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B. Sc. Part-II Paper-IV
Physics Hons
Current electricity

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Mutual Inductance

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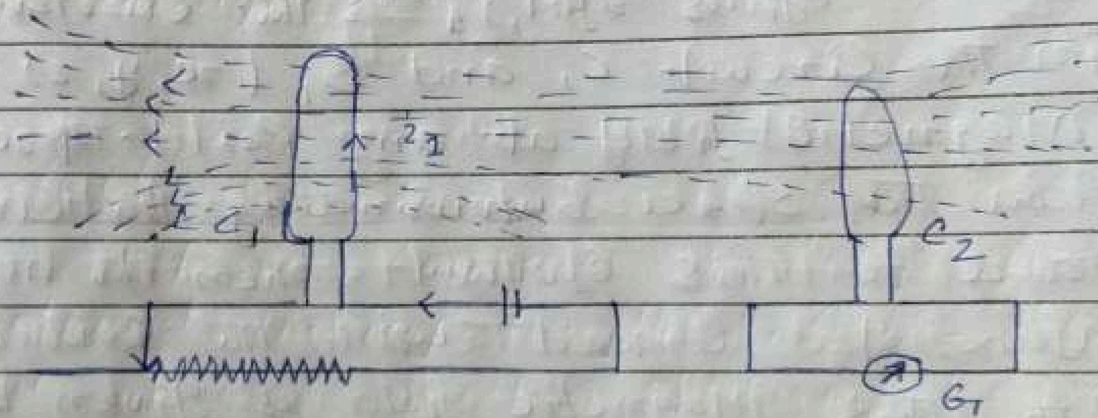
Consider a closed circuit C_2 placed in the magnetic field of closed circuit C_1 fig. The flux linked with circuit C_2 depends upon its position and the current flowing in the coil C_1. If the relative position of C_2 is fixed, the flux linked with C_2 is constant for a constant current in C_1



As the magnetic field at any point produced due to the current flowing in C_1 is directly proportional to the current flowing in circuit C_1; hence the flux linked with the circuit C_2 will depend upon the current flowing in circuit C_1. In general whenever the current flowing through a circuit (C_1) changes the magnetic flux linked with the neighbouring circuit (C_2) also changes.

Hence an induced e.m.f. is set up in the neighbouring circuit. This phenomenon is called Mutual Induction. The circuit in which the current changes is called the primary circuit, while the neighbouring circuit in which e.m.f. is induced is called the secondary circuit.

Thus if i_1 is the current flowing in the circuit C_1 and $B_1(x, y, z)$ is the magnetic field at any point (x, y, z) in the space surrounding the circuit C_1 due to this current, then the magnetic flux ϕ_2 linked with the coil C_2 due to this magnetic field is given by

$$\phi_2 = \iint_{S_2} B_1 \cdot SA_2$$

where S_2 represents the effective surface area enclosed by the coil C_2.

If the shapes orientations ~~by the~~ and the positions of the two circuits C_1 and C_2 are fixed, then the magnetic flux ϕ linked with circuit C_2 is proportional to the current i_1 flowing in circuit C_1

i.e. $\phi_2 < i_2$

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or $\Phi_2 = M_{21} i_1$ — (1)

where M_{21} is constant of proportionality and is termed as Mutual inductance (or coefficient of mutual induction) of circuit C_2 with respect to circuit C_1.

If the current flowing in the coil C_1 changes with time, then the flux linked with the coil C_2 also changes and so an e.m.f is induced in the circuit C_2 which is given by

$$e_2 = -\frac{d\Phi_2}{dt}$$

$$= -\frac{d}{dt}(M_{21} i_1) \quad \text{using (1)}$$

i.e. $$e_2 = -M_{21}\frac{di_1}{dt} \quad \text{— (2)}$$

Now, suppose that the current i_2 is flowing in the coil C_2. If Φ_1 is the flux linked with the coil C_1 due to this current, then

$$\Phi_1 \propto i_2$$

or $$\Phi_1 = M_{12} i_2 \quad \text{— (1')}$$

where M_{12} is the mutual inductance of circuit C_1 with respect to

Circuit C_2.

If the current flowing in the coil C_2 changes with time, then the flux linked with the coil C_1 also changes and so an e.m.f. e_1 is induced in the circuit C_1 which is given by

$$e_1 = -\frac{d\phi_1}{dt} = -\frac{d}{dt}(M_{12}\, i_2)$$

or $$e_1 = -M_{12}\frac{di_2}{dt} \quad \text{--- } (2')$$

It may shown that ~~the~~ $M_{21} = M_{12}$ i.e. if the shapes orientations and the positions of the two coils (or circuits) are fixed, then the mutual inductance of the two given coils does not depend upon which circuit (C_1 or C_2) carries the current. Therefore, we may represent $M_{12} = M_{21} = M$ (say) = mutual inductance between the circuits. The practical (or M.K.S.A) unit of mutual inductance is henry. Now equation (1) and (2) or (1') and (2') enable us to define the mutual inductance between two circuits in the following two ways.

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1.) From equ^n (1) if $i_2 = 1$ amp, Then $M = M_{21} = \Phi_2$ henry i.e. The Mutual inductance (in henry) of two circuits is defined as The Magnetic flux (in webers) linked with one Circuit when unit current (1 amp) flows through The other (neighbouring) Circuit.

(2) From equ^n (2) if $-\frac{di_1}{dt} = 1$ A/S,

Then $M = M_{21} = e_2$

i.e. The Mutual inductance (in henry) of two Circuits May be defined as The e.m.f. (in Volts) induced in one Circuit when The rate of decay of Current (in amp/sec) (Neighbouring) Circuit is unity.