Week-10:-

contents:-

- Ampere's law & relation between B, H, i
- Magnetic circuits
- Hysterysis curve & coreloss.
- Transformer
- Transformer equivalent circuit.
- Noload test, Short circuit test
- Voltage regulation of transformer.
- Efficency of transformer..
- Three phase transformer. (basic introducti)

↳ magnetic field.

* B → magnetic flux density. (no. of lines per unit area).

(Tesla, T) depends on core-material. (not in circuits...)

mag. field intensity:

* H → magnetic strength | magnetic field strength |

dosen't depends on type of core material of coil. (but depends,... in circuits).

$\boxed{B = \mu H}$ → permeability.

as, $\mu\uparrow$, $B\uparrow$.

$\mu = \mu_0 \cdot \mu_r$.

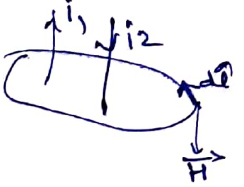
μ_r → may not be constant for a material. Function of magnetic field. intensity. (hysteresis)

mag. field intensity/strength.

* H depends on setup (n, i) but not on material.

B depends on material.
↳ mag. flux density. → depends on material.

* Ampere's law:-



$\boxed{\oint \vec{H} \cdot \vec{dl} = i_1 - i_2}$

field intensity — currents

*. Hence

$H \cdot 2\pi r = i$

$H = \dfrac{i}{2\pi r}$

$\therefore B_0 = \dfrac{\mu_0 i}{2\pi r}$.

* $\boxed{B = \mu_0 \mu_r H}$ Weber/m² or Tesla.

Weber → units of ϕ_m.

μ_r → medium variable

μ_0 → $(4\pi \cdot 10^{-7})$ Henry m⁻¹. units of L inductance.

→ magnetic equivalent circuit:-

Mag. field intensity H

$H \cdot 2\pi r = N \cdot i$

$H = \frac{Ni}{2\pi r}$

in 12th; $B = \mu_0 \left(\frac{Ni}{2\pi r}\right)$

now; all grown up... $H = \frac{Ni}{2\pi r}$

$H \times 2\pi r = Ni$

(Ni) is called magnetomotive force (mmf). $\mathcal{J}$

like $\int \vec{E} \cdot \vec{dl} = \text{emf}$.

$\int \vec{H} \cdot \vec{dl} = \text{mmf}$. units: Ampere-turn At

* $H \cdot l = Ni$

$H = \frac{N}{L} \cdot i$ At/m

$\therefore$ flux across crossection

$= AB$

$= \frac{\mu Ni}{l} \cdot A$

$B = \frac{\mu Ni}{l}$

$B \cdot l = \mu \cdot (Ni)$ mmf.

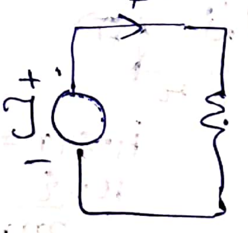
$\boxed{\mathcal{J} = Ni = \oint \vec{H} \cdot \vec{dl}}$

$\boxed{\phi = \frac{Ni}{(l/\mu A)}} = \frac{\text{mmf}}{(\ )}$.

*

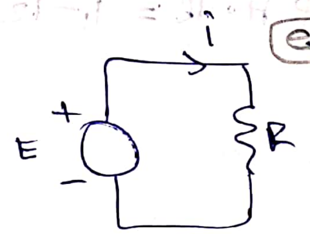
ϕ ✓

magnetic



$Ni = \mathcal{J}$ $\quad \mathcal{R} = \frac{l}{\mu A}$ ⟷

electric



$\phi = \frac{Ni}{l/\mu A}$

$= \frac{\mathcal{J}}{\mathcal{R}}$ — mmf

(reluctance of magnetic path.

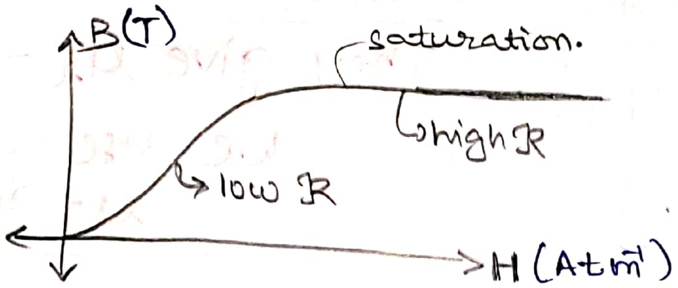
$i = \frac{E}{R}$ — emf

resistances

if A is more; H same $\phi \uparrow \Rightarrow \mathcal{R} \downarrow$

if l is more; H less ϕ same $\Rightarrow \mathcal{R} \uparrow$.

* B-H-curve:- (μ varies with H).
not constant!



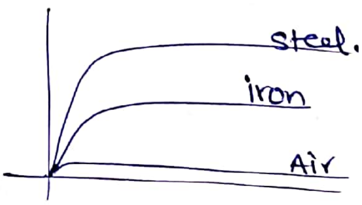
No hysteresis

H → free charges

B → Bound + free charges?...

(or) only bound.

Saturating means... bounded!



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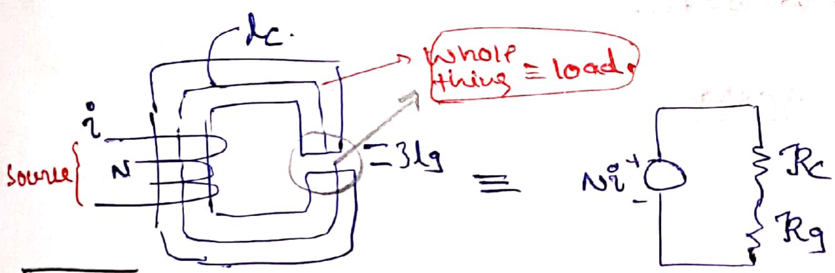
* composite Magnetic circuits:-

* * when the path of flux encounters more than one medium; then series resistors:-



air gap also a resistor. very high resistance! (as low μ_r) $\mu_r = 1$...

$\mathcal{F} = Ni$

mmf

Reluctance$_{core} = \frac{l_c}{\mu_c \cdot A_c}$

$\boxed{R_g = \frac{l_g}{\mu_0 \cdot A_g}}$ cross section of Airgap... ($\sim A_c$?)

! vaccum ≈ air.

But y?: proof:

$B_c = H_c \cdot \mu_c$

$= \frac{\phi_c}{A_c} = \frac{\phi}{A_c}$

$B_g = \frac{\phi_g}{A_g} \approx \frac{\phi_c}{\approx A_c} = \frac{\phi}{A_c}$.

$H_c = \frac{\phi}{A_c \cdot \mu_c}$; $H_g = \frac{\phi}{\mu_0 \cdot A_c}$

& Ampers law: (kirchoff's 2nd law)

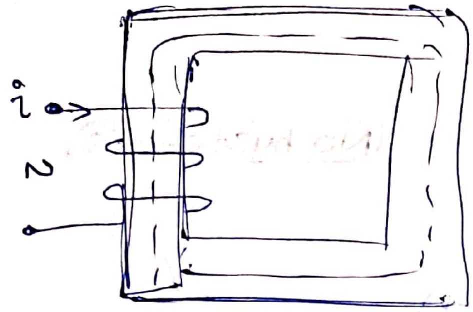
$Ni = \frac{\phi}{A_c \mu_c} \cdot l_c + \frac{\phi}{A_c \cdot \mu_0} l_g$!

$\phi_c \approx \phi_g$ as ϕ_{net} should be conserved... } kirchoff 1st law...

& since $B = \frac{\phi}{A}$; $B_c = B_g \Rightarrow H_c \neq H_g$.

this is what sir meant; when he said H depends on μ; B doesn't!

Eg:



They give $\mu_r = 200$
we use
$\mu = 200 \times 4\pi \times 10^{-7}$

$mmf = N \cdot i$

$\mathcal{R} = \frac{l}{\mu A}$, $\boxed{\text{as } \mu \uparrow, \phi \uparrow \; \therefore \mathcal{R} \downarrow}$

$\phi = \frac{Ni}{l} \cdot \mu A$] Ampere's law... $H \cdot l_c = Ni$

$\left(\frac{\phi}{A_c \cdot \mu}\right) l_c = Ni$ ✓✓

$= \frac{400 \times 1.5 \cdot 2000 \times 10 \times 5 \times 10^{-4} m^2}{(120 \times 10^{-2})}$

$\phi = 6.28 \times 10^{-3}$ Wb weber...

$B = \frac{\phi}{A} = 1.257T$ tesla

---

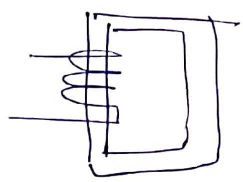
*

Now; flux linkage
$= N \cdot \phi$
net turns.

total 'N' turns.

$\therefore$ Inductance $= \frac{\text{flux linkage}}{i} = \frac{N \cdot N}{l/\mu A_c} = \frac{N^2}{\mathcal{R}}$

will be similar for



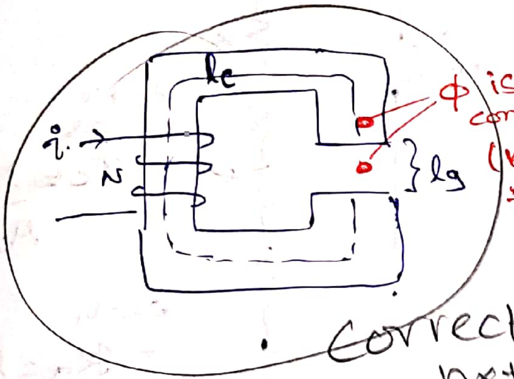
case.

Assignment:-

Q1) relay → did the job of bridging electric & electronic circuits.

need a metal rod...

(they were used; before transistors).



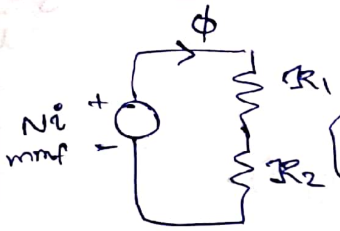
ϕ is conserved. (Kirchoffs 1st law).

∴ B is same.

∴ H is different.

so, sir said "H is dependent on material of core".

Corrected next pg.



wrong

$N = 500$.

$l_c = 360\,mm$

$l_g = 1.5\,mm$

$B = 0.8T$ to actuate the relay.

?

satisfy all equations

"cause a machine to work."

$R_1 = \frac{l_c}{\mu \cdot A_c}$

$\mu_o = 4\pi \times 10^{-7}$

$R_2 = \frac{l_g}{\mu_o \cdot A_c}$

μ_{core} ? cast steel = ?

$\therefore R_{net} = \ldots$

need 1 more variable...

$\phi = \frac{Ni}{R_{net}} = B \cdot A_c$.

i

(or)

μ

$\Rightarrow B \cdot A_c = \frac{Ni}{\frac{l_c}{\mu} + \frac{l_g}{\mu_o}} A_c$.

$\mu_{cast\ steel} = \frac{B}{H} = \frac{0.8}{450}$

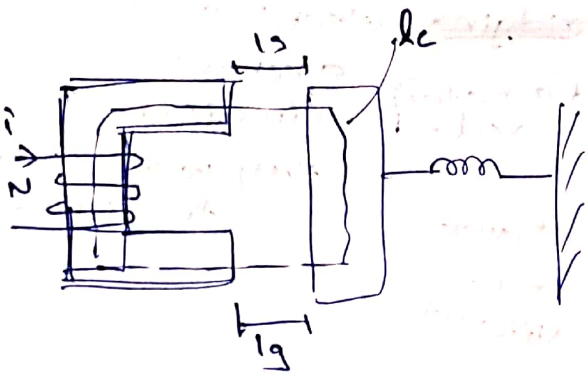
$\therefore 0.8 = \frac{500 \cdot i}{(\quad)}$

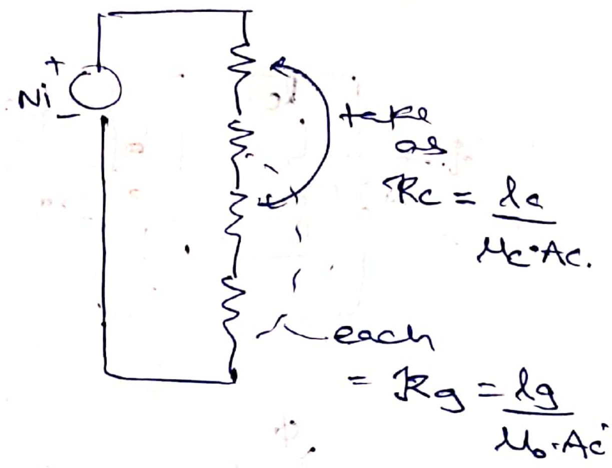
$\therefore i = \frac{0.8}{500} \times \left(\frac{360(450)}{0.8} + \frac{(1.5) \cdot 10^7}{4\pi} \right) \cdot 10^{-3}$ Amperes.

$= \frac{0.8}{500} (202500 + 1172 \ldots) \cdot 10^{-3}$

$i = 19.17A$

Q1) relay.





$N = 500$

$l_c = 360 mm$

$l_g = 1.5 mm$

$B = 0.8 T$

$(\mu_c)_r = 1150$ (from google).

$$\therefore \mathcal{R}_{net} = \left(\frac{360}{1150 \cdot A_c} + \frac{2 \cdot (1.5)}{A_c}\right) \cdot \frac{10^{-3}}{\mu_0}$$

$$= \left(\frac{36}{115} + 3\right) \cdot \frac{10^{-3}}{\mu_0 A_c}$$

$$= \frac{3.313 \times 10^{-3}}{\mu_0 A_c}$$

$$\therefore Ni = \frac{B \cdot A_c}{\cancel{A_c}} \times \frac{3.313 \times 10^{-3}}{\mu_0 A_c}$$

$$\Rightarrow i = \frac{0.8 \times 3.313 \times 10^{-3}}{4\pi \times 10^{-7} \times 500}$$

a) $\underline{i = 4.22 A}$

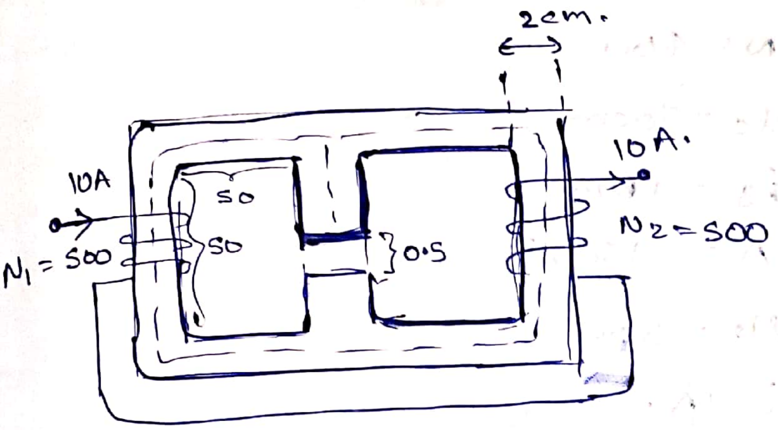
b) $\mu_c = 1.45 \times 10^{-3}$ SI units.

$\mu_{cr} = 1150$ (from google).

c) now; $\mathcal{R}_{net} = \frac{0.313 \times 10^{-3}}{\mu_0 A_c}$

$$\therefore i_{now} = \frac{0.313}{3.313} \times 4.22 = 0.398 A.$$

Q2)



$\mu_r = 1200$

ferro magnetic.

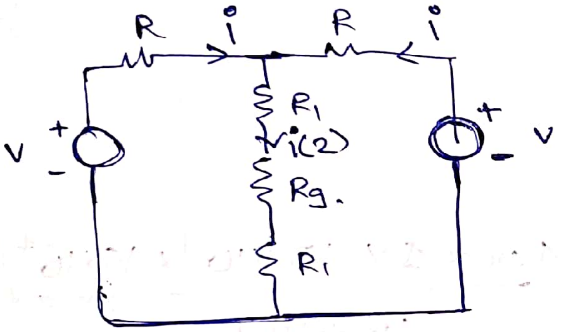
neglect ϕ leakage.

(apply Kirchoff's law)

cm

crossection = square.

taking all SI units.



find (i)

loop law in left loop:-

$$+V - iR - 2i(2R_1 + R_g) = 0$$

$$\Rightarrow i = \frac{V}{R + 4R_1 + 2R_g}$$

$$= \frac{5\times10^3 \times 4\pi\times10^{-7} \times 4\cdot10^{-4}}{10^{-2}\left(\frac{156}{1200} + 4\cdot\frac{\left(\frac{51.5}{2}\right)}{1200} + 2\cdot0.5\right)}$$

$$= \frac{2.52\times10^{-4}}{1.22}$$

$$i = 2.06\times10^{-4} A$$

$$R = \frac{(52+52+52)\,cm}{\mu_c \cdot A}$$

$$R_1 = \frac{\left(\frac{51.5}{2}\right)}{\mu_c \cdot A}$$

$$R_g = \frac{0.5}{\mu_0 \cdot A}$$

$$V = Ni = 10\times500$$
$$= 5\times10^3.$$

$$A_c = 2\times2\times10^{-4}$$
$$= 4\times10^{-4}\ m^2$$

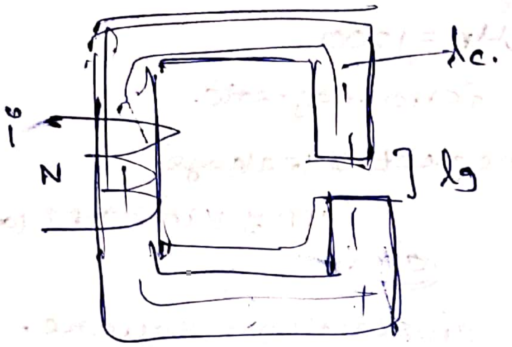
$\therefore \phi = 2.06\times10^{-4}\ W$

Sol^n) $\therefore \phi_g = 2\phi = 4.12\times10^{-4}\ W$

$$B_g = \frac{\phi_g}{A_c} = \frac{4.12\times10^{-4}}{4\cdot10^{-4}} = 1.03T$$

$$H_g = \frac{B_g}{\mu} = 821865\ At\,m^{-1}$$

Q3)



$N = 400$

$l_c = 50cm$,

$l_g = 1mm$

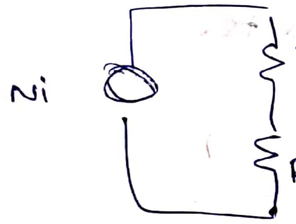
$A_C = 15cm^2$.

$\mu_r = 3000$

$i = 1A$.

Sol)

a)



$R_c = \frac{l_c}{3000 \mu_0 A_C}$

$R_g = \frac{l_g}{\mu_0 A_C}$

$$\therefore \phi = \frac{Ni\,(\mu_0 \cdot A_C)}{\frac{0.5}{3000} + 0.001} = \frac{400 \times 1 \times 4\pi \times 10^{-7} \times 15 \times 10^{-4}}{0.00117}$$

$$\phi_g = 6.4 \times 10^{-4}\ \text{weber}.$$

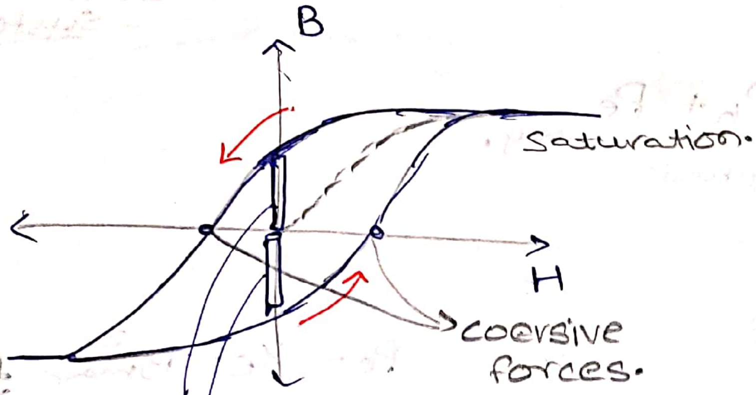
$$\therefore B_g = \frac{\phi_g}{A_C} = 0.4309\,T.$$

b)

$$L = \frac{\text{flux linked}}{i} = \frac{N \cdot \phi}{i} = \frac{400 \times 6.4 \times 10^{-4}}{1\,A}$$

$$= 0.258H.$$

→ B-H curve again!:-



(residual magnetism.) √√ cool√.

Hysterysis loss:-

- when core is subjected to alternating excitation;

✓ (loss coming)

area of BH loop $= K \cdot B_{max}^{n}$

Because we always need to negate the residual magnetism; in both direct^{n}s.

&

Hysteresis loss ~~α~~ (Heat)

$$P_h = K_h \cdot B_{max}^{n} \cdot f$$

frequency.

empirical formulas.

Loss won't come;

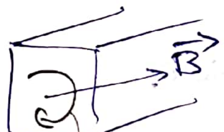
if

now; while going + → - we do work; when - to +; it is doing work for us.

Eddy current loss:-

- where $\vec{B}$; there are eddy currents (wrong!)

where $\frac{d\vec{B}}{dt}$ there eddy currents! damn!



eddy currents in core

i^2R loss.

- this is electrical loss.

above hysteresis is magnetic loss.

(Heat)

$$P_e = K_e \cdot B_{max}^{2} \cdot f^2 \cdot V_{core}$$

frequency... volume

$N = \frac{A\ell}{t}$

$V = \ell A$

$P \propto \frac{1}{N}$

$$\& \quad K_e = \frac{\pi^2 t^2}{6\rho}$$

where t = lamination thickness

ρ = resistivity. of lamination

(not core)

- make laminations; to avoid this.
- use high ρ to avoid this.

* core loss:-

losses in core material of electro magnetic systems.

$$P_{core} = P_h + P_e$$

hysteresis, eddy.

that was easy...

$P_h = K_h \cdot B_{max}^n \cdot f \quad n \simeq 2?$

$P_h = \left(\text{Area of } BH\right) \times V_{core} \times f$

K_h depends on V_{core} & material

$P_e = K_e \cdot B_{max}^2 \cdot f^2 \cdot V_{core}.$

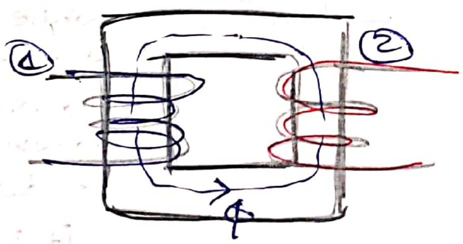
$P_e = \left(\frac{\pi^2 t^2}{6\rho} \cdot B_{max}^2\right) \cdot V_{core} \cdot f^2$

t, ρ of lamination material. Not core.

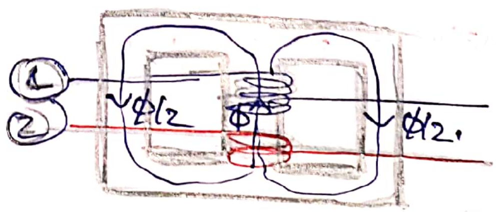
Transformer construction:-

Only AC

* first; core's construction.



core-type construction.



Shell type construction

Here windings surround core.

* hence core is core.

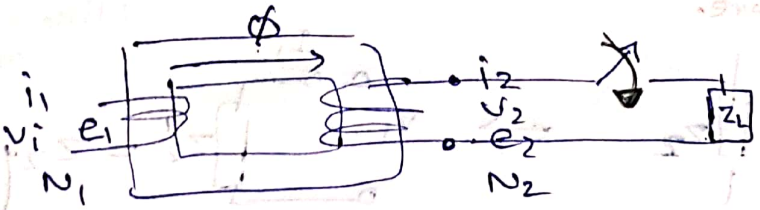
* small leakage flux existing

Here core surroundings windings "shell".

* hence shell core acts as shell.

* even smaller flux exists.

→ transformer equations:-



$v_1 = e_1 = N_1 \cdot \frac{d\phi}{dt}$ Faraday's induction law. | lenz law.

$\therefore v_2 = N_2 \cdot \frac{d\phi}{dt}$.

$\therefore \boxed{\frac{v_1}{v_2} = \frac{N_1}{N_2} = a}$ V_2 is 2ndary winding terminal voltage.

ideally; we take $\mathcal{R}_c = 0$ these are absolute. not RMS.

$\Rightarrow$ mmf = 0

$\therefore N_1 i_1 = N_2 i_2$

$\boxed{\frac{i_1}{i_2} = \frac{N_2}{N_1}}$

$\boxed{a = \frac{N_1}{N_2}}$

* ideal transformer:-

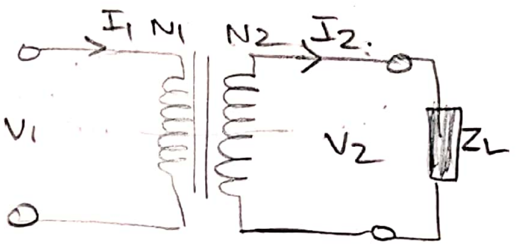
1) all core & winding losses neglected.

2) assumed $\mu_{core} = \infty$

$\therefore \mathcal{R}_{core} = 0$

net mmf = 0.

3) No leakage flux.



Z_1 = input impedance $= \frac{V_1}{I_1}$

Z_2 = secondary side impedance $= Z_L$.

to reduce the circuit diagram

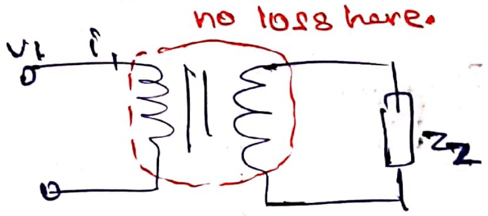
* Z_1' : primary side impedance, seen from secondary side $= Z_1 \left(\frac{N_2}{N_1}\right)^2$

* $Z_2' = Z_2 \cdot \left(\frac{N_1}{N_2}\right)^2$

* Impedance (Z_2') transfer :-

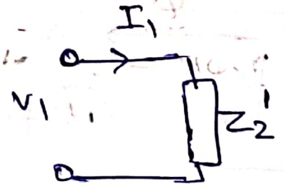
one reduction of circuits technique. (like thevenin Norton..)

no loss here.



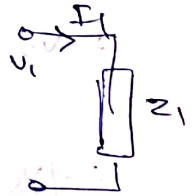
this whole is one circuit.

should be able to reduce it.



$Z_2' = Z_2 \left(\frac{N_1}{N_2}\right)^2$

∴ if say equiv. is



then $Z_1 = \frac{V_1}{i_1}$;

$= \frac{a \cdot V_2}{i_2/a}$

$a = (N_1/N_2)$

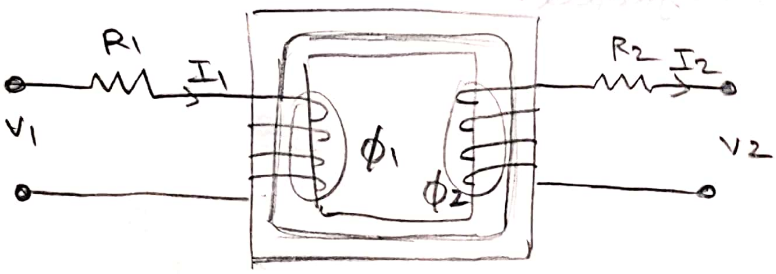
$= a^2 \cdot Z_2$

tadaan!

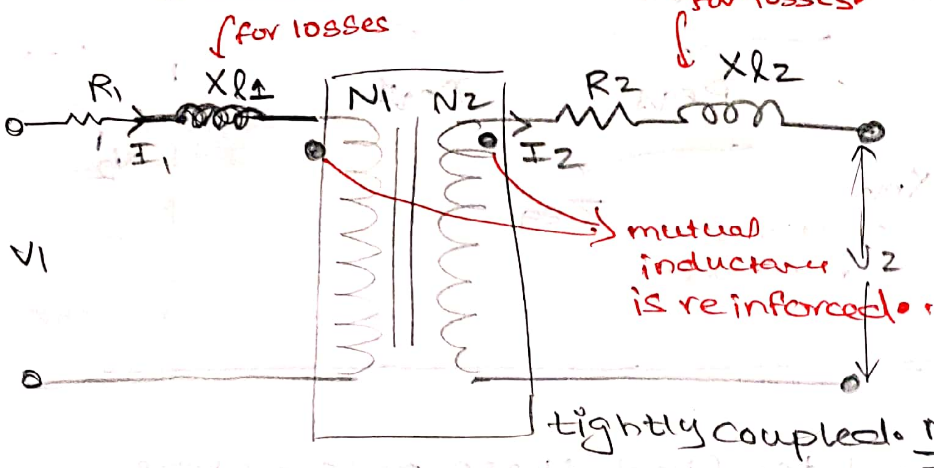
→ Practical transformers:-

$K = \frac{M}{\sqrt{L_1 L_2}}$. practical $K = 0.99$

(Flux lekage problem)



• equivalent circuit 1 :-

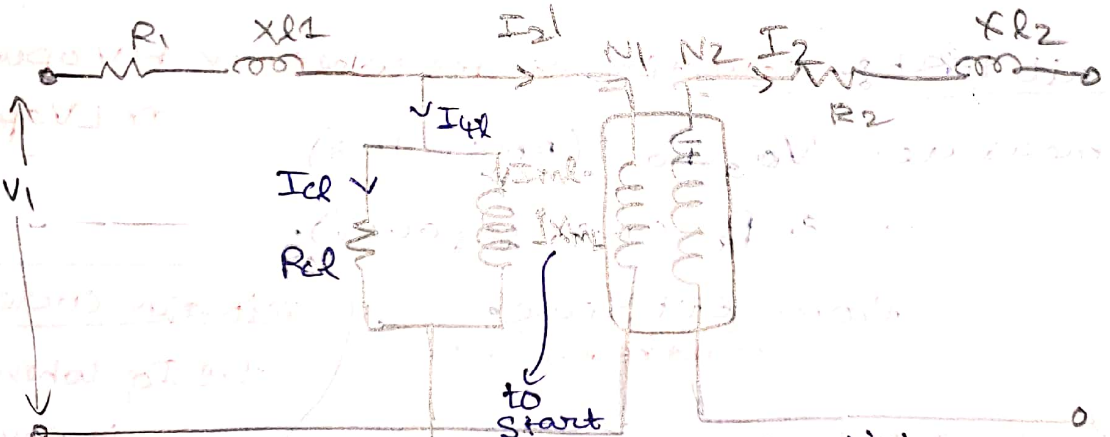


tightly coupled. $\frac{M}{\sqrt{L_1L_2}} \simeq 1$

R_1, R_2 winding resistance.

X_{l1}, X_{l2} leakage reactance.

* equv. circuit 2 :-



— magnetising current.

(mmf) ke liye.

* $\underline{I_{cl}^2 R_{cl}}$ = $P_{core} = P_h + P_e$.

net core losses.

Since $\mu \neq \infty$

$\mathcal{R} \neq 0$

$\therefore mmf = \phi \cdot \mathcal{R}$

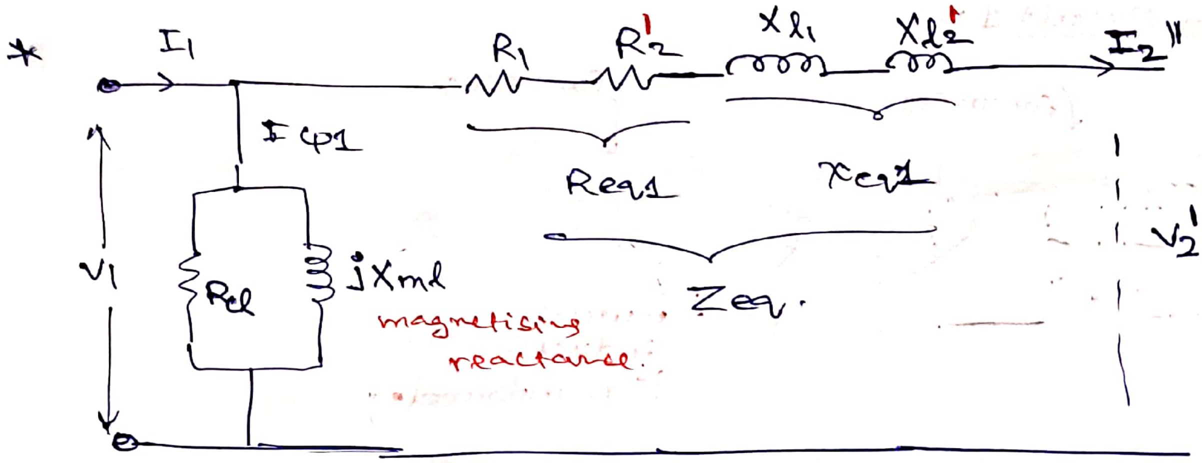
$\neq 0$

* magnetising reactance is jX_{ml}.

I_{ml} = magnetising current.

(PTO : equivalent circuit)

*



now; we need to find these parameters of transformer na!

1) open circuit test. to get R_{c1}, X_{m1}.

2) Short circuit test ✓

→ open circuit test:- (question states whether HV open, or LV open).

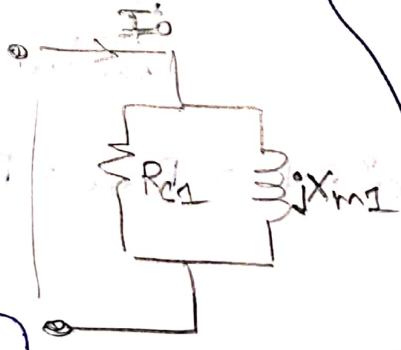
we measure. V_o, I_o (RMS values)

& P_o (average power).

from left side.
could be HV or LV

Excitation current:-
the I_o; when V_o is equal to rating; & secondary is open circuited.

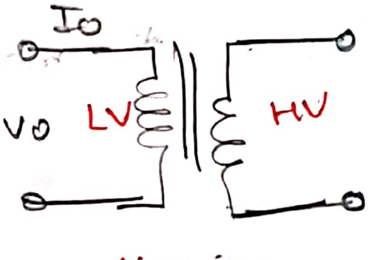
$\therefore P_o = \frac{V_o^2}{R_{c1}}$ o → open.



$$\boxed{R_{c1} = \frac{V_o^2}{P_o}}$$

$$\boxed{X_{m1} = \frac{V_o^2}{Q_o} = \frac{V_o^2}{\sqrt{(V_o I_o)^2 - P_o^2}}}$$

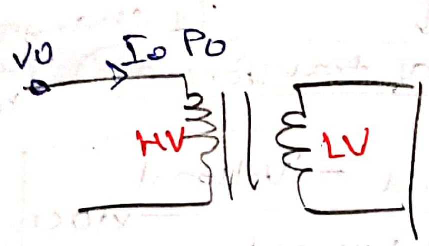
reactive power!

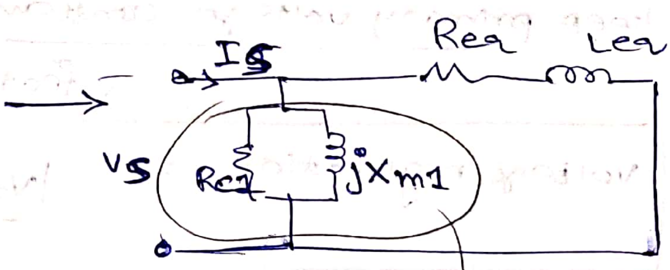


parameters of the transformer ✓✓

I, V, P → reading on Low voltage side.

→ short circuit test:- (question states, whether HV closed or LV closed)





reading on
H.V. side.
⇒ Shorted on
L.V. side.

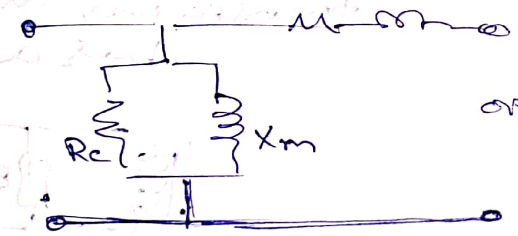
(Ps)

S-short.

ignored? ✓

$$Req = \frac{Ps}{Is^2}$$ ✓

$$Xeq = \sqrt{Zeq^2 - Req^2}\ ;\ Zeq = \frac{Vs}{Is}$$



HV, LV means;

1ϕ, 10KVA, 2200/220 V, 60H

(1ϕ: unity power factor; 10KVA: Prated; 2200: HV; 220: LV; 60H: f.)

$$Znet = \frac{Rc \cdot jXm}{Rc + jXm}$$

$$\boxed{i = \frac{Vrated}{Znet}}$$ → excitation current. | when open circuit secondary.

$$i_{rated} = \frac{Prated}{Vrated}$$

$$\therefore \ \% = \frac{(Vrated)^2}{Znet \cdot Prated}$$

will come same; if we reduce the circuit to HV reffered; or LV reffered.

→ Voltage regulation of transformer:-

* keep primary voltage constant.] feature of transformer — i_1 changes as per needs.

$$\boxed{\text{Voltage regulation} = \frac{|V_2|_{\text{No load}} - |V_2|_{\text{load}}}{|V_2|_{\text{no load}}} \times 100}$$

Exercise:-

Q) $P = 500W$. (load condition: $P_p = P_s$)] under load condition.

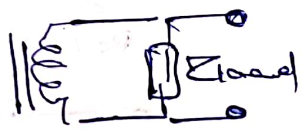
$10:1 \Rightarrow a = 10$.

$V_p = 240\ V_{(rms)}$

calculate percentage regulation; when 1.1Ω load impedance is present.

Sol)

transformer always has a load



i) $L \to \infty$ (open / No load)

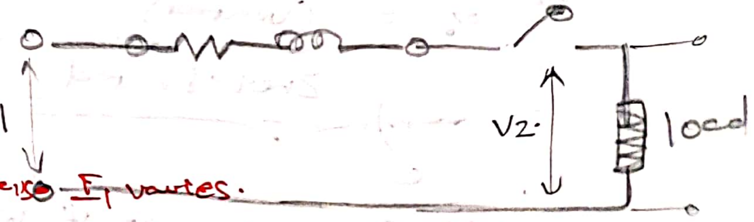
then $V_s = \frac{1}{a} \cdot V_p = 24V$.

(ii) $\boxed{P_s = \frac{(V_s)^2}{Z}}$ wow.... couldn't have done better? → No! can't do better:-

$\Rightarrow V_s = \sqrt{500 \times 1.1} = 23.45V$

the power rating corresponds to the situation when the transformer has load.

$\therefore \%\ Reg = 2.29\%$.



the fact; for the transformer is I_1 varies.

* if V_s rated is given; E_p rated, a given;

we find V_p rated using & then we get this! the $V_{noload} = V_{p\,rated}/a$

→ Efficency of transformer:-

ideally; $Power_{primary} = Power_{secondary}$.

but; $$\boxed{\eta_{efficiency} = \frac{P_{secondary}\ watts}{P_{primary}\ VA}}$$ same essentially but just written.

No moving parts in transformer.

only copper losses & iron losses.

copper losses → winding losses (i^2R)

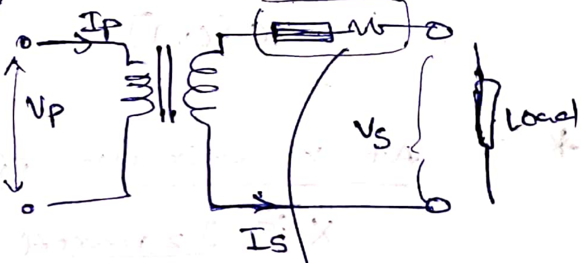
iron losses → core loss $(i^2R) + \{Hys.\}$; (i^2R) → eddy currents.

$$* \quad \eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{core} + P_{Cu}}$$

$P_{out} = V_2 I_2 \cos\theta_2$

$P_{Cu} = I_1^2 \cdot R_{net} \simeq I_2^2 \cdot R'_{net}$; $R'_{net} = R_{eq2}$

effective impedance Z.



$aI_p \simeq I_s$

θ_2 means. this Z_{eff2}'s angle of impedance

$$\therefore \quad \boxed{\eta = \frac{V_2 \cdot I_2 \cdot \cos\theta_2}{V_2 I_2 \cos\theta_2 + P_c + I_2^2 R'_{net2}}}$$

$\frac{d\eta}{dI_2} = 0$

↳ maximum efficency:

$$\boxed{P_{core\ loss} = P_{Cu\ loss}}$$

$\Rightarrow \quad I_2^2 R_{eq2} = \underline{P_c}$; P_c → $\boxed{constant}$

↳ independent of I_1, I_2.

depends on material.

(Bcoz; even though H depends on $I_1 I_2$

B_{max} doesn't

* Full load:-

$$P_{cu,FL} = I_{2,FL}^2 \cdot R_{eq2}$$

full load. → current rating!

at some other load; less than full load:-

$$P_{cu} = I_2^2 R_{eq2}$$

$$\frac{P_{cu}}{P_{cu,FL}} = \left(\frac{I_2}{I_{2,FL}}\right)^2$$

& $X = \dfrac{I_2}{I_{2,FL}}$ = per unit loading

∴ $X \in [0,1]$

* At maximum efficency: (which need not be full load)

X is $\dfrac{I_{2,maxeff}}{I_{2,FL}}$

$P_{cu} = P_c$

$$P_c = I_{2,maxeff}^2 \cdot R_{eq2}$$

$$\boxed{P_c = (X)^2 \cdot P_{cu,FL}}$$

∴ for max efficency;

$$\boxed{X_{max\ eff.} = \left(\frac{P_c}{P_{cu,FL}}\right)^{1/2}}$$

Eg: max. eff = 98%. at $\frac{3}{4}^{th}$ of weighted full load.

(meaning; $I_{2\,now} = \frac{3}{4} I_{2,rated}$.

$\cos\theta_2 = 1$.

$P_{secondary\,now} = \frac{3}{4}(P_{max})$ NO!! or $\frac{3}{4}$@ P_{rated}...)

P_{core} = 314 Watts.

compute

VA. (primary output).

Efficiency; at 50% & 100% load.

Sol) let rated power = S.

$\therefore$ now; $P_{sec.} = \frac{3}{4} S$.

Assumption:
output voltage of transformer is constant; E_1 = rated value. irrespective of what fraction load.

& now; $P_{loss\,Cu} = P_{core}$ = 314 watts.

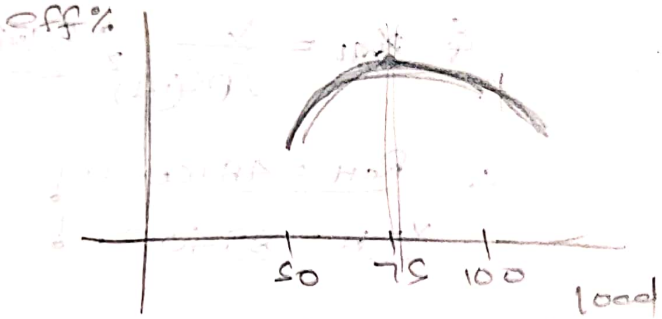
$$\frac{98}{100} = \frac{\frac{3}{4}S \;]\; P_{secondary}}{\frac{3}{4}S + 2(314) \;]\; P_{primary.} = \text{losses} + P_{secondary}}$$

$\Rightarrow$ S = 41029.3 VA.

50% load:

P_{sec} = 20,514.6 W.

P_{core} = 314 W (same)



$P_{cu} = ? \propto I_2^2 \cdot R_{eq2}$.

$P_{cu\,50\%} = \left(\frac{0.5}{0.75}\right)^2 \cdot P_{cu\,75\%}$

$\therefore P_{cu,50\%}$ = 139.6 W.

$$\therefore \text{eff.} = \frac{20514}{20514 + 314 + 139.6} \simeq 97.83\%.$$

100% load:-

$P_{secondary}$ = 41029 P_c = 314 W.

$P_{cu} = \left(\frac{1}{0.5}\right)^2 \cdot 139.6W$

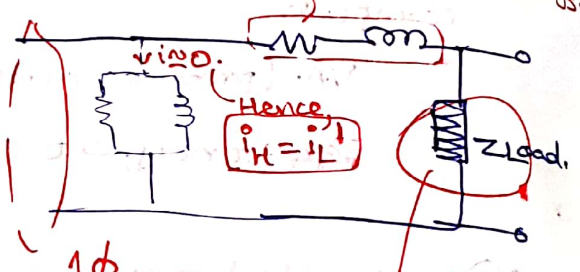
$\therefore \simeq 97\%$

Assignment Q6:-

Tests on a 1ϕ, 10kVA, 2200/220V, 60Hz transformer & the following results came:-

	open (on H.V.)	closed (on L.V.)
voltage	220V	150V
current	2.5A	4.55A
power	100W	215W

right now:- NOT LOAD due to windings.

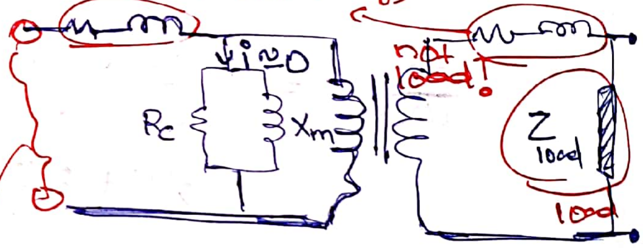


we remove this for opencircuit, closed circuit tests.

a) Find circuit parameters:-

sol) open-circuit test:-

due to winding



primary secondary

P.f. of transistor means;

$\frac{P_{out}}{V_{in} \cdot I_{in}}$ ... magnitudes

$$i_L' = \frac{i_L}{a} \cong i_H$$

$\therefore$ now;

$$Power = \frac{V^2}{R_{CL}}$$

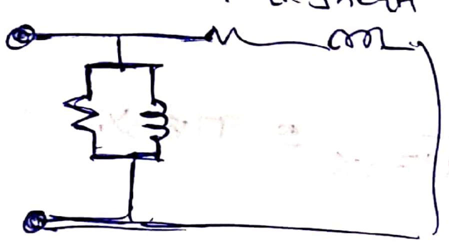
$$\therefore R_{CL} = 484\Omega$$

$$\& \ X_{mL} = \frac{V}{\sqrt{P^2 - (VI)^2}} = 89.4\Omega$$

$$\therefore \ R_{CH} = 48400\Omega. \ !$$

$$X_{mH} = 8940\Omega. \ !$$

Closed circuit:- (on Low)



$$R_{eq_H} = \frac{P}{I^2} = 10.4\Omega$$

$$Z_H = \frac{V}{I} = 32.97\Omega$$

$$X_{eq_H} = 31.3\Omega$$

b) determine voltage regulation.

for the load conditions:

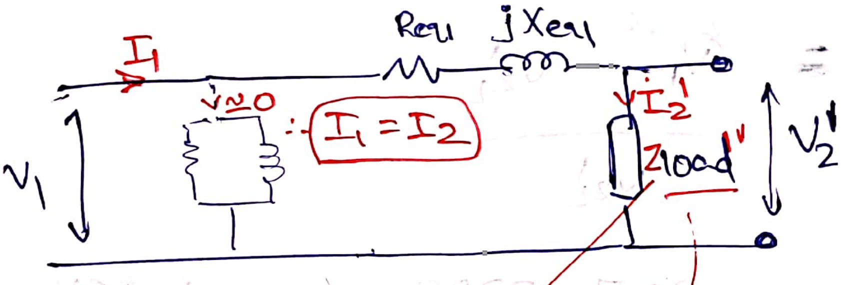
1) 75% full load & 0.6 p.f. lag.

Both I_2, P_2 out is 75% of rated values.

2) 75% full load & 0.6 p.f. lead.

sol)

1)



angle of load impedance.

0.6 is this guy's p.f.

∴ $\cos\theta_2 = 0.6$.

p.f. wont change like $R_{eq}' = a^2 \cdot R_{eq2}$

$\theta_2 = 53^\circ$

$pf_1 = pf_2$ ✓

1) lag: $\Rightarrow$ $I_2' = \frac{V_2'}{|Z_{load}|} \cdot \angle -53^\circ$

instead of this;

do $I_2' = \frac{3}{4} I_2'$ rated

gave this; instead of $|Z_{load}|$.

$= 0.75 \times \frac{10^4}{2200}$

$= 0.75 \times 4.55$

$= 3.41 A.$

$\therefore I_2' = (3.41)\angle -53^\circ = I_1$

Now;

$V_1 = V_2' + I_1 \cdot R_{eq} + I_1 \cdot jX_{eq}$

phase diff. $= -53^\circ$

$= 2200\angle 0^\circ + (3.41)\angle -53^\circ \times 10.4 + (3.41)(31.3) \cdot \angle 90-53^\circ$

$= 2307 \angle 0.9^\circ V$

$\therefore$ Voltage reg. $= \dfrac{(V_2)_{NL} - (V_2)_L}{(V_2)_L}$

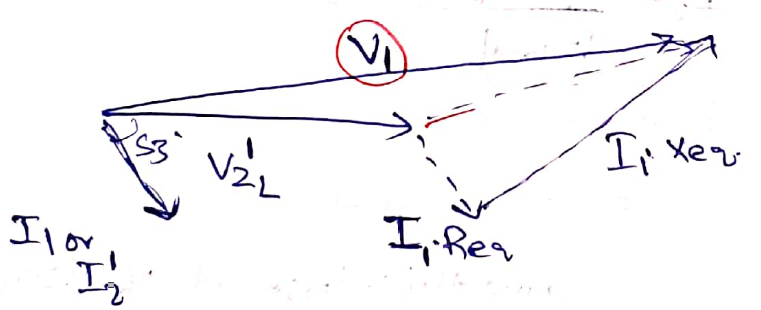
$= \dfrac{V_{2NL}' - V_{2L}'}{V_{2L}'}$ (∵ only a^2 factor)

$= \dfrac{V_1 - V_{2L}'}{V_{2L}'}$

$= \dfrac{2307 - 2200}{2200} \times 100 = \underline{4.86\%}$

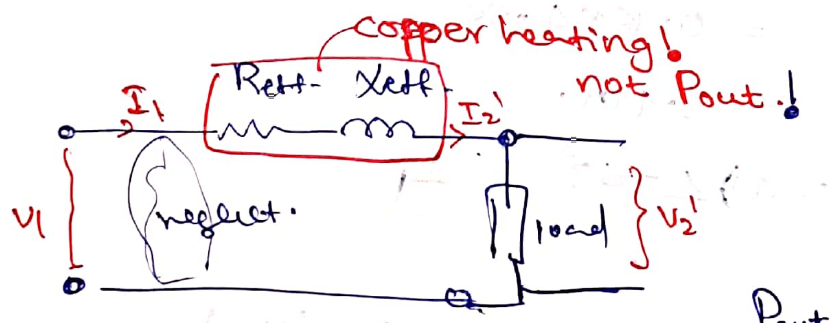
phew!

<u>phasor:</u>



c) efficiency at 75% rated output & <u>0.6 PF</u>.

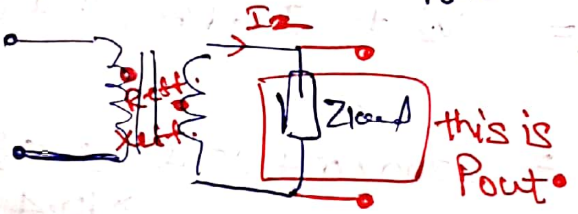
for <u>transformer!</u>



$P_{out} = I_1 V_1 (P.f.)$

$= \underline{I_2 V_2 \ (P.f.)}$

okay!



$P_{out} = V_2 \cdot I_2 \cdot (pf)$

$= V'_{2\,rated} (I'_2 \times 75\%)(0.6)$

$= 2200 \times \frac{10^4}{2200} \times \frac{3}{4} \times 0.6$

$= 4500W$

$P_c = 100W$ given

$P_{copper\,loss}$

$= (I'_2)^2 \cdot R_{eq_1}$

$= (0.75 \times 4.55)^2 \cdot (10.4)$

$= 121 W$

$\therefore \eta = \frac{4500}{4500+221} = 95.32\%$

d) max efficiency!

means;

$P_{copper} = P_{cu} = 100$.

$P.f. = ?$ letswait.

$(I'_2)^2 \cdot (10.4) = 100$

$I'_2 = 3.1A$.

$I_2 = 31A$.

$V_2 = 220$

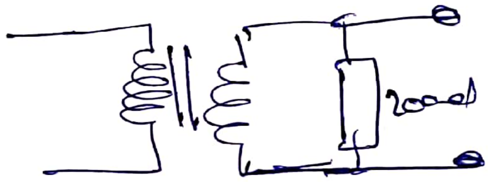
$\therefore \eta = \frac{(220).(31)\cos\theta_2}{6820\cos\theta_2 + 200}$

$\therefore \cos\theta_2 = 1$ for max... ✓

$\eta_{max} = 97.15\%$

Transformer:-

order:



1) V_1

2) $V_2 = a^{-1} V_1$

3) $I_2 = \frac{V_2}{Z_{load}}$

4) $I_1 = \frac{I_2}{a}$.

Sequence of how physical quantities attain Harmony.

* our sources fixes V_1.

But can't fix I_1.

Hence, voltage transformers.

$P_{out} = P_{in} - 200$

$\therefore P_{VA} = 7020$

% load $= \frac{3.1}{4.55} = 68.2\%$