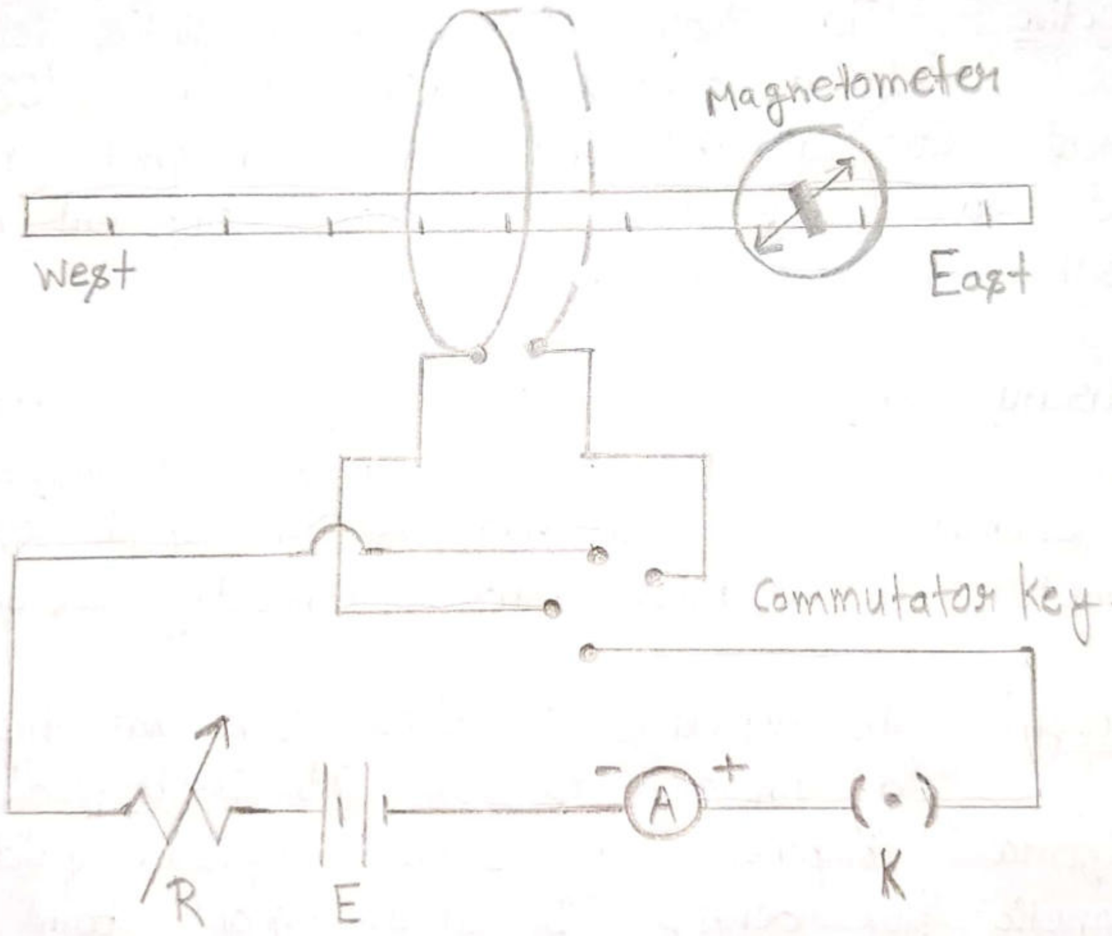

Arrangement for measurement of magnetic field along the axis of current carrying coil.

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"Experiment - 9"

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"Stewart and Gee Experiment"

Objective :- To study variation of magnetic field with distance along the axis of a Circular Current Carrying Coil placed in magnetic meridian, and to evaluate horizontal Component of the Earth's magnetic field.

Apparatus required :- Stewart and Gee apparatus, a power supply, a rheostat, a Commutator key, a plug key, spirit level, an ammeter, sand paper and Connecting wires.

Theory :- The apparatus is placed such that the magnetic field generated by the coil is prependicular to horizontal Component of Earth's magnetic field. The magnetic flux density B at a distant point x meter away from center on the axis of a Current carrying Circular Coil is given by,

$$B(x) = B_H \tan\theta$$
$$= B(0)\ f(x) \quad wb/m^2 \text{ or Tesla}$$

where, $B(0) = \dfrac{\mu_0 n i}{2r}$

and $f(x) = \dfrac{1}{\left(1 + \dfrac{x^2}{r^2}\right)^{3/2}}$

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the symbols have following meaning :-

i = Current Flowing through coil
n = number of turn of wire in the Coil
r = radius of Coil
x = distance of the point from the centre of the Coil on its axis.
θ = deflection of the needle of magnetometer.

The graph between Tan θ and B is straight line. The slope of line is equal to the horizontal Component of Earth's magnetic field.

Procedure :- (1) Level the apparatus with the help of spirit level and the leveling screws.

(2) Adjust the magnetometer Compass box such that the magnetic needle is at the centre of Coil.

(3) Rotate the Compass box until the needle in the Compass box read zero at both ends on Circular scale. Thus plane of Coil is now approximately in magnetic meridian.

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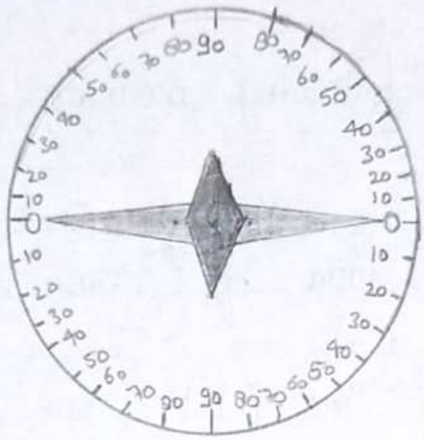
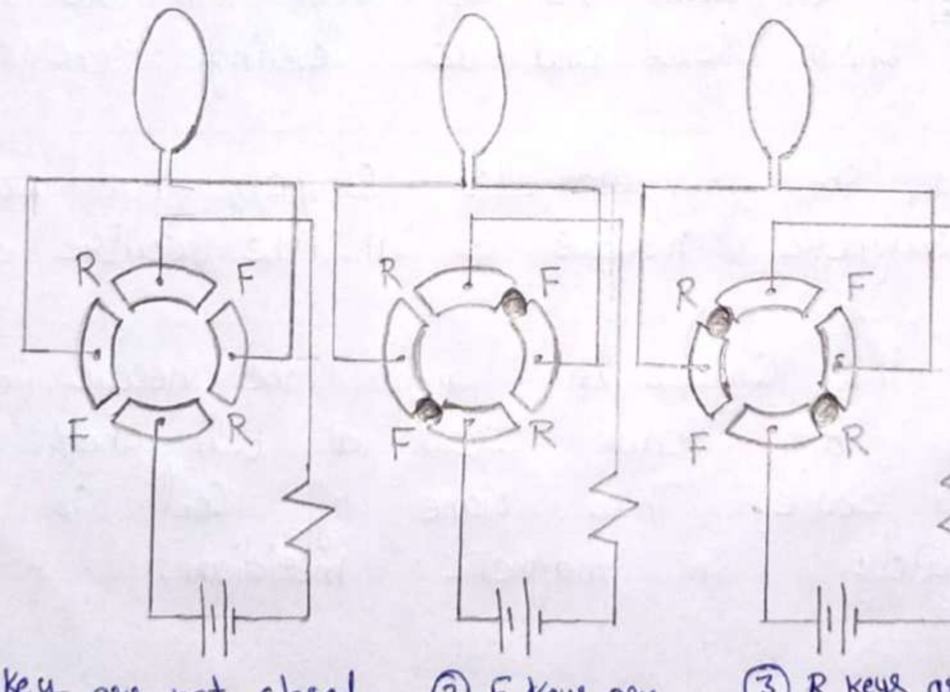


Schematic for magnetometer Compass box.



① key are not closed so current doesnot flow in coil

② F keys are closed to flow forward current in the coil

③ R keys are closed to flow reverse current in the coil.

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④ Close the key F-F (R-R open), record the deflection θ_{F1} and θ_{F2} for forward current. Note down these values for $x = 0, 2, 4, \ldots, 18$ cm towards right of the coil

⑤ open the key F-F and close key R-R to reverse direction of current. Note down deflection θ_{R_1} and θ_{R_2} of two ends of magnetometer needle. Note down the deflections θ_{R_1} and θ_{R_2} for $x = -1, -2, -3, \ldots -17$ cm.

⑥ After reaching leftmost end again open R-R key and close F-F key to again change the direction of current. Note down the deflections θ_{F_1} and θ_{F_2} for $x = -17, -16, -15, \ldots 0$, i.e move towards right unless you reach center of coil.

Observations :-

Radius of coil, $r = 9.5$ cm
Least Count of ammeter $= 0.5$ mA
Current passing through coil, $i = 250.0$ mA
Number of turns in the coil, $n = 50$

$r^2 = 90.25 \text{ cm}^2$

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Table :- Deflection of the needle at various distances from the coil.

Right hand side							Left hand side							
Distance from the centre	Current flowing in one direction		Current flowing in reverse direction		Mean	Tan(θ)	Distance from the centre	Current flowing in one direction		Current flowing in reverse direction		Mean	Tan(θ)	$f(x) = \frac{1}{\left(1+\frac{x^2}{r^2}\right)^{3/2}}$
x(cm)	θ_{F_1}	θ_{F_2}	θ_{R_1}	θ_{R_2}	θ (in degree)		x(cm)	θ_{F_1}	θ_{F_2}	θ_{R_1}	θ_{R_2}	θ (in degree)		
0	67	68	68	67	67.50	2.414	-	-	-	-	-	-		1.000
1	67	66	65	65	65.75	2.220	-1	66	66	66	67	66.25	2.273	0.984
2	64	65	65	65	64.75	2.120	-2	65	65	64	64	64.50	2.096	0.937
3	62	63	64	64	63.25	1.984	-3	63	63	62	64	63.00	1.963	0.867
4	60	60	61	62	60.75	1.786	-4	61	60	62	62	61.25	1.823	0.783
5	56	57	59	60	58.00	1.600	-5	58	57	58	59	58.00	1.600	0.693
6	54	53	56	56	54.75	1.415	-6	54	55	54	56	54.75	1.415	0.604
7	50	49	52	52	50.75	1.224	-7	49	51	51	50	50.25	1.202	0.522
8	46	45	48	48	46.75	1.063	-8	47	48	46	47	47.00	1.072	0.447
9	42	41	44	45	43.00	0.932	-9	43	42	43	42	42.50	0.916	0.382
10	36	37	38	39	37.50	0.767	-10	37	38	37	38	37.50	0.767	0.327
11	34	32	34	35	33.75	0.668	-11	34	33	35	33	33.75	0.668	0.279
12	29	28	30	30	29.25	0.560	-12	29	28	29	29	28.75	0.549	0.239
13	26	26	26	26	26.00	0.488	-13	26	27	25	26	26.00	0.488	0.205
14	23	22	22	23	22.50	0.414	-14	23	23	22	23	22.75	0.419	0.177
15	20	19	19	20	19.50	0.354	-15	20	20	19	20	19.75	0.359	0.153
16	17	16	17	18	17.00	0.306	-16	17	17	18	17	17.25	0.310	0.133
17	15	14	14	15	14.50	0.259	-17	15	15	15	16	15.25	0.273	0.116

[where θ is in degree]

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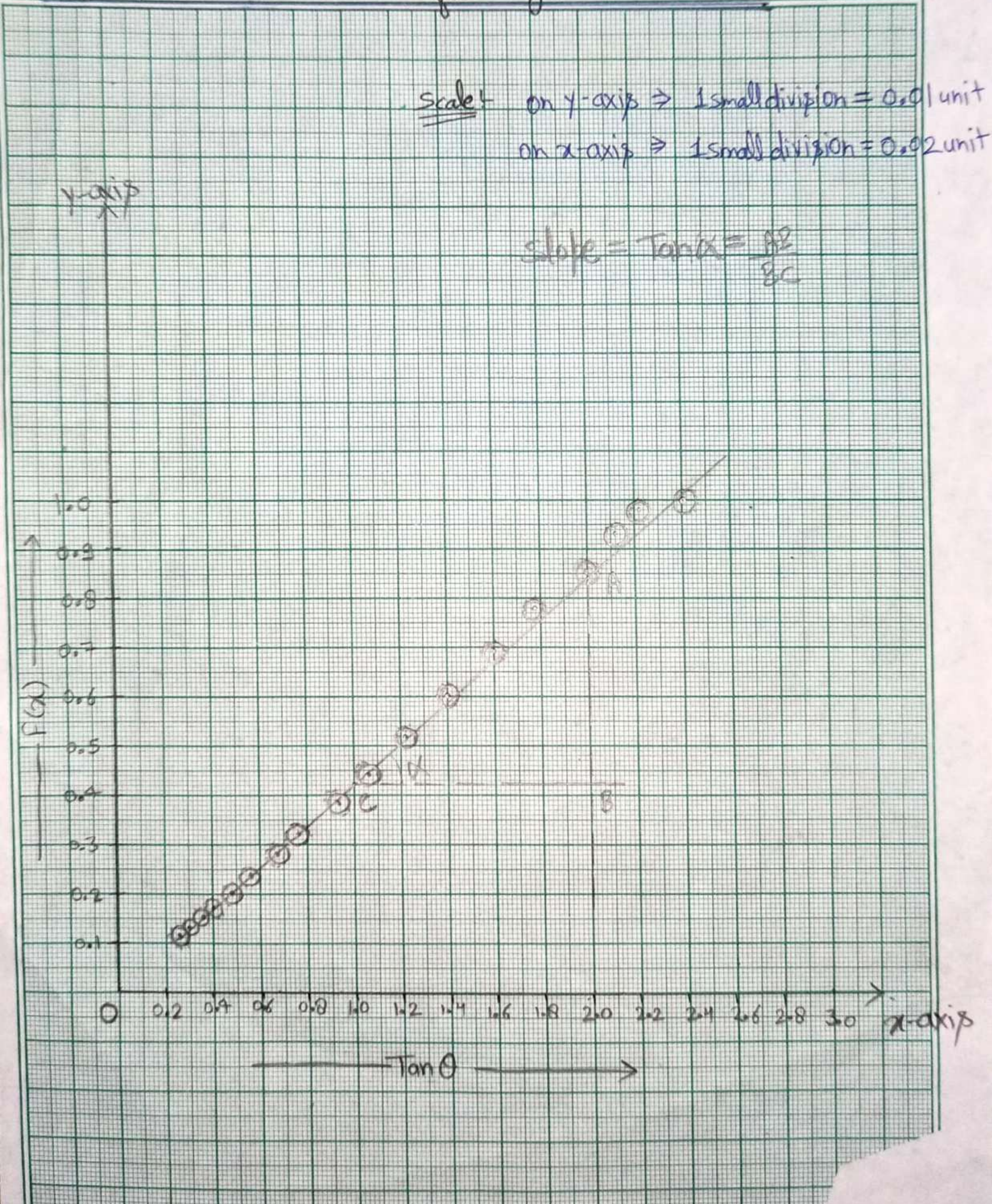
Graph b/w^n $f(x)$ and Tanθ for Right hand side :-



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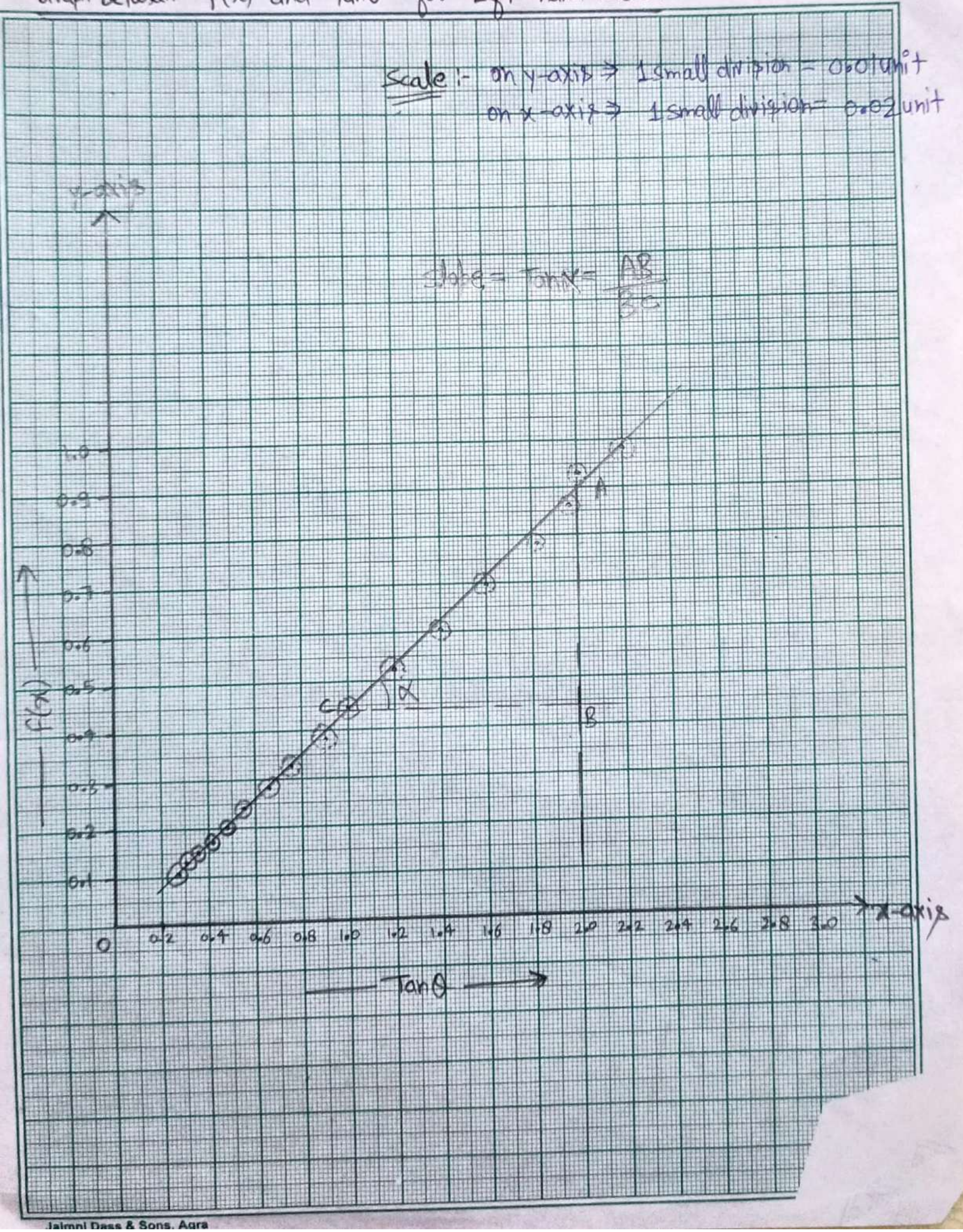
Graph between f(x) and Tanθ for Left hand side :-



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Calculations :-

Magnetic field at the centre of coil $B(0)$:-

$$B(0) = \frac{\mu_0 n i}{2r} = \frac{4 \times 3.14 \times 10^{-7} \times 50 \times 0.25}{2 \times 9.5 \times 10^{-2}}$$

$$B(0) = \underline{8.263 \times 10^{-5} \text{ Tesla}}$$

$\therefore$ From expression, $B(x) = B(0)\,f(x) = B_H \tan\theta$, we have

$$\boxed{f(x) = \frac{B_H}{B(0)} \tan\theta}$$

Thus the graph b/w^n $f(x)$ and $\tan(\theta)$ is a straight line with slope $\frac{B_H}{B(0)}$. There the horizontal component of Earth's Magnetic field is given by

$$\boxed{B_H = B(0) \times \text{slope of straight line}} \quad \text{-----}(i)$$

For Right hand side :-

for more accuracy, taking 3 slopes of the straight line obtained and taking mean of them -

$$m_1 = \frac{0.84 - 0.42}{2.00 - 1.00} = \frac{0.42}{1.00} = 0.42$$

$$m_2 = \frac{0.92 - 0.50}{2.20 - 1.20} = 0.42$$

$$m_3 = \frac{0.63 - 0.21}{1.50 - 0.50} = 0.42$$

hence $m = \frac{m_1 + m_2 + m_3}{3} = 0.42$

slope of straight line = 0.42.

putting in equ^n (i)

$B_H = B(0) \times$ slope of straight line

$B_{H_R} = 8.263 \times 10^{-5} \times 0.42 = \underline{3.47 \times 10^{-5} \text{ Tesla}}$.

<u>For left hand side</u> :-

$$m_1 = \frac{0.90 - 0.45}{2.00 - 1.00} = 0.45$$

$$m_2 = \frac{0.98 - 0.53}{2.20 - 1.20} = 0.45$$

$$m_3 = \frac{0.67 - 0.22}{1.50 - 0.50} = 0.45$$

hence slope of straight line $= m = \frac{m_1 + m_2 + m_3}{3} = 0.45$

putting in equ^n (i)

$B_{H_L} = 8.263 \times 10^{-5} \times 0.45 = \underline{3.71 \times 10^{-5} \text{ Tesla}}$

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Taking mean of B_H Calculated from both sides -

$$B_H = \frac{B_{H_R} + B_{H_L}}{2} = \frac{(3.47 + 3.71) \times 10^{-5}}{2} \text{ Tesla}$$

$$B_H = \underline{3.59 \times 10^{-5} \text{ Tesla}}$$

Result :- The horizontal Component of Earth's magnetic field is 3.59×10^{-5} Tesla.

Discussion :- The Theoretical value of $B_H = 3.5 \times 10^{-5}$ T hence, our theoretical and Calculated values are approximately same.

Precautions :- (i) The coil should be adjusted Carefully in the magnetic Meridian.

(ii) All the magnetic materials and Current carrying Conductors should be at a Considerable distances from apparatus.

(iii) The Current passed in the coil should be of such a value as to produce a deflection of nearly 60 - 60.

(iv) Parallax should be removed while reading the position of pointer.

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Other Remark :- The circular coil should be set in the Magnetic meridian position that makes the magnetic field of coil prependicular to the horizontal Component of earth's magnetic field so that Tangent law can be applicable.

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