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ENERGY STORED IN MAGNETIC FIELD

(అయస్కాంత క్షేత్రం లో నిల్వ ఉన్న శక్తి)

Consider a very long solenoid of length 'l' and area of cross section 'A'. When a current 'i' flows through this, a uniform magnetic field is established inside and negligible outside. Therefore, the volume associated with this field is 'Al'. it is known that the amount of work done in establishing a current i_0 is given by $\frac{1}{2}Li_0{}^2$ where, L is inductance of the solenoid. This work done is stored as energy in magnetic field.

$\therefore$ *The energy stored U is given by* $U = \frac{1}{2}Li_0{}^2$

The inductance of the solenoid is given by $L = \mu_0 n^2 A\, l$

Where, 'n' is the number of turns in the solenoid per metre.

$$\therefore U = \frac{1}{2}(\mu_0 n^2 A)i_0{}^2 = \frac{1}{2}\frac{(\mu_0 n i_0)^2}{\mu_0} Al$$

As the magnetic field inside the solenoid 'B' is $\mu_0 n i_0$

$$U == \frac{1}{2}\frac{(B)^2}{\mu_0} Al$$

This energy is distributed throughout the volume Al of the solenoid. The energy density(energy per unit volume) in a magnetic field 'u' is given by

$$u = \frac{U}{Al} = \frac{\frac{1}{2}\frac{(B)^2}{\mu_0}Al}{Al} = \frac{1}{2}\frac{B^2}{\mu_0}\frac{joule}{metre^3}$$

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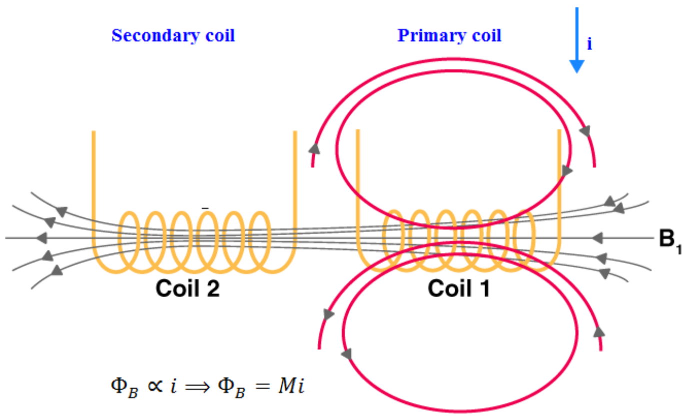
$$u = \frac{B^2}{2\mu_0} \frac{joule}{metre^3}$$

The above expression gives an expression for energy density 'u' in a magnetic field of induction 'B'

COEFFICIENT OF MUTUAL INDUCTION (అన్యోన్య ప్రేరణా స్థిరాంకం)

Consider, two coils viz., primary and secondary coils, placed near to each other as shown in the following figure. When a current 'i' is passed through the primary coil, there will be a change in the magnetic flux linked with it due to which an induced e.m.f. is developed in the secondary coil. This phenomenon of induction of e.m.f. is the secondary coil is said to be 'mutual induction'. Similarly the secondary coil also induces e.m.f in the primary coil. Hence the total induction through the secondary during time the induced current lasts in it, is the difference between the inductions due to primary and secondary. Any two circuits in which mutual inductance is observed, is called as mutually coupled circuits.



Let a current 'i' amp current passes through the primary circuit 'P' which produces a magnetic flux Φ_B in the secondary 'S'. further, when two coils are fixed in their positions, the magnetic flux linked with secondary is proportional to the current passing through the primary.

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Therefore, $\Phi_B \propto i \Longrightarrow \Phi_B = Mi$ ---(1)

Here, M is a constant called as 'coefficient of mutual induction or mutual inductance of the two coils.

The induced e.m.f. in the secondary coil 'S' is given by $e = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}(Mi) = -M\frac{di}{dt}$ ---(2)

From equations (1) & (2), mutual inductance can be defined in the following ways..

1. It is the flux linked with a circuit due to a unit current flowing through the other.
2. It is the e.m.f. induced in the circuit, when the rate of decay of current in the other circuit is unity.

Further, the unit of mutual inductance is henry.

Questions

1. Obtain an expression for the energy stored in magnetic field.
2. What is mutual inductance? Explain.
3. Define the coefficient of mutual inductance
4. Define mutual inductance and give its unit.
5. Define self and mutual induction.

References:

1. Unified Physics, Volume III, Jai Prakash Nath Publications, Meerut

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