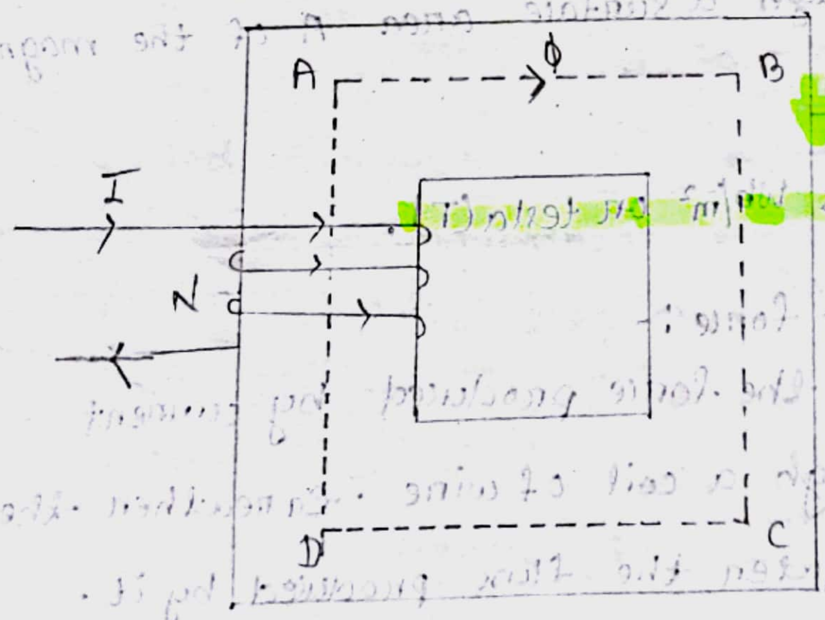
Chapter-01 MAGNETIC CIRCUIT

Magnetic Circuit :-

The closed path followed by magnetic flux is called magnetic circuit. A magnetic circuit usually consists of materials having high performance eg. iron, soft steel etc. It is because these material offer very small oppositions to the 'flow' of magnetic flux. Consider a coil of N turns wound on the iron core. When current I is passed through a coil, magnetic flux ϕ is set up in the core. The flux follows the closed path ABCDA and ABCDA is the magnetic circuit. The ammount of magnetic flux set up in the coil depends upon current (I) and no. of turns (N). If we increase the current or number of turns, the amount of magnetic flux also increased and vice-versa. The product NI is called magnetomotive force (m.m.f) and determines the amount of magnetic flux set up in the magnetic circuit.

m.m.f = NI ampere turns.



Magnetic field strength :- (H)

It is the magnetising force that produces flux in a given magnetic circuit. It is defined as magnetomotive force per unit length of the magnetic circuit. If in a given magnetic circuit, mmf = NI and l, the average length of magnetic path then.

$$H = \frac{mmf}{length} = \frac{NI}{l} \text{ ampere/metre}$$

Magnetic flux (ϕ) :-

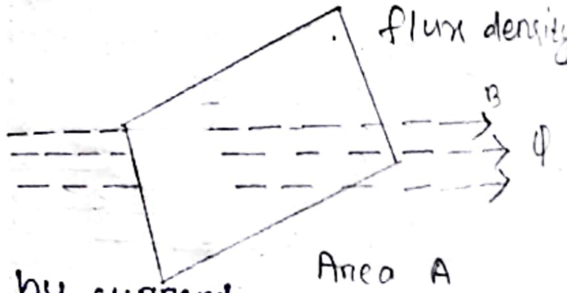
It equals the entire number of lines of force produced by a magnetic. The more the lines of force, the greater the flux and stronger the magnetic field. The unit of magnetic flux is weber (Wb). One weber equals to 10^8 lines.

flux density (B) :-

The flux density B is given by the flux ϕ passing normally through a surface area A of the magnetic field.

$$B = \frac{\phi}{A}$$

Its unit is Wb/m^2 or tesla (T).



Magnetmotive force :-

It is the force produced by current flowing through a coil of wire. Greather the mmf of a circuit greater the flux produced by it.

$$mmf = NI \text{ AT}$$

for example, if a coil has 500 turns and carries a current of 10 mA, then mmf produced

$$= 5000 \times 10 \times 10^{-3} = 50 \text{ AT}$$

Reluctance (S) :-

It is the oppositions that a magnetic circuit offers to the passage of magnetic flux through it. It is given by the ratio of the mmf and the amount of flux produced

$$S = \frac{mmf}{\phi} = \frac{NI}{\phi} \text{ AT/Wb}$$

In terms of the magnetic quantities. it is given by,

$$S = \frac{l}{\mu A} = \frac{l}{\mu_0 \mu_r A} \text{ AT/Wb}$$

Since 1AT/Wb = 1/Henry, Hence unit of reluctance is also 'reciprocal' henry.

Permence :-

It is reciprocal of reluctance and means the ease with which magnetic flux is produced. Its unit is Henry or Wb/AT.

Permability of a medium :-

The ability of a meterial to concentrate magnetic flux is called permability. Any meterial that is easily magnetised tends to concentrate magnetic flux. Because of a soft iron is easily magnetised. We say that it has a high permeability. Since the permeability of every magnetic medium is compared with the permability of the meterial has two permabilities :-

(i) Relative Permability (μ_r):-

It is the given by the ratio of the permability of the meterial and permability of air:

$$\mu_r = \frac{\mu}{\mu_0}$$

Where μ_0 is the permability of air or vacuum. It may be that μ_r has no units.

Meterials like iron, stell, cobalt and nickel have values of μ_r ranging from 100 to 1,00,000.

Absolute Permability (μ):

It is given by $\mu = \mu_0 \mu_r$

It is also given by $\mu = B/H$

Where 'H' is the magnetising force and B is the flux density in the meterial.

It is called the ~~abs~~ absoult permability of a meterial. Since relative permability of air with respect to itself is unity, hence its absoulte permeability is μ_0. Its value is $4\pi \times 10^{-7}$ henry/metre.

Relation bettween the Magnetic Circuit :-

Consider the magnetic circuit shown in figure. Suppose the mean length of the magnetic circuit is l metrer, cross-section area of the core is 'a' m^2 and the relative permeability of core meterial is μ. When current I is passed through the coil, it will set up magnetic flux ϕ in the meterial.

Flux density in the meterial, $B = \frac{\phi}{a}$ Wb/m^2

Magnetising force in the material, $H = \frac{B}{\mu_0 \mu_r} = \frac{\phi}{a\mu_0\mu_r}$ AT/m

Now magnetising force H is equal to mmf per unit length of the magnetic circuit.

$$H = \frac{NI}{l} \Rightarrow Hl = NI$$

$$\frac{\phi}{a\mu_0\mu_r} \times l = NI$$

$$\Rightarrow \phi = \frac{NI}{(l/a\mu_0\mu_r)}$$

$$\Rightarrow \phi = \frac{\text{mmf}}{\text{reluctance}}$$

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Analogy bett^n Electric & Magnetic Circuit :-

Magnetic Circuit :-

1→ flux = $\frac{\text{mmf}}{\text{reluctance}}$

2→ mmf (ampere-turn)

3→ flux ϕ (Weber)

4→ flux density B (Wb/m^2)

5→ Reluctance, $S = \frac{l}{\mu A} = \frac{l}{\mu_0 \mu_r A}$ (AT/Wb)

6→ Magnetic field intensity (AT/m)

7→ Permeance = 1/reluctance (henry)

8→ reluctance (AT-m/Wb)

9→ Permeability = 1/reluctivity (Wb/AT-m)

Electric Circuit :-

1→ Current = $\frac{\text{emf}}{\text{resistance}}$.

2→ emf (volt)

3→ current (ampere)

4→ Current density (A/m^2)

5→ Resistance, $R = \rho \frac{l}{A} = \frac{l}{\gamma A}$ (Ohm)

6→ electrical field intensity (V/m)

7→ Conductance = 1/resistance (siemens)

8→ resistivity (ohm-meter)

9→ Conductivity = 1/resistivity (siemens/metre)

Calculation of Ampere turns :-

$$\text{flux}(\phi) = \frac{\text{mmf}}{\text{reluctance}}$$

$$= \frac{NI}{\frac{l}{a\mu_0\mu_r}}$$

$$\text{Ampere turns required} = \frac{\phi \times l}{a\mu_0 \times \mu_r} = \frac{\phi}{a} \times \frac{l}{\mu_0\mu_r}$$

$$= \frac{Bl}{\mu_0\mu_r} = Hl \quad \left(\frac{B}{\mu_0\mu_r} = H\right)$$

~~Ampere turns required for any part~~ equal

Ampere turn required is equals to magnetic strength in that part into length of that part.

Some magnetic Circuits :-

We shall discuss some magnetic circuits ~~that the~~ reader may encounter in many practical situations.

(i) Simplest magnetic circuit.

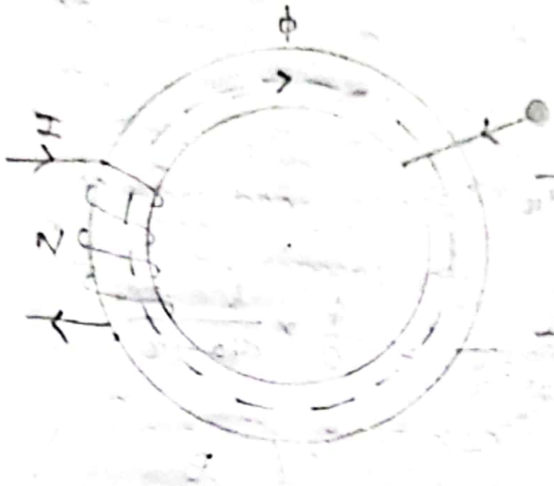
The simplest magnetic circuit is that which is of the same cross-sections and material throughout. It is in the form of an iron ring.

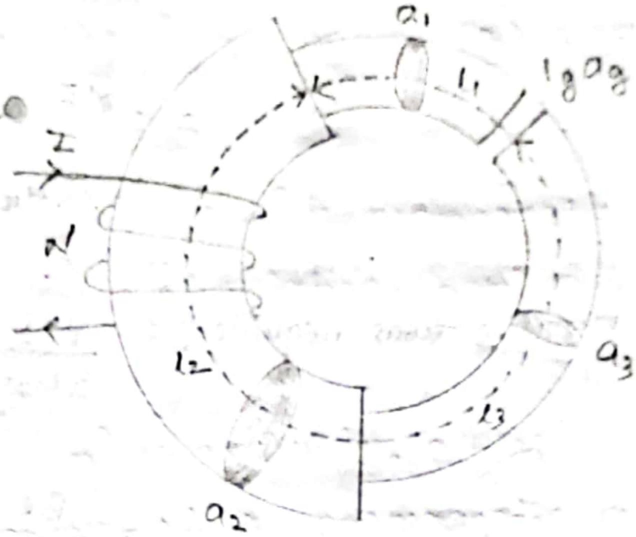
flux density in the ring. $B = \frac{\phi}{a}$

$$*H = \frac{B}{\mu_0\mu_r}$$

∴ AT required to produce flux ϕ in the ring

$= H \times$ mean length of flux path $= H \times l$





(ii) Series magnetic circuit :-

In a series magnetic circuit, the same flux 'ϕ' flows through each path of the circuit. It can just be compared to a series electric circuit which carryies the same current throughout. Consider a composite magnetic circuit consisting of three different magnetic materials of different relative permeability along with an air gap. Since the parts do not have the same cross-sectional area, the flux density will be different in different parts. If we are given the flux and it is required to find the m.m.f. we take one part at a time and find the flux density B, the magnetising force H ($H = B/\mu_0\mu_r$ or more accurately from B-H curve for magnetic meterials; not-air-gap) and product Hl for that part. The total m.m.f required will be the sum of these products.

Required m.m.f $= H_1 l_1 + H_2 l_2 + H_3 l_3 + H_g l_g$.

(iii) Magnetic core having parallel branches:-

A magnetic circuit which has more than one path for flux is called a parallel magnetic circuits. It can just be compared to a parallel electric circuit which has more than one path for electric current. The concept of parallel magnetic circuit is illustrated. Here a coil of N turns wound on limb AF carries a current of I amperes. The flux Φ_1, set up by the coil divides at B into two parts.

namely; (i) flux Φ_2 passes along the path BE.

(ii) flux Φ_3 follows the path BCDE.

The magnetic paths BE and BCDE are in parallel and from a parallel magnetic circuit. The AT required for this parallel circuits is equal to AT required for any one of the paths.

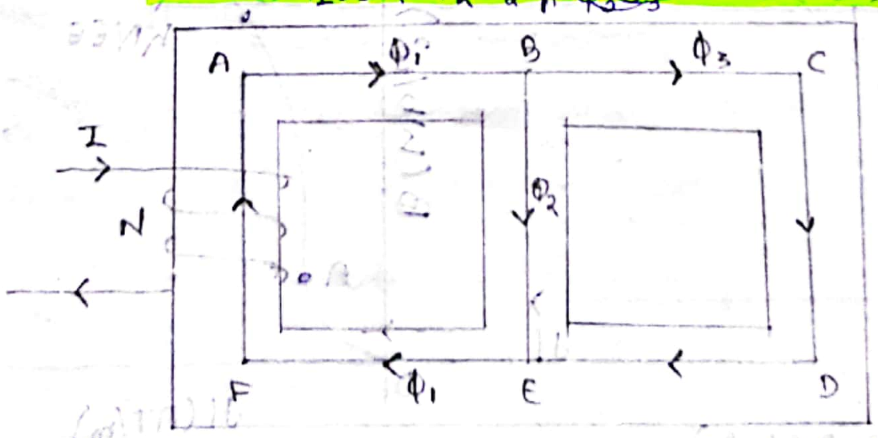
Let S_1 = reluctance of path EFAB

S_2 = reluctance of path BE

S_3 = reluctance of path BCDE

Total mmf required = mmf for path EFAB + mmf for path BE or path BCDA.

$$NI = \Phi_1 S_1 + \Phi_2 S_2 \,/\, \cancel{\Phi_3 S_3} \qquad \Phi_1 S_1 + \Phi_3 S_3 = NI$$



BH CURVE :-

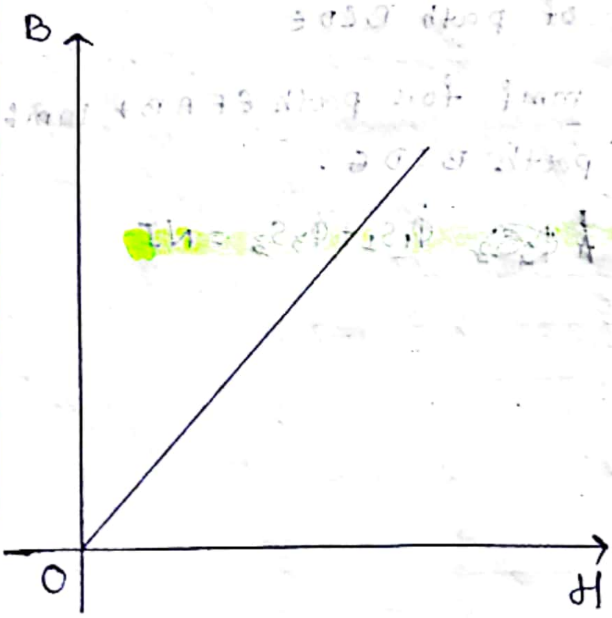
The B-H curve (or magnetisation curve) indicates the manner in which the flux density (B) varies with the magnetising force (H).

(i) for non-magnetic meterial. for nonmagnetic meterials. (eg. air, copper, wood etc.) the relation betn B & H is

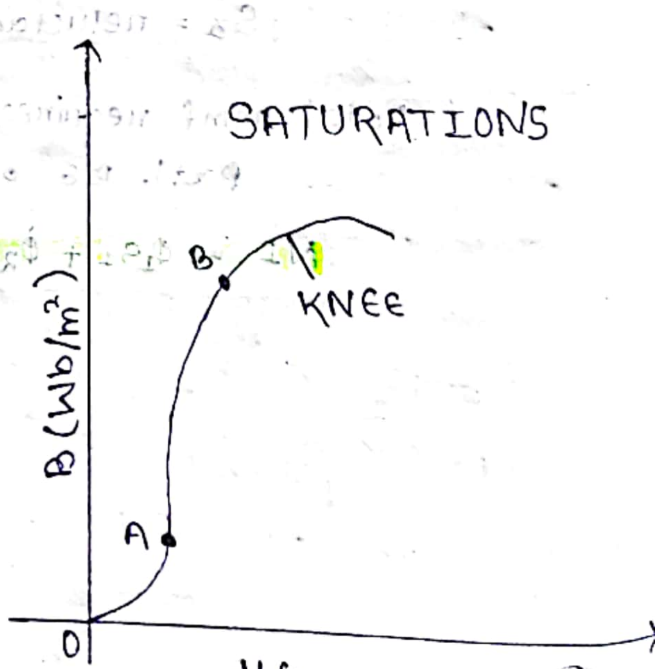
$$B = \mu_0 H$$

Since μ_0 (= $4\pi \times 10^{-7}$ H/m) is constant, $B \propto H$

Hence the B-H curve of a nonmagnetic material is a straingth line passing through the origin as shown in fig. Two things are worth noting. First, the curve never satuarates no matter how great the flux density may be. secondally, a large mmf is required to produce a given flux in the non-magnetic material.



(Non-metal)



(Metal)

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(ii) for magnetic meterial :-

for magnetic material the relation betn B & H is given by:

$B = \mu_0 \mu_r H$

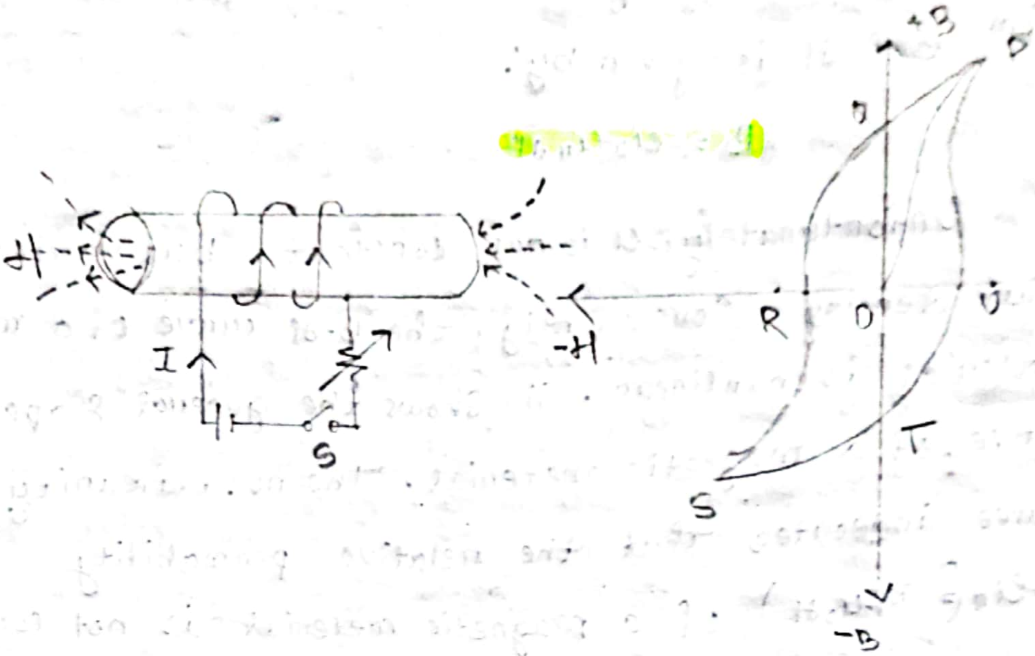
Unfortunately, μ is not constant but varies with flux density. Consequently, the B-H curve of a magnetic material is nonlinear. (ii) shows the general shape of B-H curve of a magnetic meterial. The non-linearity of the curve indecates that the relative permability $\mu_r (= B/\mu_0 H)$ of a magnetic meterial is not constant but depends upon flux density. While carrying out magnetic calculations. It should be insured that the value of μ_r and H are taken at the working flux density. for this purpose, the B-H curve of the material in question may be helpful.

(a) Explain the term magnetic hysteresis? What is it due to? What is meant by hysteresis loop and what is its Significency?

Ans:- Let us take an arrangement bar of iron and magnetise it by placing it within the magnetic field of a solenoid.

We will magnetise the bar first in one direction and then in the opposite direction by reversing the direction of current through the coil. The field H produced by the solenoid is called the magnetising field or force H. It produced magnetic flux density B in the iron bar. The value of H can be increased or desecreased by increasing or decreasing the current.

We will now plot values of B for different values of H. Let us start from point O where H=0.



As H is increased further by increasing the current I, B increases and reaches its maximum value at point P. When H is decreased to zero, B is not reduces to zero. It has a value of OQ. Let us now reverse the direction of H by reversing the direction of current I. When H = -OR, B = 0 and the iron rod is demagnetised. When H is decreased to zero, B is not ~~required~~ zero and has a value equal to OT. From the above discussion, we find that B always lags behind H. The two never becomes zero or maximum at the same time.

The value of B becomes zero much after H has become zero. This lagging of flux density B behind the magnetising force H is called hysteresis.

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The hystersis (or lagging) is produce because the magnetic domains inside the iron bar take time to align with the external magnetising force H. Also the domains do not returns exactly to their original positions when H is removed.

The B/H curve shown in fig. is called the hysteresis loop. The shape of the hystersis loop shows the qualityies of the magnetic meterial from which the bar is made. A material having a high retentivity produces a nearly square hysteresis loop. However, the area of the hysteresis loop represents the loss of energy when a unit volume of the magnetic material is carried through one reversal of magnetisations. Due to this loss of energy, the magnetic bar is heated up if carried through many cycles of reversals. This heat is produced due to frictions betn the elementary magnets in the bar as they turn from one directions to another.

(b) ~~The hysteresis loop of a sample of sheet subjected~~ to ~~a maximum flux density of 1.3 wb/m^2 has an area~~ of 93 cm^2 the ~~scales being~~ 1 cm = 0.1 wb/m^2 and 1 cm = 50 AT/m. alternating flux ~~density~~ of 1.3 wb/m^2 peak value at a frequency of 65 Hz.

Ans:-

Hysteresis Loss :-

When a magnetic meterial is subjected to a Cycle of magnetisation (i.e it is magnetised first one direction and then in the other) an energy loss takes place due to the domain friction in the material. That is the domain of the material resist being formed first in one direction and than in the other. Energy is thus expended in the material in over coming this opelection. This lose is in the form of heat and is called hysteresis loss. It is so called because it results due to the hysteresis effect in a magnetic material.

Hysteresis loss is presentation in all those electrical machines whose iron parts are subjected to cycles of magnetisation. The obvious effect of hysteresis loss is the rise of temperature of the machine. It can be shown that hysteresis energy loss per cycle is directly proportional to the area of the hysteresis loop.

Importance of Hy-steresis loop :-

The shape and size of the hysteresis loop largely depends upon the nature of the material. The choice of a magnetic material for a particular application often depends upon the shape and size of the hysteresis loop. A few cases are discussed below by way of indestration :-

(i) The smaller the hysteresis loop area of a magnetic materi The less is the hysteresis loss. The hysteresis loop for silicon steels has a very small area, for this reason, silicon steels is widely used for making transformer cores and rotating machines which are subjected to rapid

Magnetisation.

(ii) The hysteresis loop for hard steel indicated that this Material has high retentivity) and coercivity. Therefore hard steel is quite suitable for making permanent magnets. But due to the large area of the loop, there is greater hysteresis loss. For this reason, hard steel is not suitable to the construction of electrical machines.

(iii) The hysteresis loop for wrought iron shows that this material has fairly good residual magnetism and coercivity. Hence it is suitable for making cores of electromagnents.

ANALYSIS OF COUPLE CIRCUIT.

Induction is the magnetic field which is proportional to the rate of change of the magnetic field which is called inductance (L) and S.I unit of inductance is Henery.

According to faradays Law of electromagnetic induction. indution is 2 types :-

(1) Self inductions

(2) Mutual Inductance.

Self inductance :-(L)

When their is a change in the current or in magnetic flux of the coil an oppose emf is produce which is called self inductance.

$$\phi \propto I$$

$$\Rightarrow \phi = LI \quad (\because L - \text{self indutance coefficient})$$

Self inductance depends upon

(i) Cross-Sectional Area.

(ii) The permability of material.

(iii) Number of turn in the coil.

$$\text{Induced e.m.f} = \frac{d\phi}{dt} = \frac{+d(LI)}{dt} = L\frac{dI}{dt}$$

$$\because L = \frac{n\phi}{I}$$ where

n = turns

ϕ = flux

I = Current

L = co-efficent of self inductance.

$$\text{Opposed e.m.f} = \frac{-d\phi}{dt} = \frac{-d(LI)}{dt} = -L\frac{dI}{dt}$$

Mutual Inductance :- (M)

When their is a change in current or magnetic flux linked with two coils and opposing emf is produced across each coil and this phenominon is called mutual inductance.

The relation is given by

$$\phi \propto I$$

$\phi = mI$ (where is 'm' is turmed as mutual inductance of two coil.)

The rate of change of magnetic flux in a coil is given as e (opposing emf) $= -\frac{d\phi}{dt}$

$$= \frac{-dMI}{dt} = -m\frac{dI}{dt}$$

Mutual inductance $m = \frac{\mu_0 \mu_r \cdot N_1 \cdot N_2 \cdot a}{l}$

$$\Rightarrow \boxed{M = \frac{\mu N_1 N_2 a}{l}}$$

Where μ_0 = absolute permability

μ_r = relative permability

N = Number of turns.

l = length

a = crossectional area.

Difference bet^n Self inductions & Mutual inductance :-

Self Inductance	Mutual Inductance
(i) Self inductance is the characteristics of a single coil.	(i) Mutual induction is the characteristics of a pair of coil.
(ii) The induced emf opposes the descrease of current in the coil when the main current in the coil decreases.	(ii) The induced emf developed in the neighboring coil opposes the decreases of current in the coil when the main current in the coil when the main current in the coil decreases.
(iii) The induced emf opposes the growth of current in the coil when the main current in the coil when the main current of the coil increases.	(iii) The induced emf developed in the neighbour coil opposes the growth of current in the coil when the main current of the coil increases.

Derivations

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

$$LI = N\phi = N \times BA$$

$$Hl = NI$$

$$B = \mu H$$

$$L = \frac{N^2 \mu A}{l}$$

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Self inductance formula:-

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

$$LI = N\phi = NBA \quad \boxed{\because \phi = BA}$$

$$\boxed{Hl = NI}$$

$$\boxed{B = \mu H}$$

$$\Rightarrow LI = NBA$$

$$\Rightarrow L = \frac{NBA}{I}$$

$$\Rightarrow L = \frac{N \times NBA}{NI} \quad (\because \text{Multiply 'N' in both } D^m \text{ \& } N^m)$$

$$\Rightarrow L = \frac{N^2 BA}{NI}$$

$$\Rightarrow L = \frac{N^2 BA}{Hl} \quad (\because NI = HL)$$

$$\Rightarrow L = \frac{N^2 \mu \cancel{H} A}{\cancel{H} L} \quad (\because B = \mu H)$$

$$\Rightarrow L = \frac{N^2 \mu A}{l}$$

$$\Rightarrow L = \frac{N^2 \mu_0 \mu_r A}{l}$$

$$\Rightarrow \boxed{L = \frac{N^2 \mu A}{l}}$$

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Mutual Inductance :-

The magnetic flux emanating from coil 1 has two components: One component links only coil 1, and another component links both coils.

$$\phi_1 = \phi_{11} + \phi_{12}$$

Leakage flux + Linkage flux

(1) The induced voltage in the first coil

$$V_1 = N_1 \cdot \frac{d\phi_1}{di_1} \times \frac{di_1}{dt} = L_1 \frac{di_1}{dt} \qquad \left[V_1 = N_1 \frac{d\phi_1}{dt} \right]$$

(2) The induced voltage in the 2^{nd} coil

$$V_2 = N_2 \frac{d\phi_{12}}{dt}$$

$$V_2 = N_2 \frac{d\phi_{12}}{di_1} \frac{di_1}{dt} = M_{21} \frac{di_1}{dt} \qquad \left[M_{21} = N_2 \frac{d\phi_{12}}{di_1} \right]$$

Where M_{21} is known as the mutual inductance of coil 2 with respect to coil 1

* M_{21} relates the induced voltage in coil 2 to the current in coil 1.

* Thus, the open-circuit mutual voltage (or induced voltage) across coil 2 is V_2

Similarly :-

$$\phi_2 = \phi_{21} + \phi_{22}$$

$$M_{12} = N_1 \frac{d\phi_1}{di_2} \qquad \left[V_1 = M_{12} \frac{di_2}{dt} \right]$$

Mutual inductance is bilateral :-

$$M_{12} = M_{21} = M$$

Coupling Coefficient :-

Coupling coefficient is the friction of the total flux that links to both coils.

$$K = \frac{\phi_{12}}{\phi_1} = \frac{\phi_{21}}{\phi_2}$$

$$M^2 = \left(N_2 \frac{d\phi_{12}}{di_1}\right)\left(N_1 \frac{d\phi_{21}}{di_2}\right) = \left\{N_2\left(\frac{d(K\phi_1)}{di_1}\right)\right\}\left\{N_1 \frac{d(K\phi_2)}{di_2}\right\}$$

$$= K^2 \left(N_1 \frac{d\phi_1}{di_1}\right)\left(N_2 \frac{d\phi_2}{di_2}\right) = K^2 L_1 L_2$$

$$M = K\sqrt{L_1 L_2} \quad \text{or} \quad X_m = K\sqrt{X_1 X_2}$$

If all of the flux links the coil without any leakage flux then $K = 1$.

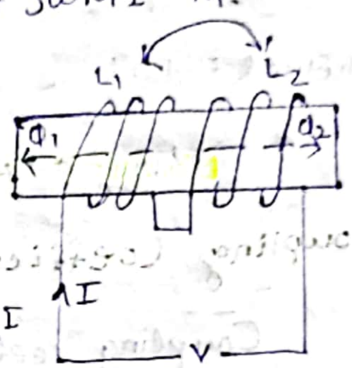
* The term close coupling is used when most of the flux links the coil, either by way of a magnetic core to contain the flux or by interleving the turns of the coils directly over one another.
* The terms loose coupling is used when coils placed side-by-side without a core and have correspondingly low values of K.

Series-Aiding and Series opposing coils :-

(1) Series Aiding Coils :-

$$V = j\omega L_1 I + j\omega M I + j\omega L_2 I + j\omega M I$$

$$= j\omega L_{eq} I$$

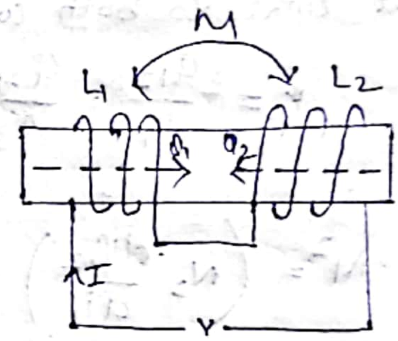


(2) Series opposing coils :-

$$V = j\omega L_1 I - j\omega M I + j\omega L_2 I - j\omega M I$$

$$= j\omega L_{eq} I$$

where $L_{eq} = L_1 + L_2 - 2M$



Substract both eqⁿ :-

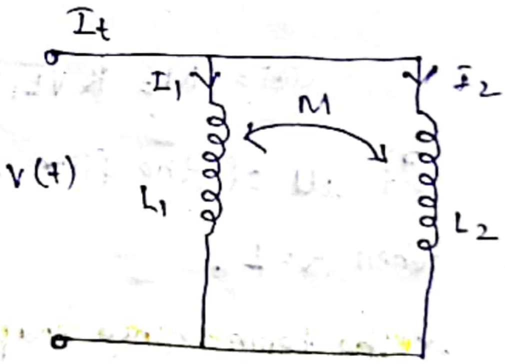
$$M = \frac{1}{4}(L_A - L_B)$$

Parallal aiding and parallal opposing coils :-

(1) Parallal aiding coils :-

$$V = j\omega L_1 I + j\omega M I_2$$

$$V = j\omega M I_1 + j\omega L_2 I_2$$



Solving these equations for I_1 & I_2 yields

$$I_1 = \frac{V(L_2 - M)}{j\omega(L_1 L_2 - M^2)}$$

$$I_2 = \frac{V(L_1 - M)}{j\omega(L_1 L_2 - M^2)}$$

Using KCL gives us

$$I = I_1 + I_2 = \frac{V(L_1 + L_2 - 2M)}{j\omega(L_1 L_2 - M^2)} = \frac{V}{j\omega L_{eq}} \quad \left[L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_2 - 2M}\right]$$

(2) Parallal opposing coils :-

$$\boxed{L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_2 + 2M}}$$

Dot conventions :-

→ Since it is inconvenient to show the construction details of coils on a circuit schematic, we apply the dot convention in circuit analysis.

→ A dot is placed in the circuit at one end of each of the two magnetically coupled.

Steps to assign the dots :-

→ Select a current direction in one coil and place a dot at the terminal where this current enters the winding.

→ Determine the corresponding flux by applications of the right hand rule.

→ The flux of the other winding, according to Lenz's law, opposes the first flux.

→ Use the right hand rule to find the natural current direction corresponding to this second flux.

→ Now place a dot at the terminal of the second winding where the natural current leaves the winding.

The dot Rule :-

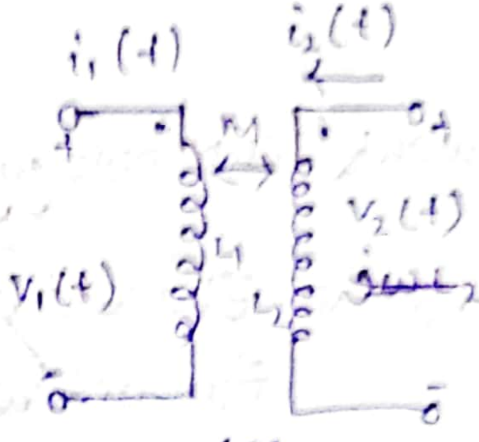
(1) When the assumed currents both entre or both leave a pair of coupled coil by the dotted terminals, the Signs on the M-terms will be the same as the signs on the L-terms.

(2) If one current enters by a dotted terminal while the other leves by a dotted terminal, the signs on the M-terms will be opposite to the signs on the L-terms.

The Dot Rule :-

$$V_1(t) = L_1 \frac{d}{dt} i_1(t) + M \frac{d}{dt} i_2(t)$$

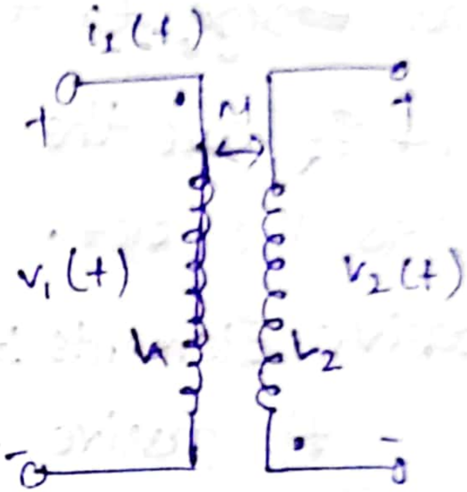
$$V_2(t) = L_2 \frac{d}{dt} i_2(t) + M \frac{d}{dt} i_1(t)$$



(a)

$$V_1(t) = L_1 \frac{d}{dt} i_1(t) - M \frac{d}{dt} i_2(t)$$

$$V_2(t) = L_2 \frac{d}{dt} i_2(t) - M \frac{d}{dt} i_2(t)$$



Circuit Elements And Analysis :-

Network Terminology :-

(1) Active Element :-

An active element is one which supplyies electrical energy to the circuit.

E_1 & E_2 are the active elements because they supply energy to the crt.

(2) Passive Elements :-

A passive elements is one which recieves ~~element~~ electrical energy and then either converts it into heat or stores in an electric field or magnetic field.

There are three passive elements, namely R_1, R_2 & R_3. These passive elements and convert it into heat.

(3) Node :-

A node of a network is an equipotential surface at which two or more than two circuit elements are joined. Circuit elements R_1 & E_1 are joined at A and hence A is a node. Similarly B, C & D are nodes.

(4) Junctions :-

A junctions is that point in a network where three or more circuit elements are joined. there are only two juncton point B & D. That B is a junction is clear from of fact that three circuit elements R_1, R_2 & R_3 are jointed at it.

(5) Branch:-

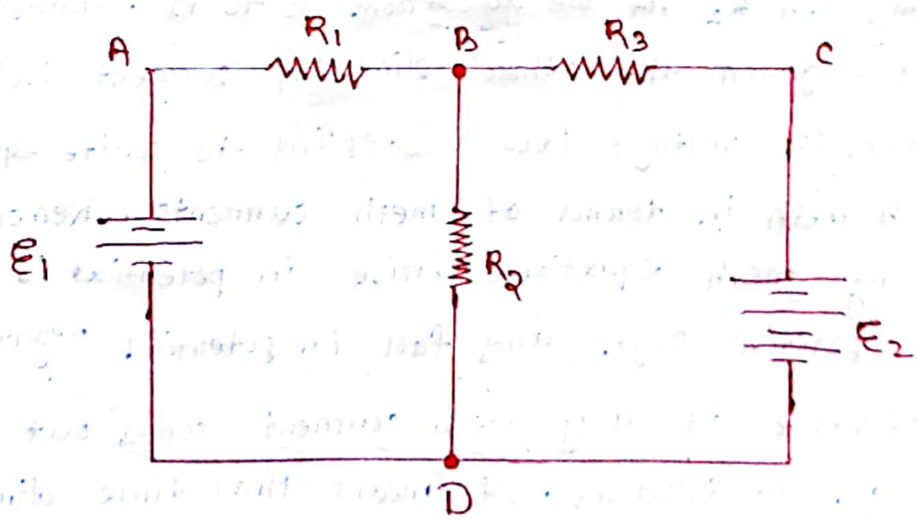
-A branch is that part of a network which lies betn two junction point. Thus referring to fig. there are a total of three branches BAD, BCD & BD. The branch BAD consists of R_1 & E_1 ; the branch BCD consists of R_3 & E_2 and branch BD merely consists of R_2.

(6) Loop:-

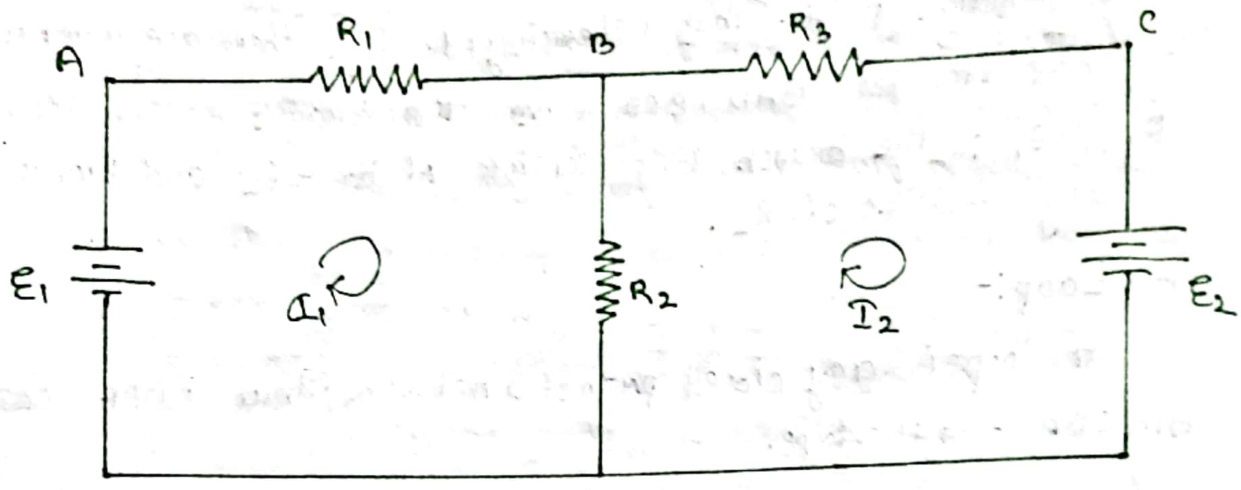
A loop is any closed path of a network. Thus ABDA, BCDB & ABCDA are the loops.

(7) Mesh:-

-A mesh is the most elementary form of a loop and cannot be further divided into other loop. In the figure both loops ABDA & BCDB qualify as meshes because they can't be further divided into other loops.



Maxwell's Mesh Analysis :-



(i) All mesh current are assumed to flow in clockwise direction. for examples meshes ABDA & BCDB have been assigned mesh current I_1 & I_2 respectively.

(ii) If two mesh currents are flowing through a circuit elements. The actual current in the circuit elements in the algebric sum of the two, there are two mesh current I_1 & I_2 flowing in R_2, if we go from B to D. Current is $I_1 - I_2$ and if we go in the other direction current in $I_2 - I_1$

(iii) Kirchoffs voltage law is applied to write equation for each mesh in terms of mesh currents. Remember while wrong mesh equations, rise in potential is assigned positive sign and fall in potential negative sign.

(iv) If the value of any mesh current comes out to negative in the solutions. It means that true direction of that mesh current is anticlosewice, opposite to the assumed closewise directions.

Applying KVL we have

Mesh ABDA :-

$$-I_1R_1 - (I_1 - I_2)R_2 + E_1 = 0$$

$$\Rightarrow -I_1R_1 - I_1R_2 + I_2R_2 = -E_1$$

$$\Rightarrow I_1(R_1+R_2) - I_2R_2 = E_1 \text{ --- eqn (1)}$$

Mesh BCDB:-

$$-I_2R_3 - E_2 - (I_2 - I_1)R_2 = 0$$

$$\Rightarrow -I_2R_3 - E_2 - I_2R_2 + I_1R_2 = 0$$

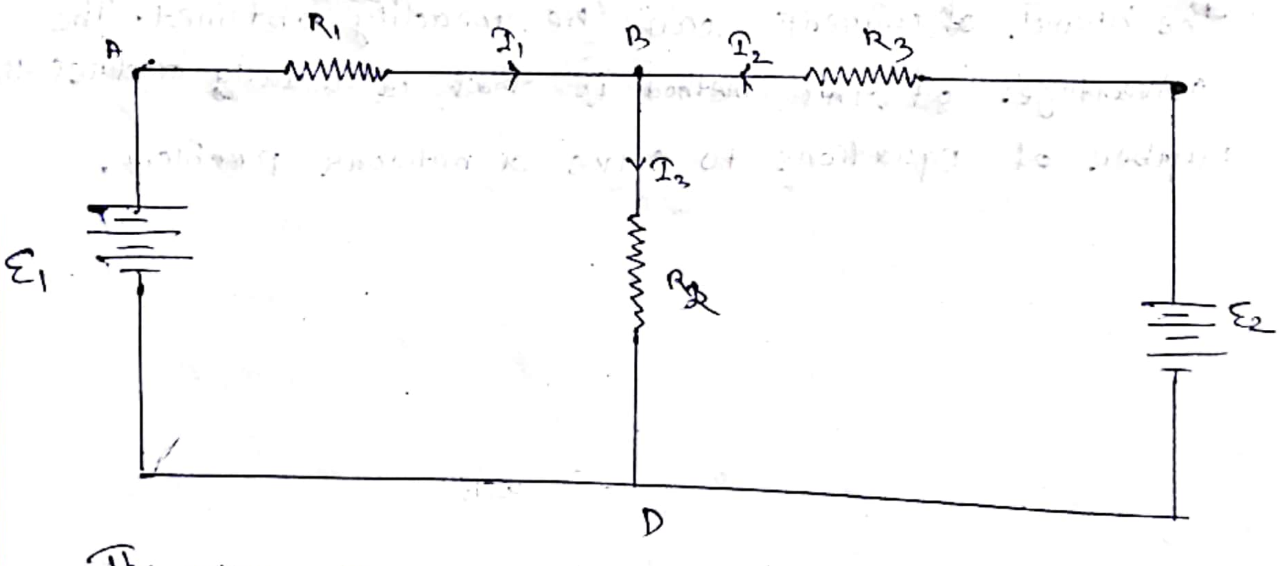
$$\Rightarrow -I_1R_2 + I_2(R_1+R_3) = -E_2$$

Solving eqn-1 & 2 simultaniously, mesh current I_1 & I_2 can be found out. Once the mesh currents are known, the branch currents can be readily obtained. The advantages of this method is that it usually reduces the number of equations to solve a network problem.

Node Anylish:—

In this method, one of the nodes is takes as the reference node. The potentials of all the points in the ckt are measured wrt this reference node. In the figure A, B, D & D are four nodes and node D has been taken as the references node. A glance at the ckt shown that voltage at nodes A & C wrt reference node D are known. These are $E_1 = 120V$ & $E_2 = 65V$ respectively. The only potential of the node B wrt D is unknown. If this potential V_B can be found, each branch current can be determined because the voltage across each resistor will then be known.

Hence Nodal analysis essential aims at choosing a references node in the network and then finding the unknowns voltage at the nodes wrt reference node.



The voltage V_B can be found by applying Kirchoff's current law at point B.

$$I_1 + I_2 = I_3$$

In mesh ABDA, the voltage drop across R_1 is $E_1 - V_B$

$$I_1 = \frac{E_1 - V_B}{R_1}$$

In mesh CBDC, the voltage drop across R_3 is $E_2 - V_B$

$$I_2 = \frac{E_2 - V_B}{R_3}$$

Also current $I_3 = \frac{V_B}{R_2}$. Putting the values of I_1, I_2 & I_3 in eqn - 1 we get

$$\frac{E_1 - V_B}{R_1} + \frac{E_2 - V_B}{R_3} = \frac{V_B}{R_2}$$

All quantities except V_B are known. Hence V_B can be found out. Once V_B is known, all branch current can be calculated. It may beseen that nodal analysis required only one equation for determining the branch current in this circuit. However, Kirchoffs solution would have needed two equations.

Sources transformation Method:-

A given independent voltage source with a series resistance can be converted into a current into a current source with parallal resistance & vise versa. This types of source is converted to the other type is that to symplify the anylishis of the crt. for example mesh anylish when the crt contant all the voltage source & nodal contained all current sources.

Unilateral Elements :-

The elements in which conducton of current in one direction is called as unilateral elements.

Exp:- Diode, triode. etc.

Bilateral Elements :-

The elements in which conduction of current in both direction is called as bidirectional elements.

Exp:- Resistor; Inductor, Capacitor. etc.

Linear Circuit :-

A linear circuit is one whose parameter don't change with voltage & current.

Non-linear Circuit :-

A linear circuit is one whose parameter change with voltage & current.