIMENT.

5. Repeat the resistance measurement for at least 8 different temperatures between room temperature and about 95 °C. Heat the water bath slowly, remove the heat source, and wait at least 1 minutes for temperature equilibrium each time.

6.For each temperature, make sure that the galvanometer deflection stay within its permitted scale and record values of R, L_1, L_2 and T.

Check out this video to see how to do an experiment in an original lab,

https://www.youtube.com/watch?v=tIRuQ5lkT4o

Procedure to perform the simulation

To calibrate the Carey Fosters Bridge

1. Drag the 'Resistor' to the gap 2 and 3 of the Carey fosters bridge.
2. Drag 'Fractional resistor' to gap 1.
3. Drag the Battery to space in between the two 'Resistors'.
4. Drag the copper strip to gap 4.
5. Press the continue button, on the top.
6. Click and unmark the resistance which has to be introduced in 'Resistor'.
7. Power On button to start and power off to stop the experiment.
8. Change the position of jockey to get balancing length l_1'.
9. Reverse connection button to interchange copper strip with fractional resistor.
10. Move jockey to get balancing length l_2'.
11. Resistance per cm of bridge wire is found using equation

$$\rho = \frac{r}{l_1{}' - l_2{}'}$$

12. Repeat the experiment for different values of Resistance.

To find the temperature coefficient of resistance

1. Repeat steps 1-3.
2. Drag ‘Unknown resistance 1’ to gap 4 in bridge.
3. Introduce the resistance and move jockey to get balancing length l_1.
4. Reverse button to interchange unknown resistance 1 with Fractional resistor.
5. Move jockey to get balancing length l_2.
6. Unknown resistance value is found using the equation

$$X = R + \rho(l_1 - l_2)$$

7. Repeat the experiment for different temperature t_1, t_2….and note corresponding resistance X_1, X_2...
8. Temperature coefficient of resistance is found using equation

$$\alpha = \frac{X_2 - X_1}{X_1 t_2 - X_2 t_1}$$

9. Repeat the experiment for unknown resistance 2.
10. A graph is plotted between values of X and t , which gives a straight line, whose slope is α.

Link for online lab,

http://emv-au.vlabs.ac.in/electricity-magnetism/Temperature_Coefficient_of_Resistance/experiment.html

Observations:

Record your observation in form of table and analyse the conclusion.

Experiment-III

Aim:

To determine the resistance per cm of a given wire by plotting a graph of potential difference versus current, and hence to determine its resistivity.

The Theory:

According to the Ohm's law, "The current flowing through a conductor is directly proportional to the potential difference across its ends provided the physical conditions (temperature, dimensions, pressure) of the conductor remains the same." If I be the current flowing through a conductor and V be the potential difference across its ends, then according to Ohm's Law,

$$I \propto V$$

$$V \propto I \ or \ V = RI$$

where, R is the constant of proportionality. It is known as resistance of the conductor.

$$\frac{V}{I} = R$$

R depends upon the material, temperature and dimensions of the conductor.

In S.I. units, the potential difference V is measured in volt and the current I in ampere, the resistance R is measured in ohm.

To establish the current-voltage relationship, it is to be shown that the ratio V / I remains constant for a given resistance, therefore a graph between the potential difference(V) and the current (I) must be a straight line.

It is the constant ratio that gives the unknown values of resistance,

$$\frac{V}{I} = R$$

For a wire of uniform cross-section, the resistance depends on the length l and the area of cross-section A. It also depends on the temperature of the conductor. At a given temperature the resistance,

$$R = \rho \frac{l}{A}$$

where ρ is the specific resistance or resistivity and is characteristic of the material of wire.

Hence, the specific resistance or resistivity of the material of the wire,

$$\rho = \frac{RA}{l}$$

If 'r' is the radius of the wire, then the cross-sectional area, $A = \pi r^2$. Then the specific resistance or resistivity of the material of the wire is,

$$\rho = \frac{\pi r^2 R}{l}$$

To know more about ohm's law, watch the video given below,

https://www.youtube.com/watch?v=AOADrgWdzrU

Materials Required:

- A resistance wire
- A voltmeter and an ammeter of appropriate range
- A battery (battery eliminator)
- A rheostat
- A metre scale
- One way key
- Connecting wires
- A piece of sand paper
- Screw gauge

Real Lab Procedure:

- First we'll draw the circuit diagram.
- Arrange the apparatus in the same manner as given in the arrangement diagram.
- Clean the ends of the connecting wires with sand paper to remove insulation, if any.
- Make neat, clean and tight connections according to the circuit diagrams. While making connections ensure that +ve marked terminals of the voltmeter and ammeter are joined towards the +ve terminals of the battery.
- Determine the least count of voltmeter and ammeter, and also note the zero error, if any.
- Insert the key K, slide the rheostat contact and see that the ammeter and voltmeter are working properly.

- Adjust the sliding contact of the rheostat such that a small current passes through the resistance coil or the resistance wire.
- Note down the value of the potential difference V from the voltmeter and current I from the ammeter.
- Shift the rheostat contact slightly so that both the ammeter and voltmeter show full divisions readings and not in fraction.
- Record the readings of the voltmeter and ammeter.
- Take at least six sets of independent observations.
- Record the observations in a tabular column
- Now, cut the resistance wire at the points where it leaves the terminals, stretch it and find its length by the meter scale.
- Then find out the diameter and hence the radius of the wire using the screw gauge and calculate the cross- sectional area A (πr^2).
- Plot a graph between current (I) along X-axis and potential difference across the wire (V) along Y-axis.
- The graph should be a stright line.
- Determine the slope of the graph. The slope will give the value of resistance (R) of the material of the wire.
- Calculate the resistance per centimeter of the wire.
- Now,calculate the resistivity of the material of the wire using the formula,

$$\rho = \frac{\pi r^2 R}{l}$$

Check out this video to see how to do an experiment in an original lab,

https://www.youtube.com/watch?v=biroBFu2Qa0

Simulator Procedure (as performed through the Online Lab)

- Select the length of the wire by dragging the end points
- Select the diameter of the wire by clicking the area button.
- See current by clicking on symbol of ampere.
- You will be prompted to collect 5 different current readings using 5 different length samples of wire.
- Each time you load this program you will get a randomly generated resistivity, so don't exit the program once you start.
- You will calculate the resistance of that segment of wire using Ohm's Law .
- Finally, you will measure the cross-sectional area of the wire to find the resistivity of the material that makes up the wire.
- Check the result at end by following the instructions given on screen.

Link for online lab,

https://www.thephysicsaviary.com/Physics/Programs/Labs/ResistanceOfWireChallengeLab/

Observations

Range of ammeters = _____ mA to _____ mA

The Least count of ammeter = _____ mA

Range of voltmeter = _____ V to ____ V

The Least count of voltmeter = _____ V

The Least count of meter-scale = _____ m

Length of the given wire, l = _____ m

S. No	The applied potential difference (voltmeter reading *V*)	Current flowing through the wire (Milliammeter Reading *A*)

Results:

Resistance per cm of the wire is ....Ωcm^{-1}.

Cross-sectional area of the wire, A = πr^2 = ...cm^2

Resistivity of the material of the wire, ρ = ...Ωcm

Experiment-IV

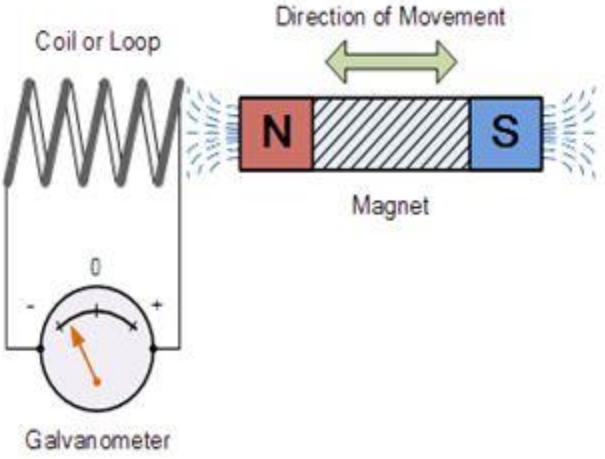
Aim:

To study how magnetism can be used to create a flow of electrons in a circuit.

Theory:

Suppose while shopping you go cashless and your parents use cards. The shopkeeper always scans or swipes the card. Shopkeeper does not take a photo of the card or tap it. Why does he swipe/scan it? And how does this swiping deduct money from the card? This happens because of the 'Electromagnetic Induction'.

Can moving objects produce electric currents? How to determine a relationship between electricity and magnetism? Can you imagine the scenario if there were no computers, no telephones, no electric lights. The experiments of Faraday has led to the generation of generators and transformers.

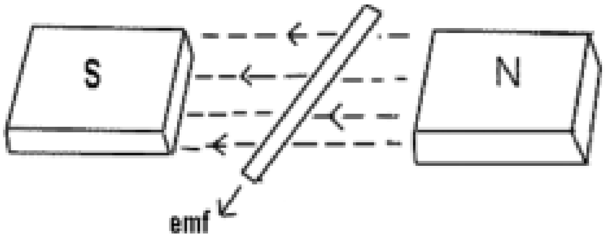


The induction of an electromotive force by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field is called 'Electromagnetic Induction'.

This either happens when a conductor is set in a moving magnetic field (when utilizing AC power source) or when a conductor is always moving in a stationary magnetic field.

This law of electromagnetic induction was found by Michael Faraday. He organized a leading wire according to the setup given underneath, connected to a gadget to gauge the voltage over the circuit. So when a bar magnet passes through the snaking, the voltage is measured in the circuit. The importance of this is a way of producing electrical energy in a circuit by using magnetic fields and not just batteries anymore. The machines like generators, transformers also the motors work on the principle of electromagnetic induction.

Faraday's law of Electromagnetic Induction



- First law: Whenever a conductor is placed in a varying magnetic field, EMF induces and this emf is called an induced emf and if the conductor is a closed circuit than the induced current flows through it.
- Second law: The magnitude of the induced EMF is equal to the rate of change of flux linkages.

Based on his experiments we now have Faraday's law of electromagnetic induction according to which the amount of voltage induced in a coil is proportional to the number of turns and the changing magnetic field of the coil.

So now, the induced voltage is as follows:

$e = N \times d\Phi/dt$

where,

e is the induced voltage
N is the number of turns in the coil
Φ is the magnetic flux
t is the time

Lenz's law of Electromagnetic Induction

Lenz law of electromagnetic induction states that, when an emf induces according to Faraday's law, the polarity (direction) of that induced emf is such that it opposes the cause of its production.

According to Lenz's law

$E = -N\,(d\Phi/\,dt)$ (volts)

Eddy currents

By Lenz law of electromagnetic induction, the current swirls in such a way as to create a magnetic field opposing the change. Because of the tendency of eddy currents to oppose, eddy currents cause a loss of energy. Eddy currents transform more useful forms of energy, such as kinetic energy, into heat, which isn't generally useful. In many applications, the loss of useful energy is not particularly desirable, but there are some practical applications. Like:

- In the brakes of some trains. During braking, the brakes expose the metal wheels to a magnetic field which generates eddy currents in the wheels. The magnetic interaction between the applied field and the eddy currents slows the wheels down. The faster the wheels spin, the stronger is the effect, meaning that as the train slows the braking force is reduces, producing a smooth stopping motion.
- There are few galvanometers having a fixed core which are of nonmagnetic metallic material. When the coil oscillates, the eddy currents that generate in the core oppose the motion and bring the coil to rest.
- Induction furnace can be used to prepare alloys, by melting the metals. The eddy currents generated in the metals produce high temperature enough to melt it.

Procedure:

Part 1: Horizontal Movement

- Open the magnetic induction program found here.
- Click on "Move Horizontal" and watch the light carefully as the coil of wires moves from left to right. The light should go on twice and off twice. Tell exactly what was happening with the coil when the light was on and when it was off. If you let the light move far enough to the right, it will travel, PacMan like, to the far left again.
- Allow the light to move through a second time, but this time view the movement of the coil from above instead of from the side.
- When the coil returns to the far left again. Hit stop. Hit the rotate button and allow the coil to rotate 90° and then stop its rotation. If you are viewing from above you should see your coil as almost a perfectly thin line and if you are viewing from the side, your coil should look like a full circle.
- Now hit move horizontal again and watch as the coil move through the field. What is different about the light as the coil move through in this orientation?

Part 2: Vertical Movement

- Move your coil into the magnetic field, but keep the light out of the magnet field as shown in the picture below. So stop your system when it looks similar to the picture shown below.
- Change your perspective to a side view.
- Move the coil vertically and tell what happens with the light as the coil moves.
- Move the coil horizontally until all the coil is out of the magnetic field. Stop the motion of the coil. Rotate the coil another 90° so that it is now viewed edge on when in viewing from the side.
- Move the coil horizontally and then stop it when most of the coil is in the magnetic field but the light is not. It should like like the picture shown below.

- Once again move the coil vertically and see what happens with the light as it moves.

Part 3: Rotation

- Stop the coil in the location and orientation shown below.
- Start the coil rotating and allow it to make at least one complete rotation. Tell about the light during this rotation.
- Remove the coil from the field totally and allow it to rotate again. Tell about the light during this rotation.

Part 4: Changing B Field

- Stop the coil in the location and orientation shown below.
- Click on Vary B and describe the light at this time.
- Stop B from Varying and then click on flip magnet a few times. Describe the light at this time.
- Rotate the coils to look like the picture below.
- Click on Vary B and describe the light at this time.
- Stop B from Varying and then click on flip magnet a few times. Describe the light at this time.

Link to lab,

https://www.thephysicsaviary.com/Physics/Programs/Labs/MagneticFlux/

Experiment-V

Aim:

• To explore how the capacitance of conducting parallel plates is related to the separation distance between the plates and the surface area of the plates.

• To determine the permittivity in free space, εo

Theory:

Capacitors are widely used in electronic circuits where it is important to store charge and/or energy or to trigger a timer electrical event. For example, circuits with capacitors are designed to do such diverse things as setting a flashing rate of Christmas lights, selecting what station a radio picks up, and string electrical energy to run an electronic flash unit. Any pair of conductors that can be charged electrically so that one conductor has positive charge and the other conductor has an equal in magnitude, negative charge on it is called a capacitor. A capacitor can be made up of two arbitrarily shaped blobs of metal or it can have any number of regular symmetric shapes such as one hollow sphere inside another, or a metal rod inside a hollow cylinder (see the figure below). The type of capacitor that is easiest to analyze is the parallel plate capacitor. We will focus exclusively on the study of the properties of parallel plate capacitors because the behavior of such capacitors can be predicted using only simple mathematical calculations and basic physical reasoning. Also, parallel plate capacitors are easy to construct. When a parallel-plate capacitor holds an amount of electric charge (q), it will support an electric potential difference (V) across the two parallel, conducting plates. The magnitude of the voltage difference across the plates is proportional to the magnitude of stored charge:

$$V= (V+) – (v-) = ql/ \varepsilon oa$$

where εo is the permittivity in free space, 8.85x10-12C2/N. m2. For an air-filled, parallel-plate capacitor, the ratio of stored charge to electric potential difference across the plates is called the capacitance (or C):

$$C=Q/V$$

Substituting for V from above yields the relationship between C and the physical properties of the capacitor: the permittivity in free space, the inner plate surface area (A), and the distance between the inner plate surfaces (L):

$$C= \varepsilon oA/l$$

Conceptually, capacitance can be considered a measure of capacity of two separated conductors to store electric charge per unit voltage .The SI unit for capacitance is the farad (F).

Procedure:

1. Consider parallel plate capacitor (air filled) with a surface area of 225.0cm2 and a charge of 1.5µC (q) on each of its plates and a plate separation distance of 1.0x10-4m.

a. Calculate the voltage difference field between the plates.

b. Determine the capacitance.

2. Consider charged, parallel plate capacitor (air-filled) with a surface area of 125.5cm2 and a plate separation distance of 5.7x10-5m. The voltage difference between the plates is 1.5V.

a. Determine the capacitance.

b. Calculate the magnitude of charge (q) that resides on the inner surface of either plate

Part 1: Capacitance vs Separation Distance

1. Open the Phet Physics simulation: https://www.thephysicsaviary.com/Physics/Programs/Labs/CapacitorPropertiesLab/

2. Record the plate radius then calculate the surface area of the plates Table 1.

3. Adjust the plate separation distance to the lowest setting.

4. Record the distance and stored charge in Table 1.

5. Repeat step 4, for a total of seven data points, increasing the separation distance by approximate increments of 5.0mm.

Voltage		Seperation Distance	Stored Charges	Capacitance
Radius	Surface Area			
Fit Equation				
Fit Constant A				
Fit Constant B				

Table1

6. Use stored charge and voltage to calculate the capacitance for each of your data points.

7. Create a graph of capacitance vs separation distance.

8. Fit the graph to an appropriate best fit equation and record the fit constants (with ±standard deviations for the fit).

9. Evaluating your graph of capacitance vs distance, explain the physical significance of the fit constants obtained from the fit.

10.Using your calculated fit constants, calculate the permittivity constant (in free space), εo and % Error with the accepted value. Show your calculations.

Part 2: Capacitance vs Surface Area

1. Set the separation distance between the plates to 2.0mm then record the value Table 2.

2. Adjust the plate area to the lowest setting.

3. Record the plate radius, surface area, and stored charge in Table 2.

4. Repeat step 3, with increasing the plate area, for a total of six data points.

Voltage		Radius	Plate Area	Stored Charge	Capacitance
Separation Distance					
Fit Equation					
Fit Constant A					
Fit Constant B					

Table 2

5. Calculate the capacitance for each data point. Record values in Table 2.

6. Create a capacitance vs plate area.

7. Fit the graph to an appropriate best fit equation and record the fit constants (with ±standard deviations for the fit).

8. Evaluating your graph of capacitance vs plate area, explain the physical significance of the fit constants obtained from the fit, in terms of Equation 1.

9. Using your calculated fit constants, calculate the permittivity constant (in free space), εo and % Error with the accepted value. Show your calculations.

Link to lab manual,

https://www.thephysicsaviary.com/Physics/Programs/Labs/CapacitorPropertiesLab/

Observations:

1. Suppose have a charged, parallel-plate capacitor, with the power supply unattached.

a. How would you expect increasing or decreasing the spacing between the plates would affect the electric field within the capacitor?

b. How would you expect increasing or decreasing the separation between the plates would affect the electric potential difference across the capacitor?

c. Use the capacitor simulation to check your answers. Disconnect the power supply by left-clicking the on/off switch. Do your observations agree with your previous predictions? Why or why not?

2. Consider charged, parallel-plate capacitor (air filled) consisting of two flat, circular plates (radius=12.0cm) and separation distance of 20.0cm, with a stored charge (q) of 120pC on each of its plates.

a. Calculate the electric field magnitude between the plates and corresponding voltage difference between the plates.

b. The spacing between the plates is then doubled.

i. What is the electric field between the plates?

ii. What is the voltage across the capacitor?

3. Summarize what you learned during this experiment. List at least three things.