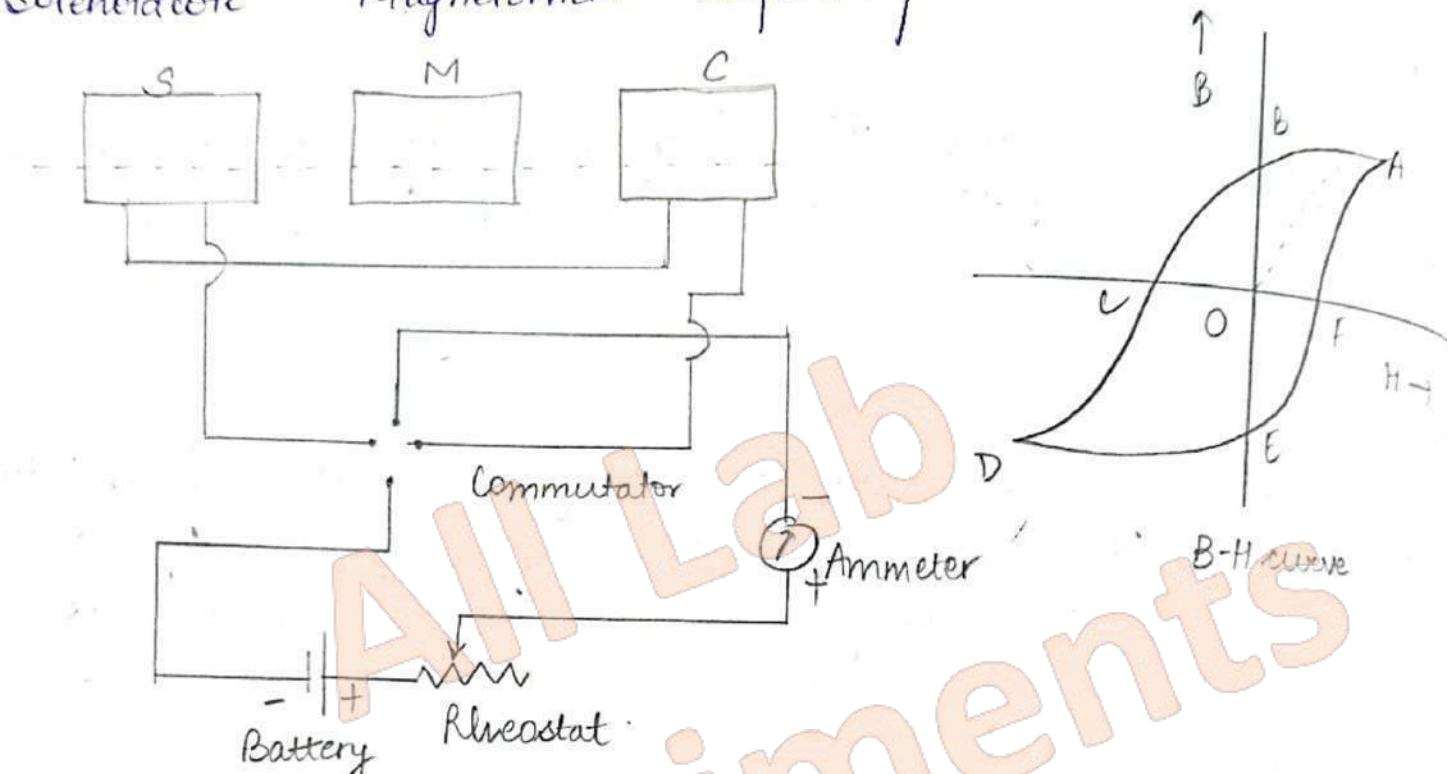
Aim :- To decaw the B-H curve of iron using a solenoid and determine the energy loss from Hysteresis.



Circuit diagram to study variation of deflection with current

Observations -

No. of turns per cm length of solenoid, $n = \frac{200}{32} = 6.25$

length of the specimen = 0.285m = 2l

Define all the symbols

$$\text{Retentivity } (X) = \frac{H_B (d^2 - l^2)^2 \tan\theta}{4ald}$$

Coercivity = 100ni

Loss of energy $= \frac{ANX}{2al}$

when $X = \frac{H_B (d^2 - l^2)}{4ald}$, $N = 100n$

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Aim :- To draw the BH curve of iron using a solenoid and determine the energy loss from hysteresis

Apparatus :- Deflection Magnetometer, a solenoid, compensating coil, Iron rod, ammeter, battery, measuring scale and connecting wires,

Theory :- In Physics laboratory, experiments with bar magnetic compass to determine the direction of earth's magnetic field. The bar magnet as well as tiny magnet of compass are generally made of iron, this is because iron can acquire permanent magnetism. An electric bell, a telephone reciever, a electric motor are device which use a solenoid will wound on soft iron core. When we pass an electric current through this coil, a magnetic field is produced around it. And an iron core confines the field to a smaller region. In its normal state, ever a ferromagnetic substance is unmagnetised. And to magnetic external magnetic field is applied. Iron bar is magnetise by placing it inside a solenoid and electric current passes through solenoid. As the current through the solenoid is gradually increased, the intensity of magnetisation (M) of the specimen increases, until it reaches a

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Current (A)	when current is increasing			when current is decreasing		
	θ_1(°)	θ_2(°)	tan θ	θ_1(°)	θ_2(°)	tan θ
0	41	41	0.0869	48	48	1.110
0.2	48	48	1.110	49	50	1.708
0.4	49	49	1.150	51	51	1.23
0.6	50	50	1.19	52	52	1.279
0.8	51	51	1.23	52	53	1.303
1.0	52	51	1.257	53	53	1.327
1.2	52	52	1.279	53	53	1.327
1.4	53	52	1.303	53	53	1.327
1.6	54	52	1.327	53	54	1.351
1.8	54	53	1.351	53	54	1.351
2.0	54	54	1.376	53	54	1.351
2.2	55	54	1.40	54	54	1.376
2.4	55	54	1.40	54	54	1.376
2.6	55	54	1.40	54	54	1.402
2.8	55	54	1.40	55	54	1.402
3	55	54	1.40	55	54	1.402

when direction of current is reversed -

Current (A)	when current is increasing			when current is decreasing		
	θ_1(°)	θ_2	tan θ	θ_1	θ_2	tan θ
0.	31	29	0.577	51	51	1.234
0.2	45	48	0.965	51	51	1.234
0.4	47	45	1.0355	51	51	1.234
0.6	50	48	1.150	52	52	1.279
0.8	52	50	1.234	54	53	1.351
1.0	53	51	1.27	55	55	1.428
1.2	55	52	1.351	55	55	1.428
1.4	56	55	1.428	56	55	1.455
1.6	56	55	1.455	57	56	1.510

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saturation value. Initially, the magnetisation increases slowly but as the field increases, it grows more rapidly and reaches saturation ultimately. In fig, the saturation is signified by point A. If the field is now reduced by gradually decreasing the current through the solenoid M does not retrace the original path (OA). Instead, it follows the line AB. When the current and hence field is reduced to zero, some magnetisation survives, shown by OB. This value of M is known as remanent magnetisation. Magnetisation can be completely destroyed by applying opp. field (by reversing the direction of current in solenoid and increased it gradually). In the figure, OC is a measure of the reverse field required to wipe out magnetisation in a ferromagnetic specimen that has been magnetised to saturation. This is called the coercivity of the specimen. This value of H (for M=0) is called the coercive force of specimen.

On further increasing the current and taking it to the same maximum value in the reverse direction the specimen gets magnetised in the opp. direction reaching a saturation value at D.

By decreasing it to zero, reversing and increasing it in the original direction, the curve OEFA is obtained.

As the magnetisation in the specimen does not keep step with the magnetising field. Instead magnetisation tends to persist i.e. lag behind the magnetising field which produce it. This phenomenon is called Hysteresis.

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1.8	59	56	1.631	58	57	1.567
2.0	59	56	1.631	58	57	1.569
2.2	59	59	1.664	59	58	1.631
2.4	59	60	1.697	59	58	1.631
2.6	59	60	1.697	59	59	1.664
2.8	60	61	1.697	59	59	1.664
3.	60	61	1.767	59	60	1.697

When again direction of current is reversed and it is increasing

Current (A)	θ_1 (°)	θ_2 (°)	tanθ
0	38	38	0.781
0.2	44	45	1.017
0.4	45	45	1.035
0.6	46	46	1.191
0.8	50	50	1.21
1	51	51	1.23
1.2	52	51	1.279
1.4	53	52	1.303
1.6	53	52	1.327
1.8	53	53	1.327
2	54	53	1.327
2.2	54	54	1.376
2.4	54	54	1.376
2.6	54	54	1.376
2.8	54	54	1.376
3	54	54	1.376

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(to lag behind). The loop ABCDEFA is called Hysteresis loop. The area of loop is energy loss in specimen per cycle of operation.

Magnetic dipole in a magnetic field -

In the absence of any magnetic field, a freely pivoted magnet orients itself along the earth's north-south direction as shown in (a). This represents the direction of earth's (horizontal) magnetic field and is known as magnetic meridian. Fig (b) shows a magnetic field along a line ⊥ to magnetic meridian. The applied magnetic field tends to deflect magnet from its original orientation, when the earth's field tends to off set this. As a result, the compass needle attains an equilibrium position at an angle θ, with meridian.

$$H = H_E \tan\theta \quad \text{---} \quad (1)$$

This is known as tangent law. It enables us to determine H once θ is known

The magnetic field due to magnet NS at point A can be written as

$$H = \frac{m}{(NA)^2} - \frac{m}{(SA)^2}$$

$$= m\left[\frac{1}{(d-l)^2} - \frac{1}{(d+l)^2}\right]$$

$$= \frac{4mdl}{(d^2-l^2)^2}$$

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Calculations

No. of turns per centimeter length of solenoid, $n = \frac{200}{32} = 6.25/cm$

length of specimen, $2l = 0.285m$

Radius of specimen, $r = 2.98 \times 10^{-3} m$

Area of cross-section of specimen, $a = 27.884 \times 10^{-6} m$

Distance of centre of specimen from magnetometer, $d = 0.31m$

The current through solenoid, $i = .2A$

$H = 100$ ns ampere turns $= 100 \times 6.25 \times 0.2 = 125 A/m$

$H_B = 0.3453 \times 10^{-5} Wb/m^2$

Total area, A = (Total no. of squares) × (values of current for each small square) × (value of $\tan\theta$ for each small square)

$= \frac{1863 \times 0.2 \times 0.4}{100} \Rightarrow 1.4904 m^2$

Retentivity $= \frac{H_B(d^2 - l^2)^2 \tan\theta}{4ald}$

$= \frac{3.453 \times 10^{-5} [(0.31)^2 - (0.1425)^2]^2 \times 1.16}{4 \times 27.88 \times 10^{-6} \times 0.1425 \times 0.31} = 0.046 Wb/m$

1.12 Mark point

$= 0.0396 Wb/m$

Coercivity $= \cancel{100} ni$

$= 100 \times 6.25 \times 0.2 = 125 A/m$

$\frac{6.25 \times 0.2A}{10^{-2}(m)}$

$= 6.25 \times 100 \times 0.2$

Loss of energy per cycle $= \frac{ANX}{2al}$ $N = 100n$

$= \frac{1.4904 \times 100 \times 6.25 \times 0.0396}{2 \times 27.824 \times 10^{-6} \times 0.1425}$

$= 9.64 \times 10^6 J/m^3$

$X = \frac{H_b(d^2 - l^2)^2}{4ald}$

$\frac{AnX}{2al} = 1.4904 \times \frac{6.25}{0.01(m)} X$

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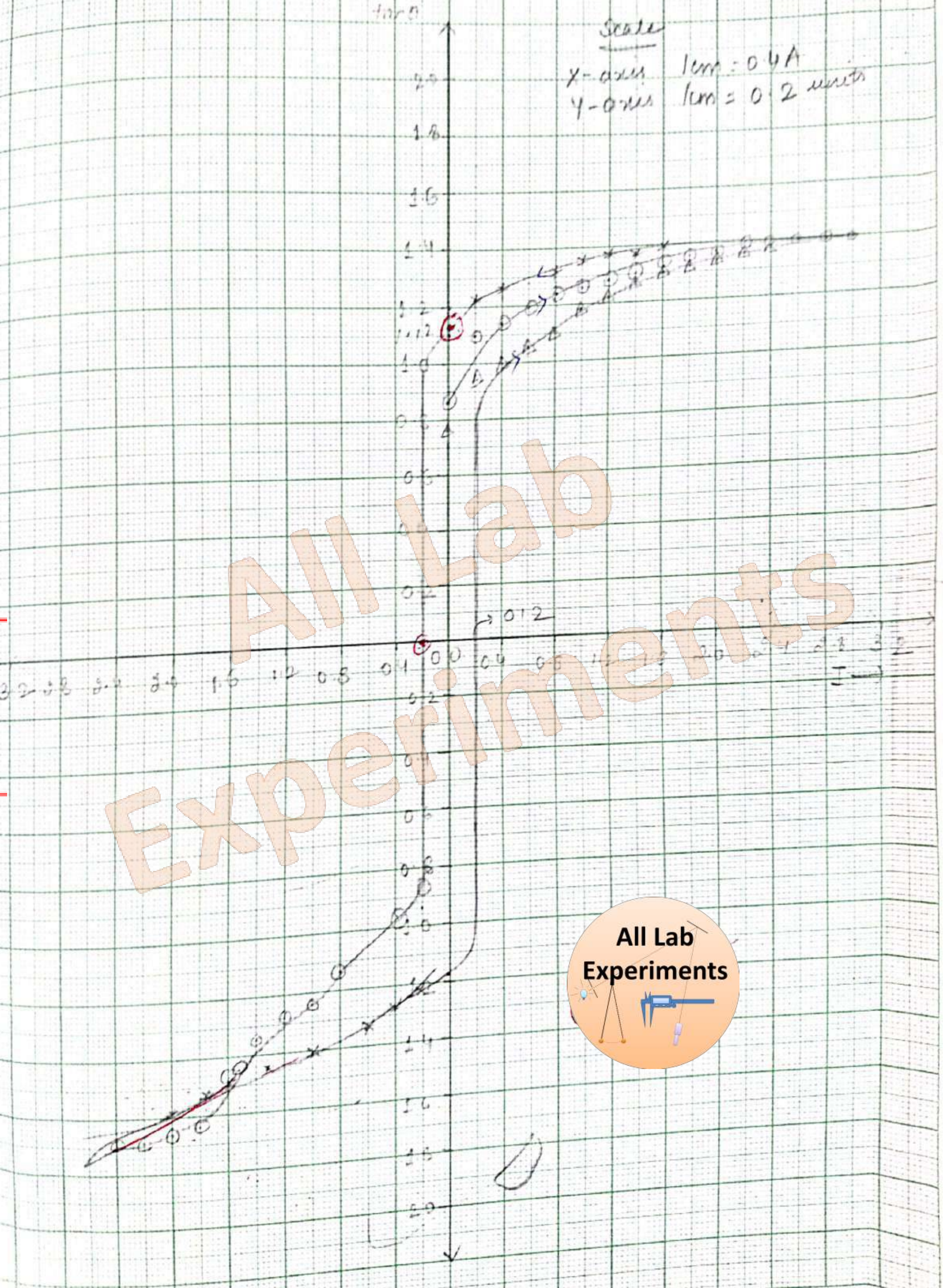

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$$H = \frac{4(l \times M)d}{(d^2 - l^2)^2} \quad \text{—— (2)}$$

where m is magnetic pole strength of magnet NS and a is area of cross-section of specimen.

from (1) and (2) →

$$\frac{4laHd}{(d^2 - l^2)} = H_E \tan\theta$$

$$\text{or } M = \frac{H_E (d^2 - l^2)^2}{4ald} \tan\theta \quad \text{—— (3)}$$

$$\Rightarrow M \propto \tan\theta \quad \text{—— (4)}$$

And the mag. field intensity H is directly related to current i through the solenoid.

$$H \propto i \quad \text{—— (5)}$$

from (2), (4) & (5), experimental plot of vs. tan θ is equivalent to the plot of H vs M.

Result –

(i) Retentivity of specimen = 0.0396 Wb/m²

(ii) Coercivity – 100 Amp turn per meter = 125 A/m.

(iii) Energy loss per cycle of operation, per unit volume of specimen = 4.64 × 10⁶ Joule/m³

Precaution and Source of Error →

i) Ensure polarity has been changed for second set of observation.

ii) While calculating area from the graph, ensure there is extra attention so as [illegible] error in area.

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