ST. LAWRENCE HIGH SCHOOL

A JESUIT CHRISTIAN MINORITY INSTITUTION

STUDY MATERIAL : 7 (Part - 1)

Subject : PHYSICS

Topic : EM induction.

CLASS : XII

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A Important Physical Quantities and their Formulae

Name of Physical Quantity	Formula
1. Magnetic flux	$\Phi_B = \vec{B}.\vec{A}. = BA\cos\theta$
2. Induced e. m. f.	$\varepsilon = \frac{-d\Phi_B}{dt}$
3. Motional e. m. f.	$\varepsilon = BvL$
4. Force needed to pull a conductor out of magnetic field	$F = \frac{B^2 l^2 v}{R}$
5. Self inductance	$L = \frac{\Phi_B}{I}$.
6. Induced e. m. f. in a coil of inductance L	$\varepsilon = -L\ \frac{-d\Phi_B}{dt}$
7. Self Inductance of an air cored coil or solenoid	$L = \frac{\mu_0 N^2 A}{l}$, N = *number of turns*
8. Self Inductance of an iron cored solenoid	$L = \mu_r \left(\mu_0 \frac{N^2 A}{l}\right)$
9. Self Inductances of the combination of two coils of inductance L_1 and L_2 connected in series	$L = L_1 + L_2$
10. Self inductance of two coils connected in parallel	$L = \frac{L_1 L_2}{L_1 + L_2}$
11. a) Energy stored in an inductor	$E = \frac{1}{2} Li^2$
b) Magnetic energy density	$\vec{E} = \frac{B^2}{2\mu_0}$
12. Mutual inductance	$M = \frac{\Phi_B}{I}$
13. Induced e. m. f. in a coil due to changing magnetic flux in neighbouring coil	$\varepsilon = -M\frac{d\Phi_B}{dt}$
14. Mutual inductance of two long solenoids	$M = \mu_0 N_1 N_2 A/l$
15. Coefficient of coupling	$K = \frac{M}{\sqrt{L_1 L_2}}$
16. Induced e. m. f. between the centre and rim of the dise rotating perpendicular to the uniform magnetic field.	$\varepsilon = \frac{1}{2}\ B\omega r^2$

B 1. Michael Faraday while doing experiments on magnets and coils showed that if a magnet is moved in or out of a coil then emf is induced across the coil. If the circuit is complete current is induced such a current is called **Induced current** and the corresponding emf is called induced emf. Faraday formulated two laws.

First Law The emf/current is induced only for the period when magnetic flux is varying.

Second Law emf induced $\varepsilon = \frac{d\Phi_B}{dt}$ where flux $\Phi_B = \int \vec{B}.\vec{ds}$. *Unit of flux is weber or* Tm^2.

The current in the loop = $\frac{\varepsilon}{R}$ where R is resistance of the loop.

B 2. **Lenz's Law** The current is induced in a direction so as to oppose the change that has induced it.

Thus $\varepsilon = -\frac{d\Phi_B}{dt}$.

Lenz's law is based on conservation of energy.

The emf may be induced in ewo different basic processes : (*a*) motional emf and (*b*) induced electric field. In motional emf coil or conductor is varied with time but magnetic field remains fixed. In induced electric field coil remains fixed and magnetic field varies with time. There could be combination of the two also.

emf $\varepsilon = \oint \vec{E}.\vec{dl} = -\frac{d\Phi_B}{dt}$ Note that to have an induced electric field the presence of conducting loop is not necessary. As long as $\vec{B}$ keeps varying, the induced electric field is present. If the loop is present free electrons start drifting and induced current results.

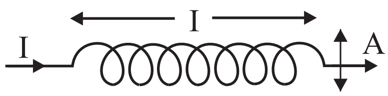
Note that $\oint E.dl \neq 0$, therefore electric field so generated is **non conservative** and is different from electric field studied in electrostatics. Such an electric field is called **non electrostatic field.**

The electric field lines so generated make closed loop like magnetic field lines. Also note that, however, like electrostatic field it gives force $\vec{F} = q\vec{E}$. The current so generated has a similarity to displacement current. $\because \oint E \cdot dl = E\,(2\pi r)$. Thus $E = \frac{1}{2\pi r}\left|\frac{d\Phi}{dt}\right|$

B 3. **Self induction** $\Phi_B \propto i$ or $\Phi_B = Li$ or $\varepsilon = \frac{d\Phi_B}{dt} = -L\frac{di}{dt}$.

If a coil has *n* turns, the flux through each turn is $\int \vec{B}.\vec{ds}$. . If this flux varies then $\varepsilon = -N\frac{d}{dt}\int \vec{B}.\vec{ds}$

$L = \mu_0 n^2 Al = \frac{\mu_0 N^2 A}{l}$ where *n* is number of turns per unit length and N total number of turns, *l* length of the coil and A its area of cross section as shown in

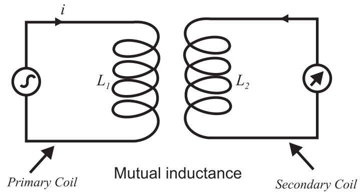


Self inductance illustration

$L = \mu_r\,\mu_0 n^2 Al$ if a core having relative permeability μ_r is introduced. A coil or a solenoid of thick wire having negligible resistance may be considered as an **Ideal inductor.**

Unit of self induction is Henry *(H).*

B 4. **Mutual induction** $\varepsilon = -\frac{d\Phi_B}{dt} = -M\frac{di}{dt}$. If two coils are placed closed to each other and time varying current is passed through one (primary coil) then current is induced in the other (secondary coil) such a phenomenon is called mutual induction. *M* is mutual inductance of two coils having self inductance L_1 and L_2 (as illustrated in fig.)



Mutual inductance

(to be continued ....)

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