B. Sc. Part II

Paper IV

Current electricity

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Mutually Coupled Circuits :-

An electric circuit is said to be a coupled circuit, when there exists a mutual inductance between the coils present in that circuit. Coil is nothing but the series combination of resistor and inductor. In the absence of resistor, coil becomes inductor. Sometimes, the terms coil and inductor are interchangeably used.

First let us discuss about the dot convention and then will discuss about classification of coupling.

Dot Convention :-

Dot convention is a technique, which gives the details about voltage Polarity at the dotted terminal. This information is useful, while writing KVL equations.

⇒ If the current enters at the dotted terminal of one coil (or inductor), then it induces a voltage at another coil, which is having Positive Polarity at the dotted terminal.

⇒ If the current leaves from the dotted terminal of one coil, then it induces a voltage at another coil, which is having negative Polarity at the dotted terminal.

Classification of Coupling :-

We can classify coupling into the following two categories –

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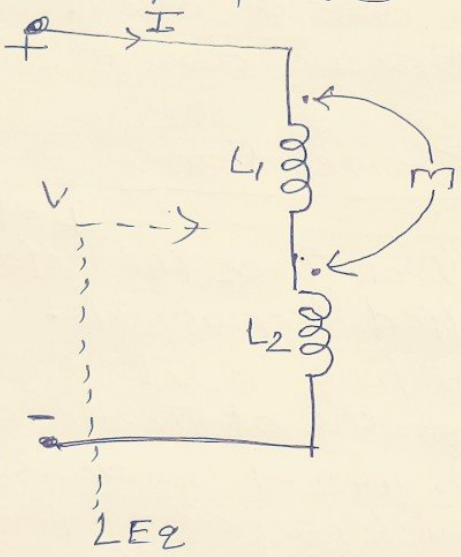
1.) Electrical Coupling :-

Electrical coupling occurs, when there exists a physical connection between two coils. This coupling can be of either aiding type or opposing type. It is based on whether the current enters at the dotted terminal or leaves from the dotted terminal.

Coupling of Aiding type :-

Consider the following electric circuit, which is having two inductors that are connected in series.



Since the two inductors are connected in series, the same current I flows through both inductors having self-inductance L_1 & L_2.

In this case, the current I enters at the dotted terminal of each inductor. Hence, the induced voltage in each inductor will be having positive polarity at the dotted terminal due to the current flowing in another coil.

Apply KVL around the loop of the above electric circuit or network.

$$V - L_1\frac{dI}{dt} - M\frac{dI}{dt} - L_2\frac{dI}{dt} - M\frac{dI}{dt} = 0$$

$$V = L_1\frac{dI}{dt} + L_2\frac{dI}{dt} + 2M\frac{dI}{dt}$$

$$V = (L_1 + L_2 + 2M)\frac{dI}{dt}$$

The above equⁿ is in the form of $V = L_{Eq}\frac{dI}{dt}$

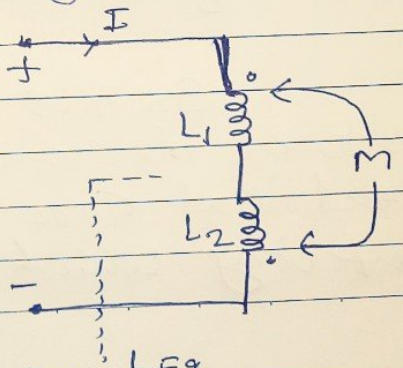
Therefore, the equivalent inductance of series combination of inductors shown in the above figure is

$$L_{Eq} = L_1 + L_2 + 2M$$

In this case, the equivalent inductance has been increased by 2M. Hence, the above electrical circuit is an example of electrical coupling which is of aiding type.

Coupling of opposing type :-

Consider the following electric circuit which is having two inductors that are connected in series.



In the circuit the current I enters at the dotted terminal of the inductor having an inductance of L_1.

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Hence, it induces a voltage in the other inductor having an inductance of L_2. So, positive polarity of the induced voltage is present at the dotted terminal of this inductor.

In the above circuit, the current I leaves from the dotted terminal of the inductor having an inductance of L_2. Hence, it induces a voltage in the other inductor having an inductance of L_1. So -ve polarity of the induced voltage is present at the dotted terminal of this inductor.

Apply KVL around the loop of the above electric circuit or network

$$V - L_1\frac{dI}{dt} + M\frac{dI}{dt} - L_2\frac{dI}{dt} + M\frac{dI}{dt} = 0$$

$$\Rightarrow V = L_1\frac{dI}{dt} + L_2\frac{dI}{dt} - 2M\frac{dI}{dt}$$

$$\Rightarrow V = (L_1 + L_2 - 2M)\frac{dI}{dt}$$

The above eqn is in the form of

$$V = L_{Eq}\frac{dI}{dt}$$

Therefore, the equivalent inductance of series combination of inductors shown in the above figure is

$$L_{Eq} = L_1 + L_2 - 2M$$

In this case, the equivalent inductance has been decreased by 2M. Hence, the above electrical circuit is an example of electrical coupling which is of opposing type.