INDUCTOR AND EMF INDUCED ACROSS IT DUE TO VARRYING CURRENT

Induced EMF in loop in variable magnetic field

Now, let's think about a round loop that isn't moving, placed in a changing magnetic field. Imagine the magnetic field is pointing into the page and getting stronger. The resulting induced emf in the loop will be

$\varepsilon = -\frac{d\phi}{dt}$ .Flux through the coil will be $\phi = -\pi r^2 B; \frac{d\phi}{dt} = -\pi r^2 \frac{dB}{dt}; \varepsilon = -\frac{d\phi}{dt} \therefore \varepsilon = \pi r^2 \frac{dB}{dt}$

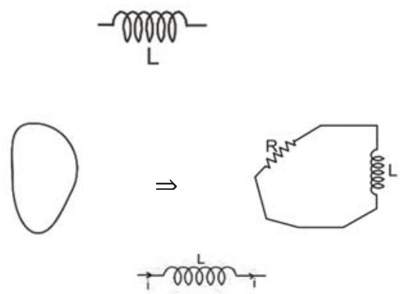
$\therefore E2\pi r = \pi r^2 \frac{dB}{dt}$

or $E = \frac{r}{2}\frac{dB}{dt}$

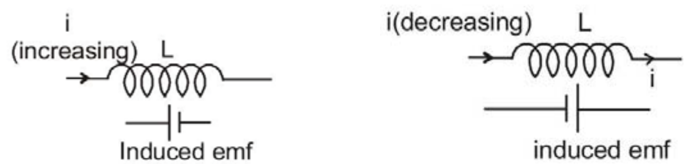
So, when the magnetic field changes, it creates an electric field that isn't conservative. The lines representing this electric field form closed curves.

Inductor

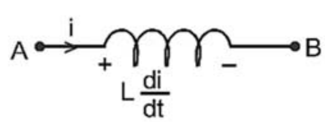
It is represent by electrical equivalence of loop



When the current flowing through the inductor is going up, the induced electromotive force (emf) will act against this increase and go in the opposite direction of the current. On the other hand, if the current through the inductor is decreasing, the induced emf will resist this decrease and align with the direction of the current.

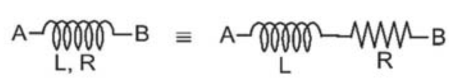


Over all result



$$V_A - L\frac{di}{dt} = V_B$$

Note: If there is a resistance in the inductor (resistance of the coil of inductor) then :



Ex. A B is a part of circuit. Find the potential difference $V_A - V_B$ if

(i) current i = 2A and is constant
(ii) current i = 2A and is increasing at the rate of 1 amp/sec.
(iii) current i = 2A and is decreasing at the rate 1 amp/sec.

sol.:

$$L\frac{di}{dt} = 1\frac{di}{dt}$$

writing KVL from A to B

$$V_A - 1\frac{di}{dt} - 5 - 2i = V_B$$

i. Put $i = 2, \frac{dl}{dt} = 0$
$V_- - 5 - 4 = V_B$ $\therefore V_4 - V_B = 9$ volt
ii. Put $i = 2, \frac{di}{dt} = 1; V_A - 1 - 5 - 4 = V_B$ or $V_A - V_B = 10\ V_0$
iii. Put $i = 2, \frac{di}{dt} = -1; V_A + 1 - 5 - 2 \times 2 = V_B$ or $V_A = 8$ volt.

Self-Inductance and factor affecting it

Self-induction is when a coil generates an electromotive force (emf) because its own current is changing. The total flux, represented by $N\phi$, passing through the coil due to its own current, is directly proportional to the current. This relationship is expressed as $N\phi = L\,i$, where L is called the coefficient of self-induction or inductance.

Inductance, denoted by L, is purely a geometrical property. This means we can determine the inductance value even if a coil is not connected in a circuit. The inductance depends on the shape and size of the loop and the number of turns it has.

If current in the coil changes by ΔI in a time interval Δt, the average emf induced in the coil is given as

$$\varepsilon = -\frac{\Delta(N\phi)}{\Delta t} = -\frac{\Delta(LI)}{\Delta t} = -\frac{L\Delta I}{\Delta t}.$$

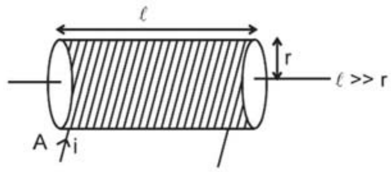
The instantaneous emf is given as

$$\varepsilon = -\frac{d(N\phi)}{dt} = -\frac{d(LI)}{dt} = -\frac{LdI}{dt}$$

S.I Unit of inductance is wb/amp or Henry(H)
L - self-inductance is +ve quantity .
L depends on :

(1) Geometry of loop
(2) Medium in which it is kept. L does not depend upon current. L is a scalar quantity.

Self-inductance of solenoid



Let the volume of the solenoid be V , the number of turns per unit length be n.

Let a current I be flowing in the solenoid. Magnetic field in the solenoid is given as $B = \mu_o nI$. The magnetic flux through one turn of solenoid $\phi = \mu_o\, n\, I\, A$.

The total magnetic flux through the solenoid = $N\,\phi = N\mu_o nI\, A = \mu_o n^2\, l\, A\, I$

∴ $L = \mu_0 n^2\; l\; A = \mu_0 n^2\, V$

$\phi = \mu_0 n i \pi r^2 (n\ell)$

$L = \dfrac{\phi}{i}$

$= \mu_0 n^2 \pi r^2 \ell$

Inductance per unit volume = $\mu_o n^2$.

Self-inductance is the physical property of the loop due to which it opposes the change in current that means it tries to keep the current constant. Current cannot change suddenly in the inductor.