Losses in Transformer:-

→ Loss in any machine is broadly defined as the difference b/w input power and output power.

→ when input power is supplied to the primary of T/R, some portion of that power is used to compensate core losses in T/R i.e hysterisis loss and eddy current loss in T/R and some portion of the input power is lost as I^2R loss and hence dissipated as heat in the primary and secondary windings, because these windings have some internal resistance in them.

→ The first one is called core loss or iron loss in T/R and the later one is known as ohmic loss or copper loss in T/R.

1):- Copper loss or Ohmic loss:-

→ These losses occur due to ohmic resistance of the T/R windings.

→ If I_1 and I_2 are the primary and secondary current R_1 and R_2 are the resistance of primary and secondary winding, then the copper losses occuring in the primary and secondary winding will be $I_1^2R_1$ and $I_2^2R_2$ respectively.

Therefore, the total copper losses will be:-

$$P_C = I_1^2R_1 + I_2^2R_2$$

As the both primary and secondary currents depends upon load of the T/R, hence copper loss in T/R vary with load.

2):- Eddy current loss:-

→ As we know that in T/R, when we supply alternating current in the primary, this alternating current produces alternating flux in the core of the T/R.

→ when this flux links with the primary and secondary windings, an emf is induced in both the windings.

→ Some of this alternating flux may also link with other conducting parts like steel core or iron body of T/R and hence induces a locally induced emf.

→ Due to these emfs, there would be currents which will circulate locally at that parts of the T/R. Specially in core.

→ These circulating currents are called eddy currents.

→ As these currents are not responsible for doing any useful work and produces a loss (I^2R) in the magnetic material, hence they are termed as eddy current loss.

→ These losses can be minimized by making the core with thin laminations.

The equation of the eddy current is given as:-

$$P_e = K_e B_m^2 t^2 f^2 V \text{ watts}$$

where:-

→ K_e = coefficient of eddy current and its value depends upon the nature of magnetic material like resistivity of core material, thickness of laminations

→ B_m = Maximum value of flux density (wb/m^2)

→ t = thickness of laminations (in meters)

→ f = frequency of magnetic field (in Hz)

→ V = volume of magnetic material (in m^3)

3):- Hysteresis loss:-

→ when a magnetic material is subjected to a cycle of magnetisation (i.e it is magnetised first in one direction and then in the other), an energy loss takes place due to the molecular friction in the material. That is, the atoms of the material resist being turned in one direction first and then in the other.

→ Energy is thus lossed in the material in overcoming this opposition.

→ This loss of energy in the form of heat is called hysteresis loss.

→ Hysteresis loss is present in all those machines whose iron parts are subjected to cycles of magnetisation.

→ The obvious effect of hysteresis loss is the rise of temperature of the machine

Hysteresis loop:-

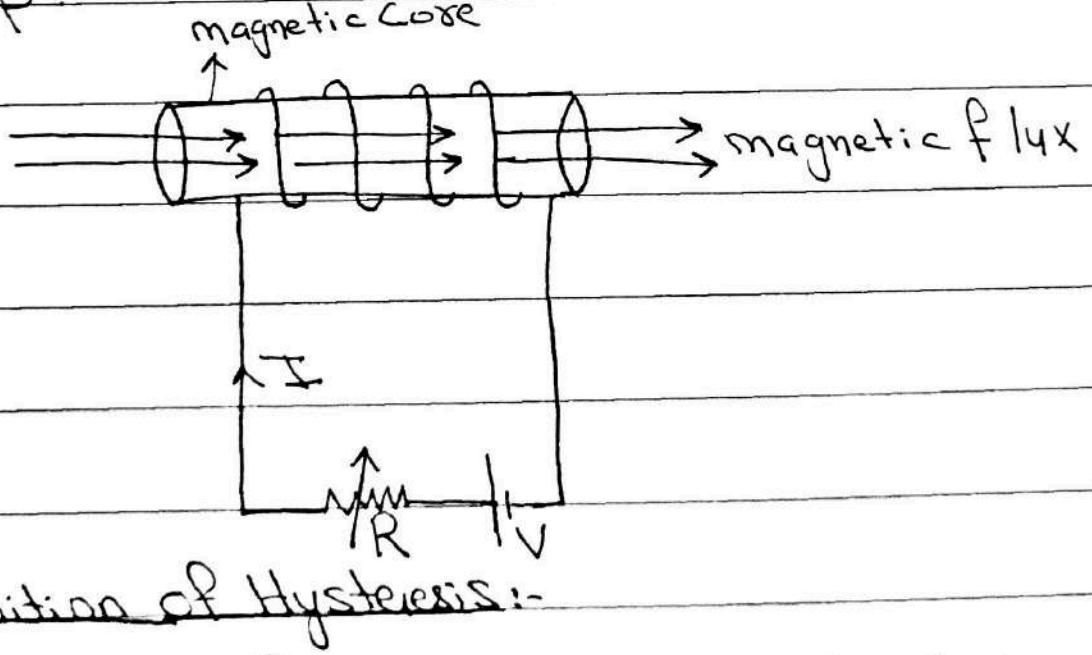
Hysteresis loop is a four quadrant B-H graph from where the hysteresis loss for a certain magnetic material is obtained.

→ To understand hysteresis loop, consider a magnetic material (to be used as a core) around which insulated wire is wound.

→ The coil is connected to the DC supply through a variable resistor to vary the current.

→ The magnetizing force H(=NI/L) produced by this wire can be changed by varying the current through the coil.

→ We shall see that when the iron piece is subjected to a cycle of magnetization, the resultant B-H curve traces a loop called hysteresis loop.



Definition of Hysteresis:-

Hysteresis of a magnetic material is a property by virtue of which the flux density (B) lags behind the magnetizing force (H).

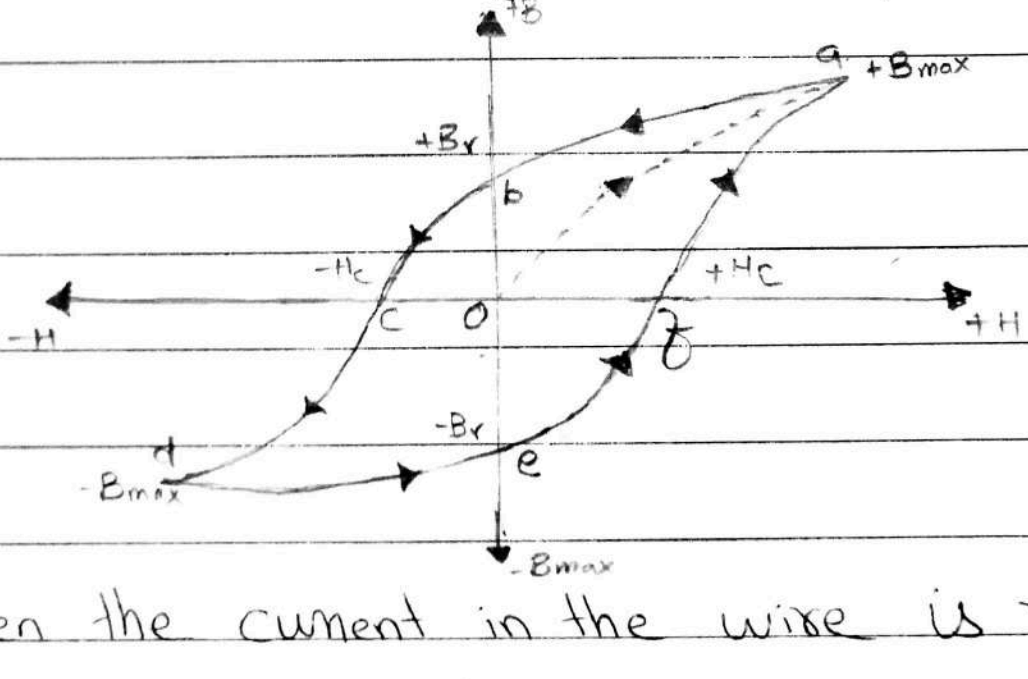
Coercive Force:-

coercive force is defined as the negative value of magnetizing force (-H) that reduces residual flux density of a material to zero.

Residual Flux Density:-

Residual flux density is the certain value of magnetic flux per unit area that remains in the magnetic material without the presence of magnetization force (i.e H = 0).

Explaination of hysterisis loop:-



→ When the current in the wire is zero, H = 0 and hence B in the iron piece is zero.

→ As H is increased (by increasing current), the flux density (+B) also increases until the point of maximum flux density ($+B_{max}$) is reached.

→ At this point, the material is saturated and beyond this point, the flux density will not increase regardless of any increase in current or magnetizing force.

→ Note that B-H curve of the iron piece follows the path oa.

→ If now H is gradually reduced (by reducing current), it is found that the flux density B does not decrease along the same line by which it had increased but follows the path ab.

→ At point b, the magnetizing force H is zero but flux density in the material has a finite value $+B_r$ (= ob) called residual flux density.

→ It means that after the removal of H, the iron piece still retains some magnetism (i.e $+B_r$)

→ In other words, B lags behind H.

→ The power of retaining residual magnetism is called retantivity of the material.

→ To demagnetize the iron piece, (ie remove the residual magnetism ob), the magnetizing force

H is reversed by reversing the current through the coil.

→ when H is gradually increased in the reverse direction, the B-H curve follows the path bc so that when H = oc, the residual magnetism is zero.

→ The value of H (= oc) required to wipe out residual magnetism is known as coercive force (Hc).

→ If H is further increased in the reverse direction, the flux density increases in the reverse direction (-B).

→ This process continues (curve cd) till the material is saturated in the reverse direction (-Bmax) and can hold no more flux.

→ If H is now gradually decreased to zero, the flux density also decreases and the curve follows the path de.

→ At point e, the magnetizing force is zero but flux density has a finite value -Br (= oe) ie the residual magnetism.

→ In order to wipe out residual magnetism oe, magnetizing force is applied in positive direction

So that when H = of (coercive force), the flux density in the iron piece is zero.

→ Note that the curve follows the path ef.

→ If H is futher increased in the positive direction, the curve follows the path fa to complete the loop abcdefa.

→ Thus when a magnetic material is subjected to one cycle of magnetisation, B always lags behind H So that the resultant B-H curve forms a closed loop called hysteresis loop.

→ For the 2nd cycle of magnetization, a similar loop abcdefa is formed.

→ If a magnetic material is located Within a coil through which alternating current (50Hz frequency) flows, 50 loops will be formed every Second.

→ The shape and size of the hysteresis loop depends upon the nature of the material

→ The smaller the hysteresis loop area of a magnetic material, the less is the hysteresis loss.

→ The hysteresis loop for a silicon Steel has a very small area Thus, silicon steel is widely used for making T/R cores and rotating machines.