Magnetic flux :-

Magnetic flux through a plane of area A placed in a uniform magnetic field $\vec{B}$ can be written as —

$$\phi_B = \vec{B} \cdot \vec{A}$$

$$= B A \cos\theta$$

Where, θ is the angle between B & A.

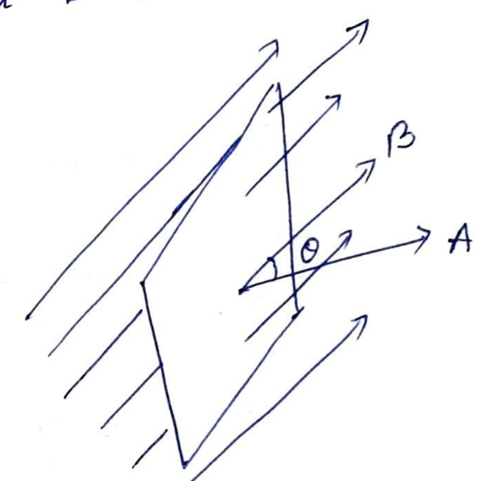


Fig:- A plane of area $\vec{A}$ placed in mag. f. $\vec{B}$.

If the magnetic field has different magnitudes & directions at various parts of a surface, ~~as shown in fig~~ then the magnetic flux through the surface is given by —

$$\phi_B = B_1 . dA_1 + B_2 . dA_2 + \dots + B_n . dA_n$$

$$\boxed{\phi_B = \sum_{i=1}^{n} B_i . dA_i}$$

Faraday's Law of Induction :-

Faraday's law of electromagnetic induction can be stated as - The ~~magnetic~~ magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

Mathematically, the induced emf is given by -

$$\mathcal{E} = -\frac{d\phi_B}{dt}.$$

The negative sign indicates the direction of $\mathcal{E}$ and hence the direction of current in a closed loop.

In case of closely wound coil of N turns, the expression for total induced emf is given by -

$$\boxed{\mathcal{E} = -N\frac{d\phi_B}{dt}}$$

Lenz's law :-

Lenz's law can be stated as -

the polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

Illustration of Lenz's law :-

When the north pole of a bar magnet is moved towards a closed coil, the induced current in the coil flows in the anticlockwise direction as shown in fig1.

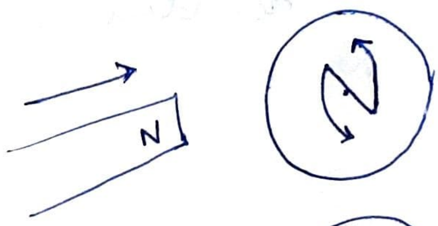


fig1

When the north pole of a magnet is taken away from a closed loop, the induced current in the coil flows in clockwise direction.

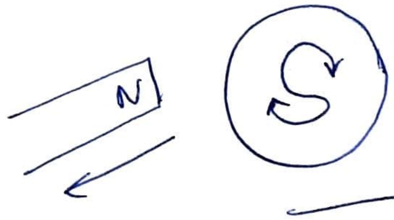


fig2

Inductance:-

The flux through a coil is proportional to the current. i.e,

For

$$\phi_B \propto I$$

$$\Rightarrow \phi_B = k I$$

The constant of proportionality in this relation is called the inductance.

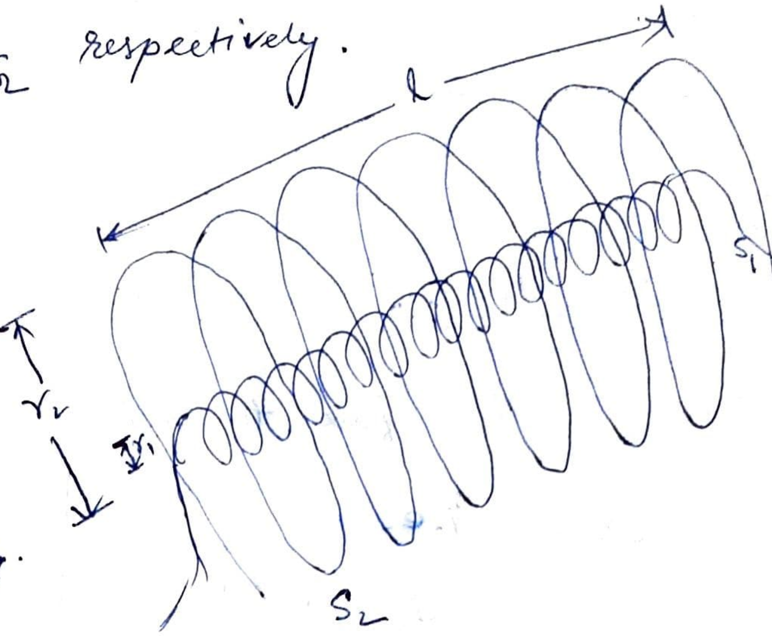
Inductance is a scalar quantity. It has the dimension of $[ML^2T^{-2}A^{-2}]$.

The S.I. unit of inductance is Henry (H).

Mutual Inductance:-

Let us consider two long co-axial solenoids each of length l. The radius of the inner solenoid S_1 be r_1 and number of turns per unit length be n_1. Similarly, the radius of the outer solenoid S_2 be r_2 and number of turns per unit length be n_2.

Let N_1 and N_2 be the total no. of turns of the coils ~~respec~~ S_1 & S_2 respectively.



When a current I_2 is set up through S_2, it in turn sets up a magnetic flux through S_1. Let us denote it by ϕ_1. The corresponding flux linkage with solenoid S_1 is,

$$N_1 \phi_1 = M_{12} I_2 \quad \text{——— (1)}$$

M_{12} is called the mutual inductance of solenoid S_1 with respect to solenoid S_2. It is also referred to as the co-efficient of mutual induction.

Calculation of M_{12} :-

Let us consider the co-axial solenoid. The magnetic field due to current I_2 in S_2 is $\mu_0 n_2 I_2$. The resulting linkage with S_1 is —

$$N_1 \phi_1 = (n_1 l)(\pi r_1^2)(\mu_0 n_2 I_2)$$

$$= \mu_0 n_1 n_2 \pi r_1^2 l_1 l_2 \quad \text{——— (2)}$$

where $n_1 l$ is the total number of turns in solenoid S_1.

From equation (1),

165 0
34 6 0
19966

$$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l .$$

See the reverse case too.

It is also important to know that the mutual inductance of a pair of coils, solenoids etc. that depends on their separation as well as their relative orientation.

Self inductance :-

It is also possible that emf is induced in a single isolated coil due to change of flux through the coil by means of varying the current through the same coil. This phenomenon is called as self induction.

In this case flux linkage through a coil of N turns is proportional to the current through the coil and is expressed as —

$$N \phi_B \propto I$$

$$\Rightarrow N \phi_B = L I.$$

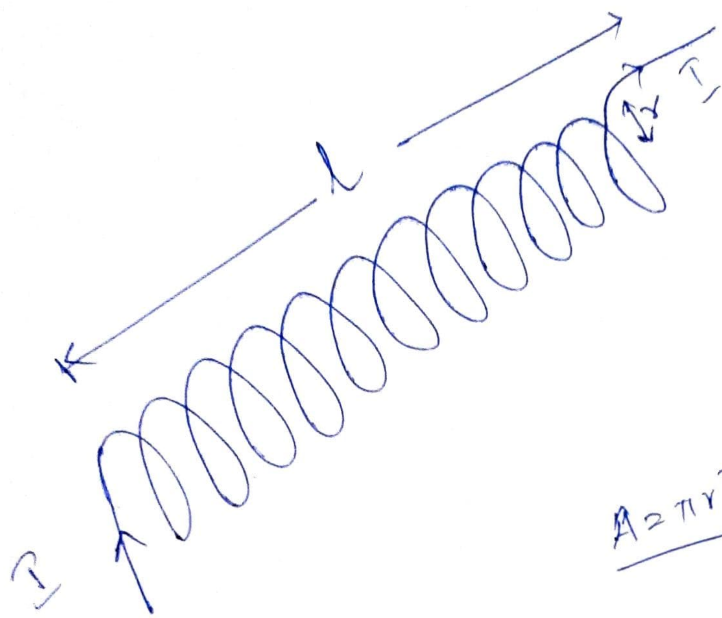
Where the proportionality constant L is called as self inductance of the coil. It is also called as the co-efficient of self inductanction of the coil.

When the current is varied, the flux linked with the coil also changes and a emf is induced in the coil. The induced emf is given by —

$$\mathcal{E} = - \frac{d (N \phi_B)}{dt}$$

$$= - L \frac{dI}{dt}$$

This induced emf always oppose any change



$$n = \frac{N}{l}$$

$$A = \pi r^2$$

of the current in the coil.

Calculation of self inductance :-

Let us consider a long solenoid of cross sectional area A, length 'l', having 'n' turns per unit length. The magnetic field in the solenoid is —

$$B = \mu_0 n I.$$

The total flux linked with the solenoid is given by —

$$N \Phi_B = (nl).(\mu_0 n I).A.$$

$$= \mu_0 n^2 I (Al)$$

where, 'nl' is the total no. of turns in the coil.

Thus, the self inductance is given by —

$$L = \frac{N \Phi_B}{I}$$

$$\boxed{L = \mu_0 n^2 A l}$$

As there is 'A' and 'l' terms in the expression of self inductance, we can say that self inductance depends on the geometry of the coil. As it opposes any changes in the current in a circuit, it is also called as back emf.