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ELECTROMAGNETISM LABORATORY

EXPERIMENT-3

Title: TO STUDY THE VARIATION OF MUTUAL INDUCTANCE WITH THE ANGLE BETWEEN TWO PLANE CIRCULAR COILS

Aim:

To study the variation of mutual inductance with the angle between two plane circular coils.

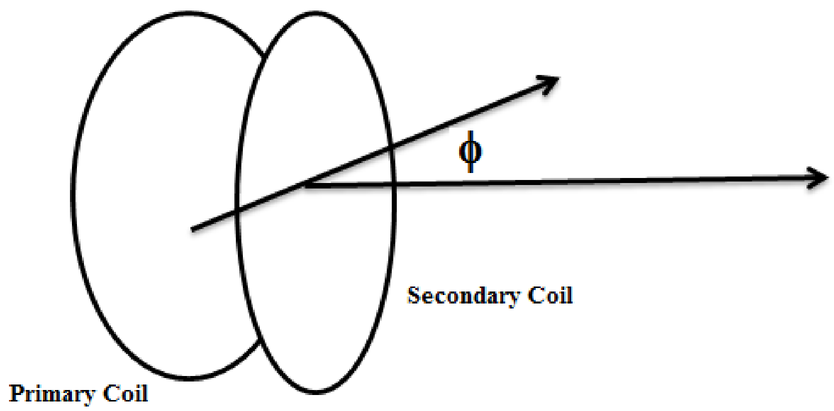
Apparatus and Accessories:

1. One plane circular coupled coil
2. AC Source
3. Ammeter
4. Oscilloscope
5. Connectors

Theory:

When a secondary coil of N_S turns is brought to a primary coil of N_P turns carrying a current I_P, the magnetic field of the primary coil will pass through the secondary coil. Any change in flux in the primary coil will be echoed in the secondary coil and induced an e.m.f. across the secondary coil.

i.e., $V_S = \frac{d}{dt}\left(N_S B_P A_S \mathrm{Cos}(\phi)\right)$ (Considering the magnitude of induced e.m.f)



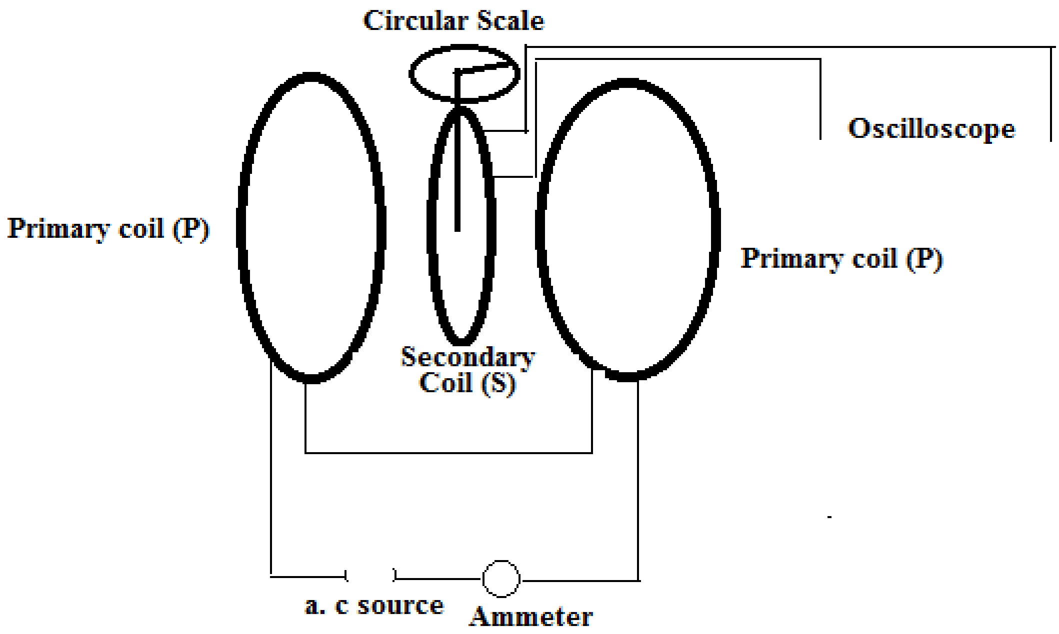
Again from the definition, $V_S = M_{SP}\frac{dI_P}{dt} = M_{SP}\frac{d}{dt}\left(I_\circ \mathrm{Sin}(\omega t)\right) = M_{SP} I_\circ \omega \mathrm{Cos}(\omega t)$

Where $I_P = I_\circ \mathrm{Sin}(\omega t)$ is current in the primary coil and M_{SP} is the mutual inductance.

$$\therefore V_S = \frac{d}{dt}\left(N_S B_P A_S \mathrm{Cos}(\phi)\right) = M_{SP}\frac{dI_P}{dt} = M_{SP}\frac{d}{dt}\left(I_\circ \mathrm{Sin}(\omega t)\right) = M_{SP} I_\circ \omega \mathrm{Cos}(\omega t)$$

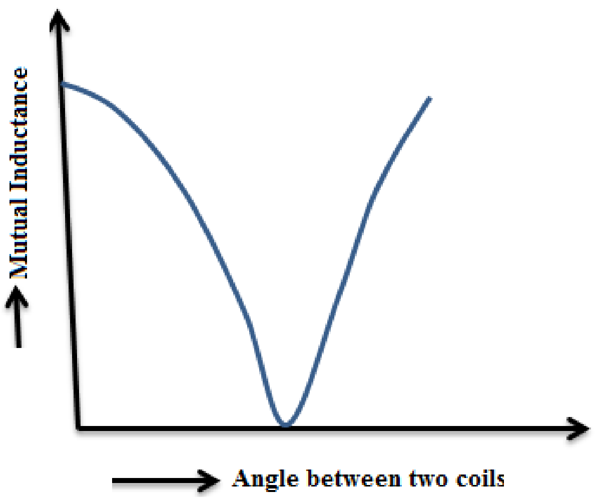
Or, $V_S = N_S B_\circ A_S Cos(\phi) \frac{d}{dt}(Sin(\omega t)) = M_{SP} \frac{dI_P}{dt} = M_{SP} \frac{d}{dt}(I_\circ Sin(\omega t)) = M_{SP} I_\circ \omega Cos(\omega t)$

Where, $B_P = B_\circ (Sin(\omega t))$ is magnetic flux density produced by the primary coil due to primary coil current $I_P = I_\circ Sin(\omega t)$, and A_S is the area of the secondary coil and Φ is the angle between the two coils.



V_S will depend on the total secondary flux and be linked to the changing current in the primary coil.

Here M_{SP} is called the coefficient of mutual inductance and has the SI unit of the henry.
If the coils have their roles interchanged so that there is a changing current in the secondary coil then an e.m.f. will appear across the primary coil.
On plotting a graph of Mutual Inductance(M_{SP}) vs Angle between two coils, we obtain the following graph as shown below-



Observations:

The least count of $\Phi = 1°$.

The least count of $I_{RMS} = 2mA$.

The least count of $V_{PP} = 0.01V$.

The least count of $f = 0.1Hz$.

Table-1-

$I_{rms} = 65$ mA, $f = 100$ Hz, $\omega = 628.3185$ rad s^{-1}

Sl. No.	Φ (deg.)	V_{PP} (Volts)	M_{SP} (Henry)
1	0	12.24	0.1059176731
2	10	12.18	0.1053984688
3	20	11.68	0.1010717665
4	30	11.04	0.0955335875
5	40	9.76	0.08445722953
6	50	8.16	0.07061178207
7	60	6.40	0.05538178986
9	70	4.48	0.0387672529
10	80	2.64	0.02284498832
11	90	0.08	0.0006922723732
12	100	1.28	0.01107635797
13	110	3.04	0.02630635018
14	120	4.56	0.03945952527
15	130	6.8	0.05884315172
16	140	8.56	0.07407314393
17	150	10.24	0.08861086377
18	160	11.24	0.09726426843
19	170	12.00	0.103840856
20	180	12.24	0.1059176731

Calculations:

Using the given below, M_{SP} can be calculated-

$$V_S = M_{SP}\frac{dI_P}{dt} = M_{SP} I_\circ \omega Cos(\omega t)$$

$$V_{\max} = \frac{V_{pp}}{2} = \frac{M_{SP} I_o \omega}{2}$$

$$I_o = \sqrt{2} I_{RMS}$$

$$M_{SP}(\Phi) = \frac{V_{PP}}{2\sqrt{2} I_{RMS} \boldsymbol{\omega}}$$

For set-1 reading from observation table-

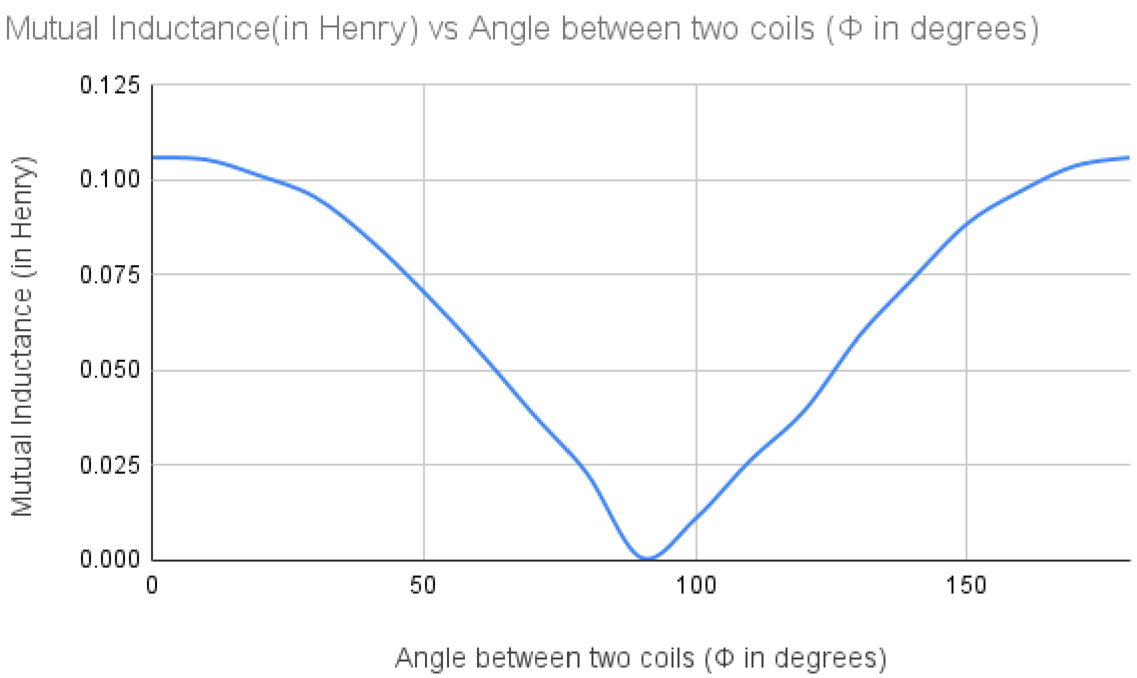
V_{PP}=12.24V, I_{RMS}=65mA and $\boldsymbol{\omega} = 2\pi f = 628.3185$ rad s^{-1}, therefore substituting these values in the above equation, we get -

$$M_{SP} = \frac{12.24}{2\sqrt{2} \cdot 0.065 \cdot 2 \cdot 100\pi} = 0.1059176731\, H$$

Similarlarily, the same can be done for the remaining set of readings to compute M_{SP} in Henry.

Graphs:

Graph-1 of Observation Table-1-



Scale of the above graph:

- X-axis- 1unit=50°
- Y-axis - 1unit=0.025 Henry

Error:

$$M_{SP} = \frac{V_{PP}}{2\sqrt{2} I_{rms} \omega}$$

$$\Rightarrow \frac{\Delta M_{SP}}{M_{SP}} = \frac{\Delta V_{PP}}{V_{PP}} + \frac{\Delta I_{rms}}{I_{rms}} + \frac{\Delta\omega}{\omega}$$

Given-

- The least count of $\Phi = 1°$.
- The least count of $I_{RMS} = 2mA$.
- The least count of $V_{PP} = 0.01V$.
- The least count of $f = 0.1Hz$.

Since, $\boldsymbol{\omega} = 2\pi f$, therefore, the least count of $\boldsymbol{\omega}$ is same as the least count of f.

For maximizing the error, the following data has been considered-

$\rightarrow At \varnothing = 80°;\ V_{PP} = 2.64\ V$

$I_{rms} = 65\ mA$

$f = 100\ Hz \therefore \omega = 2\pi f = 200\pi$ rad s^{-1}.

It should be noted that at $\varnothing = 90°$ according to theory mutual inductance will be zero, therefore for minimum V_{PP} , here it can be considered $\varnothing = 80°$ *or* $100°$.

Therefore, on substituting the above values, we get the following -

$$\frac{\Delta M_{SP}}{M_{SP}} = \frac{0.01}{2.64} + \frac{2}{65} + \frac{0.1}{200\pi} = 0.034716264$$

$$\frac{\Delta M_{SP}}{M_{SP}} \approx 0.03472$$

$$\frac{\Delta M_{SP}}{M_{SP}} \cdot 100 = 3.472\%$$

$$\Delta M_{SP} = M_{SP} \cdot 0.034716264 = 0.02284498832 \cdot 0.034716264 = 7.930926456 \cdot 10^{-4}\ H$$

$$\Delta M_{SP} \approx 7.931 \cdot 10^{-4} H$$

Therefore, the fractional error of M_{SP} is 0.03472 and its maximum percentage error is 3.472%.

Result:

1. The fractional error of mutual inductance (M_{SP}) is 0.03472 and its maximum percentage error is 3.472%.

Precautions:

1. It is important that the current passing through the primary of the mutual inductor, should have a purely sinusoidal wave-form, since the harmonics may introduce serious error.
2. It is better to have a uniform magnetic field to strengthen the signal.
3. AC source must be used.

Discussion:

1. From the graph of the mutual inductance vs angle between two coils, it is clear that the maximum mutual inductance occurs at 0°, which is in accordance with the theory. Since the maximum inductance occurs at 0°, we can say that the planes of the primary and secondary coils are parallel at 0°.
2. Sometimes, the maximum mutual inductance does not occur at 0°, i.e, the planes of the primary and secondary coils are not parallel to each other at 0°. This happens due to the error in the box which connects the secondary coil and the cap at top of the box.
3. From this experiment, I have learnt by altering the angle between the coils, will help in finding the maximum mutual inductance, which in turn, can be used to find the maximum secondary voltage. The positioning of two coils in the circuit decides the amount of mutual inductance that links with one to the other coil.
4. From the graph, it also clear that the lowest magnitude of the mutual inductane is not zero, although its magnitude is quite low, i.e, approximately, 0.0006922723732 H. This is not in accordance with the theory, in which the lowest magnitude of mutual inductance is zero.
5. I have learnt the significance and various applications of mutual inductors. Their applications are Transformer, Electric motors, generators, Digital signal processing and many more.