PHYSICS PROJECT

To study the variation of magnetic field with distance along the axis of a circular coil carrying current by Stewart and Gee’s method for plotting a graph.

G1-1(ELECTRONICS AND MECHANICAL)

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ACKNOWLEDGEMENT

Gratitude cannot be seen or expressed. It can only be felt in heart and is beyond description. Often words are inadequate to serve as a model of expression of one's feeling, specially the sense of indebtedness and gratitude to all those who help us in our duty.

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OBJECTIVE OF THE REPORT

To study the variation of magnetic field with distance along the axis of a circular coil carrying current by Stewart’s and Gee’s method by plotting a graph.

APPARATUS REQUIRED:

1. Stewart and Gee’s type Tangent galvanometer
2. A Battery
3. A Rheostat
4. An Ammeter
5. A one way key and a Reversing key
6. Connecting leads
**THEORY:**

SIR WILLIAMS Gilbert was the first person to interpret about the earth’s magnetic field in the year 1600. He suggest that earth itself is a huge magnet.

**Evidence based on the above statement:**

- A magnetic needle suspended from a thread and free to rotate in a horizontal plane comes to rest along the north-south direction.
- When a soft iron piece is buried under the surface of earth in the north-south direction, it is found to acquire the properties of a magnet after sometime.
- When we draw field lines of a magnet, we come across neutral points. At these points, magnetic field due to the magnet is neutralized or cancelled exactly by the magnetic field of earth. If the earth has no magnetic field then we never observe neutral points.
Magnetic Field of the Earth

The Earth’s magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth. The Earth’s core is hotter than that and therefore not magnetic. So how did the Earth get its magnetic field?

Magnetic fields surround electric currents, so we surmise that circulating electric currents in the Earth’s molten metallic core are the origin of the magnetic field. A current loop gives a field similar to that of the earth. The magnetic field magnitude measured at the surface of the Earth is about half a Gauss and dips toward the Earth in the northern hemisphere. The magnitude varies over the surface of the Earth in the range 0.3 to 0.6 Gauss.

The strength of earth’s magnetic field is of the order of $10^{-4}$ tesla. E.g. At Delhi the earth magnetic field is 0.35 gauss.
CAUSE OF EARTH’S MAGNETISM:

✓ Due to rotation of earth about its axis. Since every substance is made up of charged particles so a substance rotating about an axis is equivalent to circulating current, which are responsible for the magnetization.
✓ The earth’s core is very hot and molten. Circulating ions in the highly conducting liquid region of the earth’s core could form current loops and hence magnetic field.
✓ In the outer layers of earth’s atmosphere, gases are in the ionized state on account of cosmic layers. As earth’s rotates, strong electric currents are set up due to movement of (charged) ions which are responsible for the earth’s magnetization.

The Earth’s magnetic field is described by seven parameters. These are as follows-

- Declination (D)
- Inclination (I)
- Horizontal intensity (H)
- Vertical intensity (Z)
- Total intensity (F)
- The north (X) and east (Y) components of the horizontal intensity.
1. **Magnetic declination (θ):**
   The small angle between magnetic axis and geographic axis at a place is defined as the magnetic declination at the place. It is represented by θ.

2. **Magnetic Dip (δ):**
   Magnetic Dip or Magnetic inclination at a place is defined as the angle which the direction of total strength of earth's magnetic field makes with a horizontal line in the magnetic meridian. It is denoted by δ.

3. **Horizontal Component (H):**
   It is the component of total intensity of earth's magnetic field in the horizontal direction in magnetic meridian.

4. **Vertical Component (H):**
   It is the component of total intensity of earth's magnetic field in the vertical direction in magnetic meridian.
**Mathematical relations:**

\[ H = R \cos \delta \]
\[ V = R \sin \delta \]

Squaring and adding,

\[ H^2 + V^2 = R^2 (\cos^2 \delta + \sin^2 \delta) \]

\[ \Rightarrow R = \sqrt{H^2 + V^2} \]

\[ \left( \frac{R \cos \delta}{R \sin \delta} \right) = \frac{V}{H} \]

\[ \tan \delta = \frac{V}{H} \]

The value of \( H \) at the surface of the Earth is of the order of \( 3.2 \times 10^{-5} \) tesla.

The geomagnetic field measured at any point on the Earth's surface is a combination of several magnetic fields generated by various sources. These fields are superimposed on and interact with each other. More than 90% of the field measured is generated INTERNAL to the planet in the Earth's outer core. This portion of the geomagnetic field is often referred to as the Main Field. The Main Field varies slowly in time and can be described by Mathematical Models such as the International Geomagnetic Reference Field (IGRF) and World Magnetic Model (WMM). The Main Field creates a
cavity in interplanetary space called the magnetosphere, where the Earth’s magnetic field dominates in the magnetic field of the solar wind.

**OERSTED EXPERIMENT:**

In 1820 Oersted performed a science demonstration. He planned to demonstrate the heating of a wire by an electric current, and also to carry out demonstrations of magnetism, for which he provided a compass needle mounted on a wooden stand. While performing his electric demonstration, Oersted noted to his surprise that every time the electric current was switched on, the compass needle moved. This shows that current carrying wire produce an electric current.

![What Oersted saw.](image)
EXPERIMENT SHOWING THE EFFECT OF MAGNETIC FIELD B/W TWO CURRENT CARRYING WIRES

If a current in a wire exerted a magnetic force on a compass needle, two such wires also should interact magnetically. This interaction was simple and fundamental--parallel (straight) currents attract, anti-parallel currents repel. The force between two long straight parallel currents was inversely proportional to the distance between them and proportional to the intensity of the current flowing in each.

Given two short parallel currents I1 and I2, flowing in wire segments of length L2 and L1 and separated by a distance R, then the Force b/w them is proportional to-

\[ F \propto \left( I_1 I_2 L_1 L_2 / R^2 \right) \]

--Two circular currents in the same direction attract each other.

--Two circular current in opposite directions repel each other.

Parallel currents in two loops also attract
According to tangent law in magnetism, when a magnet is suspended under the combined action of two uniform magnetic fields of intensities $F$ & $H$, acting at $90^\circ$ to each other, the magnet comes to rest making an angle of $\theta$ with the direction of $H$, such that

$$F = H \tan \theta;$$

Two coils of many parallel loops, with currents in the same direction, attract each other and act like magnets.
STEWART'S & GEE'S TANGENT GALVANOMETER:

PRINCIPLE:

It is based on tangent law in magnetism.

CONSTRUCTION:

It consists of a circular frame denoted by K of a non magnetic material such as:

- Brass (generally used in college labs)
- Ebonite
- Wood

The circular frame is mounted vertically on a horizontal base called **TURN TABLE**.

The **TURN TABLE** is provided with two leveling screws $S_1$ and $S_2$ at the base.

**USES of leveling screws:**

1. To keep the turn table horizontal
2. To keep the frame Vertical

By doing this adjustment the frame is set in magnetic meridian.
HOW CAN WE VARY THE CURRENT?

1. Using Battery eliminator.

2. Using Rheostat.

3. We generally have four coils of insulated copper wire in this galvanometer having 5, 20, 50 and 100 number of turns wound on the circular frames. Taking two coils at a time we have several combinations that can be made.

   E.g. in the experiment we use 5 and 20 turns coils making a total of 25.

CIRCULAR MAGNETOMETER BOX

It is made up of non magnetic material held at the center of a circular frame. This box has a small magnetic needle ns pivoted at its centre on a vertical axis with a long thin RED colored pointer p fixed at 90° to the needle. The ends of the needle lie over a horizontal circular scale graduated in degrees and divided into four quadrants of 90° each.

A small MIRROR is fixed at the base under the pointer.
USE OF POINTER:

It is used in removing the parallax in reading the position of the pointer on the scale.

ZERO ADJUSTMENT & ZERO ALIGNMENT

By Zero adjustment we mean to make the turn table parallel by using leveling screws so that it will set exactly into magnetic meridian. By Zero alignment we mean to rotate the vertical frame so that the plane of the frame having needle points to 0°.

CALCULATIONS:

The intensity of magnetic material at a point on the axis of a circular coil of radius a having n number of turns at a distance x from the centre of the coil, in S.I. units is given by

\[ B = \frac{\mu \times 2\pi n a x a l}{1.5 \sqrt{a^2 + x^2}} \]

Where I is the current flowing through the coil and is in amperes
μ is constant and is equal to 4\pi \times 10^{-7}
π is also constant and is equal to 3.1447
If the field $B$ is perpendicular to horizontal component of earth’s magnetic field and is the deflection produced in the magnetometer

$$B = B_H \tan \theta$$

Or $B = \tan \theta$

Hence a graph between $\tan \theta$ and $x$ is similar to the graph between $B$ and $x$.

**Procedure for the Experiment**

- Place the instrument on the table so that the arms of the magnetometer lie roughly east and west and the magnetic needle lies at the center of vertical coil. Place the eye a little above the coil and rotate the instrument in the horizontal plane till the coil, the needle and its image in the mirror provided at the base of the compass box, all lie in the same vertical plane. The coil is set roughly in the magnetic meridian. Rotate the compass box so that the pointer lies on the 0-0 line.

- Connect the Galvanometer to a battery, a rheostat, one way key and an ammeter through reversing key.
• Adjust the value of the current so that the magnetometer gives a deflection in the second case agrees closely, the coil lies exactly in the magnetic meridian. If the mean difference deflection in the two cases does not agree closely, slightly turn the instrument till the deflection with the direct and the reversed currents agree closely.

• Now slide the magnetometer along the axis and find the position where the maximum deflection is obtained. In this position the center of the needle coincides with the center of vertical coil.

• Note the position of the arm against the reference mark and also the value of hit current as indicated by the ammeter. Read both ends of the pointer in the magnetometer, reverse the current and again read both the ends. Shift the magnetometer by two centimeter and note the reading of magnetometer keeping the current constant at the same value of both for direct and reversed current. In this position the center of the magnetic needle is at a distance of two centimeter from the center of vertical coil. Take a number of observations by shutting the magnetometer by two centimeter at a time.
• Simply repeat the observations by shifting the magnetometer in the opposite direction and keeping the current constant at same value.

• To plot the graph, to show how the field varies along the axis of the coil, we plot the graph between $\tan \theta$ and $x$, it will be similar to graph between $B$ and $x$. 
# Observations and Calculations

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<th>No.</th>
<th>distance from center x(cm)</th>
<th>Left side</th>
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<th>tanθ</th>
<th>Right side</th>
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</table>
$B_c = B_H \tan \theta$  \hspace{1cm} \text{when } \theta = 45, \hspace{0.5cm} B_c = B_H$

But $\tan \theta = 1; \hspace{0.5cm} x = 9 \text{ cm} = 0.09 \text{ m}$

$$B = \frac{\mu x \pi n a x a l}{1.5 a^2 + x^2}$$

$\mu = 10^{-7}, \pi = 3.14, a = 0.1, I = 0.4A, n = 25$

$x = 0.09 \text{ m}$

$B = 0.257 \times 10^{-4} \text{ T}$
RESULT:

1. Intensity of field is maximum at 0. If we move away from 0 towards the right or left, the intensity of magnetic field decreases. The curve first concaves toward 0 but the curvature becomes less and less quickly changes sign at P and Q and afterwards becomes convex towards 0. The point of inflection P and Q where the curvature changes its sign i.e. at distance r/2 from center. Hence the distance between P and Q is the radius of the coil.

2. The distance where the field due to the coil becomes equal to $B_H$ due to earth field can be determined from graph between $\theta$ and $x$ for $\theta = 45$

   a. $B = B_H = 0.257 \times 10^{-4} \ T$
   b. The radius of the coil = 10 cm

Precautions:

1. No magnet or magnetic substance or current carrying conductor should be near the apparatus.
2. The place of the coil should be vertical and in the magnetic meridian.
3. The current should be constant and should not be reversed for each observation.