Name of Lab Partner	: UDIT PATEL	Roll No.	: 12775
Section	: B-10	Instructor	:
Date of Experiment	: 12/2/13	Remarks by the Instructor	:
Date of Submission	:		
Experiment	: Electro-magnetic induction		

AIM

To study the flux and emf in a solenoid coil as a function of time, when a magnet passes through it

THEORY

When the magnetic flux through a coil changes, an emf is produced in the coil which is given by $\mathcal{E} = -\frac{d\phi}{dt}$

This is the Faraday's law of induction. In this experiment, the induced emf $\mathcal{E}$ is measured as a function of time when a bar magnet moves through a solenoid with a velocity v.

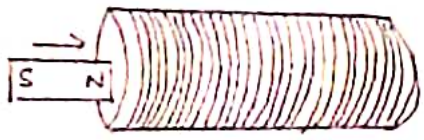

Fig 1

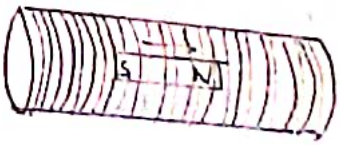

Fig 2

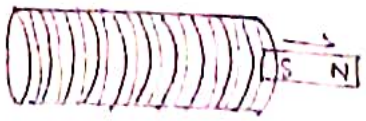

Fig 3

As the magnet comes closer, flux through each turn is positive and increases. When the magnet goes in fig 2, the flux through turns like EF will decrease as the magnet moves ahead and the flux through turns like AB will increase. Till the magnet reaches the middle, the net effect is that the total flux increases

As the magnet moves in the second half of the solenoid, more number of turns are left behind from which contribution to Φ decreases. Net result is that Φ starts decreasing. This continues even after the magnet comes out.

If the frame is left from an initial angular position θ_0, it will oscillate with a time period

$$T = 2\pi\sqrt{\frac{I}{Mgd}}$$

where d is the distance of the point of suspension from the centre of mass.

The angular speed of the frame, when it passes through the equilibrium position is

$$\omega_{max} = \frac{4\pi}{T}\sin(\theta_0/2)$$

and hence the speed of the magnet when it is at the centre of the solenoid is

$$V_{max} = \omega_{max} R = \frac{4\pi R}{T}\sin(\theta_0/2)$$

where R is the radius of the circular arc of the frame.

OBSERVATION

As recorded in observation table

CALCULATION

1 Calculating velocity of magnet using

$$V = \frac{4\pi R}{T} \sin(\theta_0/2)$$

a) $\theta_0 = 5^\circ$ $T = 1.448\,s$ $R = 0.5\,m$

$$V = \frac{4\pi \times 0.5 \sin(2.5^\circ)}{1.448} = 0.17\ m/s$$

b) $\theta_0 = 10^\circ$ $T = 1.454\,s$ $R = 0.5\,m$

$$V = \frac{4\pi \times 0.5 \times \sin(5^\circ)}{1.454} = 0.34\ m/s$$

c) $\theta_0 = 15^\circ$ $T = 1.454\,s$ $R = 0.5\,m$

$$V = \frac{4\pi \times 0.5 \times \sin(7.5^\circ)}{1.454} = 0.51\ m/s$$

d) $\theta_0 = 20^\circ$ $T = 1.455\,s$ $R = 0.5\,m$

$$V = \frac{4\pi \times 0.5 \times \sin(10^\circ)}{1.455} = 0.68\ m/s$$

e) $\theta_0 = 25^\circ$ $T = 1.431\,s$ $R = 0.5\,m$

$$V = \frac{4\pi \times 0.5 \times \sin(12.5^\circ)}{1.431} = 0.86\ m/s$$

f) $\theta_0 = 30^\circ$ $T = 1.463\,s$ $R = 0.5\,m$

$$V = \frac{4\pi \times 0.5 \times \sin(15^\circ)}{1.463} = 1.00\ m/s$$

2) For the V_{max} vs E_{max} curve,

centroid (x_m, y_m)

$$y_m = \frac{1}{6}\sum_{i=1}^{6} V_i = \frac{0.17+0.34+0.51+0.68+0.86+1.00}{6}$$

$$= 0.59$$

For x_{fm}, $x_{fm} = \frac{1}{6}\sum_{i=1}^{6} \varepsilon_i = \frac{0.71 + 0.38 + 0.44 + 0.52 + 0.58 + 0}{6}$

$= 0.55$

Slope of graph $= m = \frac{0.59 - 0.51}{0.55 - 0.52} = \frac{8}{3}$

So $\varepsilon \propto v$

3) From the graph of flux vs time, the peak or the maximum flux is $10.3\ T\ m^2$

INDIAN INSTITUTE OF TECHNOLOGY, KANPUR
LABORATORY REPORT SHEET

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Name of Lab Partner	: UDIT PATEL	Roll No.	: 12775
Section	: B10	Instructor	:
Date of Experiment	: 12/2/13	Remarks by the Instructor	:
Date of Submission	:		
Experiment	: Electromagnetic Induction		

ERROR ANALYSIS

1) For the error analysis of V_{max}

$$\frac{\Delta V_{max}}{V_{max}} = \frac{\Delta R}{R} + \frac{\Delta T}{T} + \text{error due to angle measurement}$$

using,

$$V_{max} = \frac{4\pi R}{T}\sin(\theta_0/2) \Rightarrow \ln(V_{max}) = \ln 4\pi + \ln R - \ln T + \ln \sin(\theta_0/2)$$

$$\Rightarrow \frac{dV_{max}}{V_{max}} = 0 + \frac{dR}{R} - \frac{dT}{T} + \frac{\frac{1}{2}\cos\theta_0/2\, d\theta_0}{\sin\theta_0/2}$$

$$\Rightarrow \left|\frac{\Delta V_{max}}{V}\right| = \left|\frac{\Delta R}{R}\right| + \left|\frac{\Delta T}{T}\right| + \frac{1}{2}\left|\Delta\theta \cot\theta/2\right|$$

ΔR = least count of meter scale = 1 mm

R = 500 mm

ΔT = 0.1 ms (least count in milli seconds of the time measuring device)

$\Delta\theta$ = least count for angle measurement. = $5^\circ = \frac{5\pi}{180}$ rad

calculating the error for different T and θ_0,

V_{max} (m/s)	T (s)	θ_0 (degree)	$\cot\theta/2$	$\Delta V_{max}/V_{max}$
0.17	1.448	5	22.90	1
0.34	1.454	10	11.43	0.5

θ_0 (deg or rad)	V_{max} (m/s)	$\Delta R/R$	T in (s)	$\Delta T/T$	$\cot \theta/2$	$\frac{1}{2}\Delta\theta \cot\frac{\theta}{2}$	$\frac{\Delta V}{V}_{max}$
15°	0.51	0.002	1.454	0.000	7.59	0.331	0.333
20°	0.68	0.002	1.455	0.000	5.67	0.247	0.249
25°	0.86	0.002	1.431	0.000	4.51	0.196	0.198
30°	1.00	0.002	1.463	0.000	3.73	0.162	0.164

∴ Percentage error in calculation of velocity are 100%, 50%, 33.3%, 24.9%, 19.8% and 16.4% for different values of θ_0

This high percentage of error is attributed to the least count of the angle measurement which is in the order of our angle of observation. (5°, 10° etc)
If we neglect this error, our percentage error would be 0.2% (due to $\Delta R/R$ and $\Delta T/T$)

2 For the error analysis of measurement of Time period.

Time period from 6 observations are :-
1.44, 1.45, 1.45, 1.46, 1.43, 146 in seconds.

So average time period is :-

$$\frac{1.44 + 1.45 + 1.45 + 1.46 + 1.43 + 1.46}{6} = 1.45\ s$$

Time Period (s)	1.44	1.45	1.45	1.46	1.43	1.46
$(T^2 - T_{mean})^2$	0.0001	0	0	0.0001	0.0004	0.0001

$$\sqrt{\frac{\Sigma (T - T_{mean})^2}{n}} = \text{Standard deviation} = \sqrt{\frac{0.0007}{6}}$$

$= 0.011 \text{seconds} \approx 0.01\,s$

Error due to least count of apparatus is negligible as in error 1.

3 Error from graphical analysis of V_{max} VS E_{max}

$m = 2.67$ as from calculations

Centroid is $(0.55, 0.59)$

$$m_1 = \frac{0.59 - 0.17}{0.55 - 0.38} = \frac{42}{17} = 2.47 \text{ m/s per Volt (SI units)}$$

$$m_2 = \frac{0.68 - 0.59}{0.58 - 0.55} = 3 \text{ SI units}$$

$$\Delta m_1 = |m - m_1| = |2.67 - 3| = 0.33$$

$$\Delta m_2 = |m - m_2| = |2.67 - 2.47| = 0.20$$

$$\Delta m = \frac{\Delta m_1 + \Delta m_2}{2\sqrt{n}}$$ where n is the number of points plotted on the graph (found experimentally)

$$\Delta m = \frac{0.33 + 0.20}{2\sqrt{6}} = 0.11 \text{ SI units}$$

$\therefore$ Slope of graph $= (m \pm \Delta m) = (2.67 \pm 0.11)$ m/Vs.

4 Error in calculation of Φ_{max}

The $-\int \mathcal{E}\,dt$ done by the computer had least count $0.01\ Tm^2$. $= d\Phi$ or $\Delta\Phi$

$\therefore$ Maximum flux $= (10.30 \pm 0.01)\,T\,m^2$

RESULT

1 $\varepsilon_{max} = -v_{max} \frac{d\phi}{dx}$ holds true with the slope of v_{max} vs ε_{max} curve as (2.67 ± 0.11) m/Vs

2 Time period of oscillating frame (with the magnet) is (1.45 ± 0.01) s

3 The flux reaches a peak when the magnet passes through the centre of the solenoid. Its value at peak is (10.30 ± 0.01) T m^2

PRECAUTIONS

1 The magnet must not touch the solenoid while it passes through it. It may hamper its motion and result in irregular change in flux.

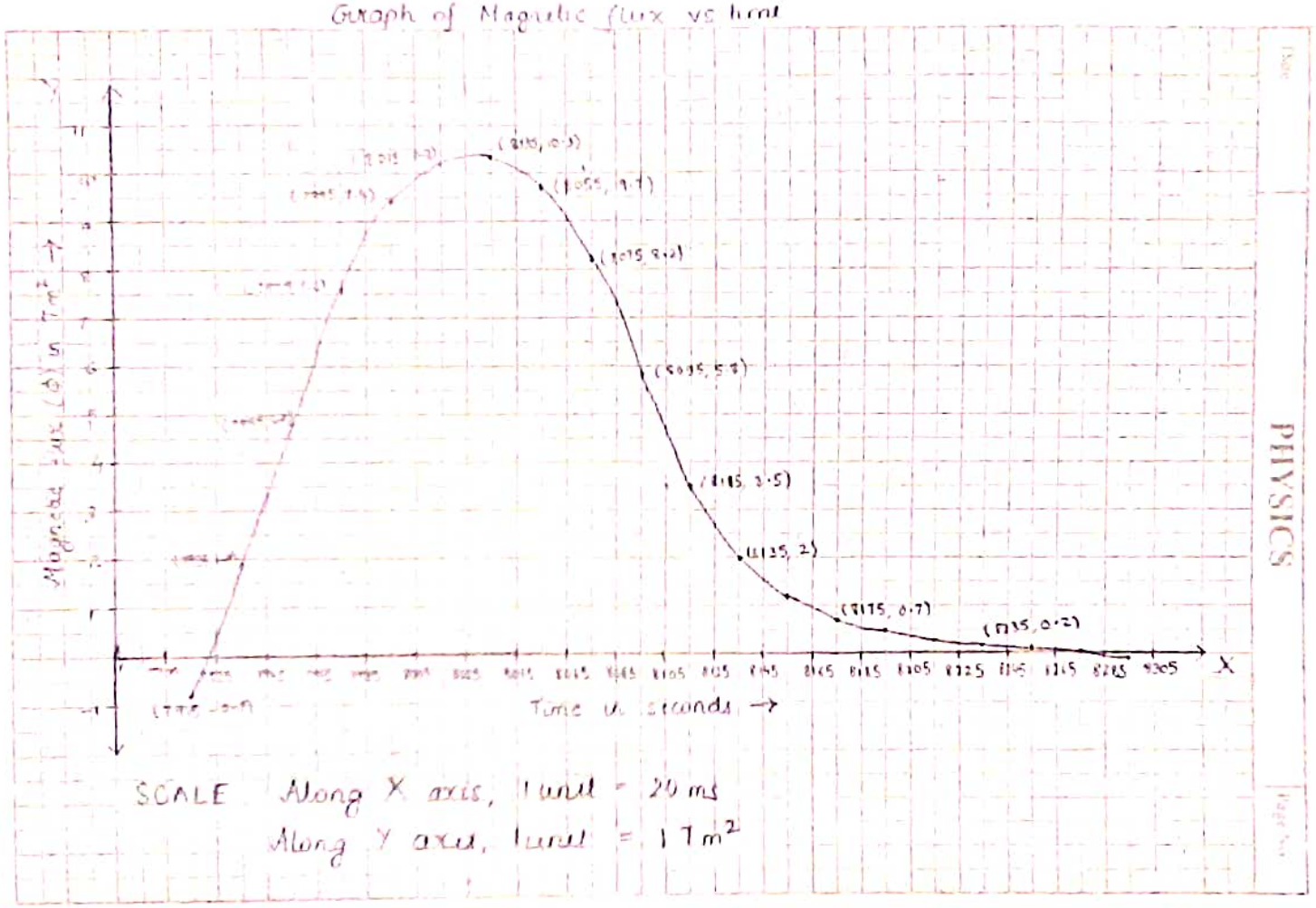
2 While calculating time period, 2 peaks of ε vs time graph must be considered instead of 1 peak.

3 Since the least count of the angle of oscillation is not precise, one should be careful while pushing the frame to see that the angle is a multiple of least count.

QUESTIONS

1 Is it necessary that the magnet passes through the central axis of the coil to obtain maximum emf?

Graph of Magnetic flux vs time



SCALE Along X axis, 1 unit = 20 ms

Along Y axis, 1 unit = 1 Tm²

Graph of Velocity (V_{max}) vs EMF_{max}

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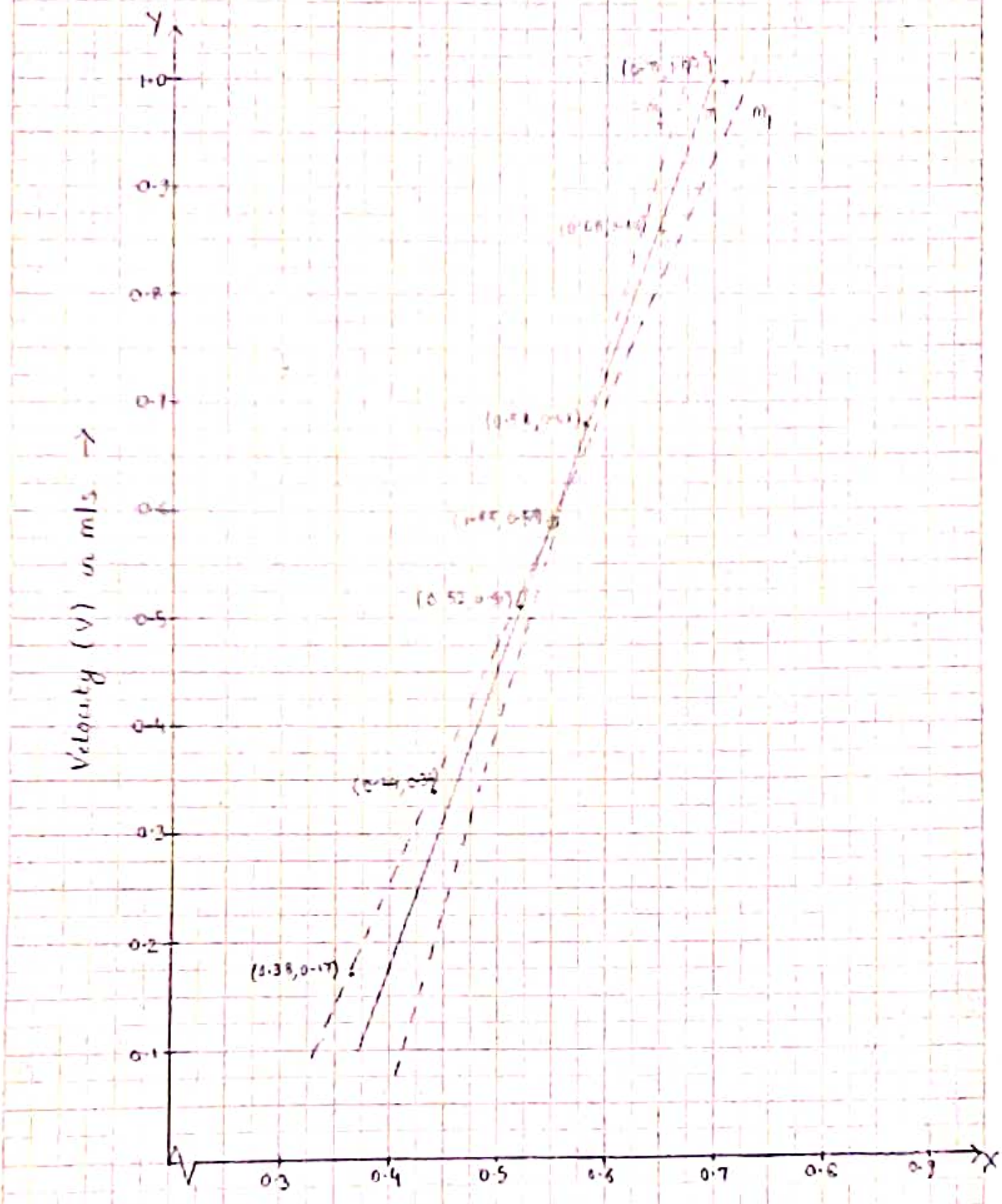

SCALE Along X axis, 1 unit = 0.05 V
Along Y axis, 1 unit = 0.05 m/s

Electro Magnetic Induction

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Partner's name: UDIT PATEL Date of experiment: 12/2/13 Instructor: _____

Observation table 1

Length R: 50 cm

θ_0	Calculated V_{max} m/s	Observed ε_{max} 'V'	T (ms)
5°	0.17	0.38	1448
10°	0.34	0.314	14854
15°	0.51	0.52	1454
20°	0.68	0.58	1455
25°	0.86	0.65	1431
30°	1.00	0.71	1463

Least Count

For radius 0.1 cm

For time 0.1 ms

For angle 5°