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Internal Assesment Test –II

Sub:	Electric Machine Design (EMD)							Code:	15EE64
Date:	20/ 04/ 2019	Duration:	90 mins	Max Marks:	50	Sem:	6th	Branch:	EEE
Answer any 5 questions from remaining.Sketch figures wherever necessary.									

		Marks	OBE	
			CO	Level
Q1(a)	Explain procedure to determine the no load current of transformer with relevant expression.	[05]	CO5	L2
Q1(b)	A 400 kVA , 6600 V/400 V,50 Hz, delta-star, 3-φ, core type transformer has the following data : width of HV winding=35mm, width of LV winding=26 mm, Height of coils is 0.8 m, length of mean turn=1.0 m, HV winding turns=960, width of duct between LV and HV winding=20 mm. Calculate leakage reactance of the transformer referred to HV side.	[05]	CO5	L3
Q2	List the factors to be considered during the selection of number of poles in DC machines.	[10]	CO4	L1
Q3	Obtain an expression for the leakage reactance of a transformer with primary and secondary coils of equal length.	[10]	CO5	L3

Q4	A 300 kVA 11000/440 V, 50Hz, 3-φ, delta/star, core type oil immersed, self-cooled transformer gave the following results during design calculations of magnetic frame and windings centre to centre distance of cores=36 cm , height of window= 44 cm, height of yoke 17 cm, total weight of magnetic frame =700 kg, average specific iron loss =2.1 W/kg, outer dia of HV winding=35 cm, resistance of LV winding per phase = 0.0047 Ω, resistance of HV winding per phase = 9.74 Ω. Calculate i. Dimensions of tank with clearance of ΔL=8 cm , ΔW=10 cm , ΔH= 45 cm ii. Number of cooling tubes if temperature rise not to exceed 35°C. Assume diameter of cooling tubes as 5 cm and length of cooling tube =95 cm	[10]	CO5	L3
Q5	A single phase, 50 Hz oil cooled core type transformer is built from stampings having a relative permeability of 1000. Length of flux path is 3 m, area of cross section of core is 2.25 *10^{-3} $m^2$and primary winding has 800 turns. Estimate the maximum flux density and no load current of the transformer. Given loss at working flux density is 2.6 w/kg, weighs 7.8*10^3 kg/m^3, stacking factor=0.9.	[10]	CO5	L3
Q6	Determine the main dimensions, number of poles, number of armature conductors, number of slots, conductors per slot and size of armature conductor for a 250 kW, 400 V, 625 A, 600 rpm, lap wound compound generator, assuming following data: average flux density =0.63 T; specific electric loading= 33000 ampere conductors/m, field and armature copper loss = 5 % of output; ratio of pole arc to pole pitch=0.7; pole arc= gross length of armature. Armature drop=3 % of terminal voltage, current density δ= 5 A/mm^2; slot pitch =2.6 cm.	[10]	CO4	L3
Q7 a	From first principles derive output equation of DC Machine.	[04]	CO2	L4
Q7 b	Define specific magnetic loading and specific electrical loading. Also mention the advantages of choice of higher values of specific loadings in the design of any machine.	[06]	CO3	L1

*******All the Best******

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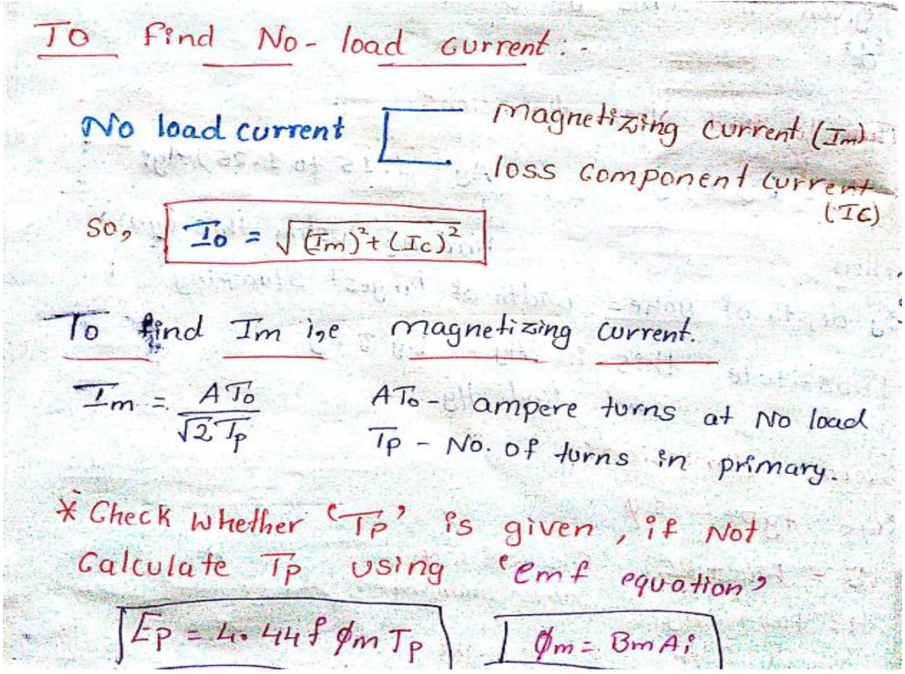
Solution

Q1. (a)



TO find No-load current:-

No load current – magnetizing current (I_m) / loss component current (I_c)

So, $\boxed{I_0 = \sqrt{(I_m)^2 + (I_c)^2}}$

To find I_m i,e magnetizing current.

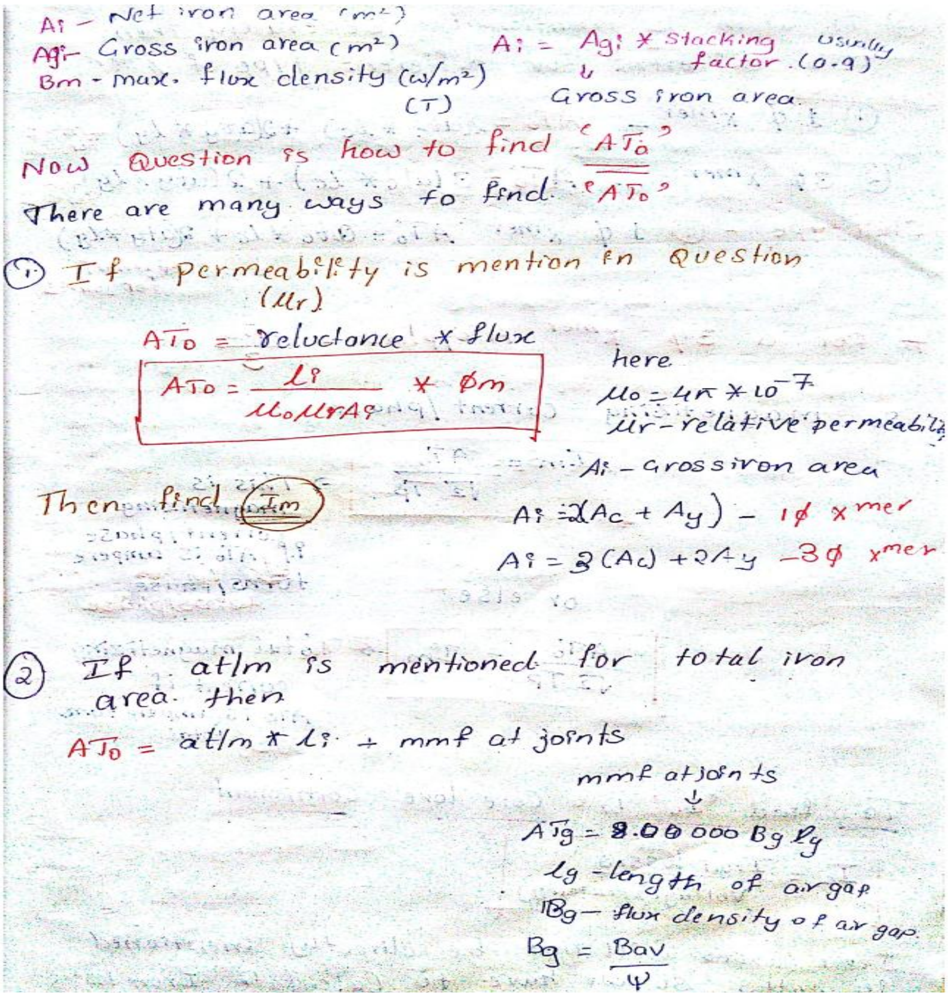
$I_m = \frac{AT_0}{\sqrt{2}\,T_p}$

AT_0 – ampere turns at No load

T_p – No. of turns in primary.

* Check whether 'T_p' is given, if Not Calculate T_p using 'emf equation'

$\boxed{E_p = 4.44 f \phi_m T_p}$ $\boxed{\phi_m = B_m A_i}$



A_i – Net iron area (m^2)

A_{gi} – Gross iron area (m^2)

B_m – max. flux density (w/m^2) (T)

$A_i = A_{gi} * \text{stacking factor}$ usually (0.9)

A_{gi} ↓ Gross iron area.

Now Question is how to find 'AT_0'

There are many ways to find 'AT_0'

① If permeability (μ_r) is mention in Question

AT_0 = reluctance * flux

$\boxed{AT_0 = \frac{l_i}{\mu_0 \mu_r A_i} * \phi_m}$

here

$\mu_0 = 4\pi * 10^{-7}$

μ_r – relative permeability

A_i – Gross iron area

$A_i = 2(A_c + A_y)$ – 1ϕ xmer

$A_i = 3(A_c) + 2A_y$ – 3ϕ xmer

Then find I_m

② If at/m is mentioned for total iron area then

AT_0 = at/m * l_i + mmf at joints

mmf at joints

↓

$AT_g = 8.00\,000\, B_g l_g$

l_g – length of air gap

B_g – flux density of air gap.

$B_g = \frac{B_{av}}{\psi}$

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③ if at/m is mentioned seperately then it's different for different type of x^{mer}

core type

① 1ϕ x^{mer} – $AT_0 = 2(at_c * l_c) + 2(at_y * l_y)$ + mmf for join

② 3ϕ x^{mer} – $AT_0 = 3(at_c * l_c) + 2(at_y * l_y)$ + m for Join

Shell type – ① 1ϕ x^{mer} $AT_0 = at_c * l_c + 2(at_y * l_y)$ + mmf for joints

* For a 3ϕ x^{mer} $AT_0/\text{phase} = \frac{AT_0}{3}$ *

So magnetizing current/phase :

$$\boxed{I_m = \frac{AT_0}{\sqrt{2}\,T_p}}$$ → This is magnetizing current/phase if AT_0 is ampere turns/phase

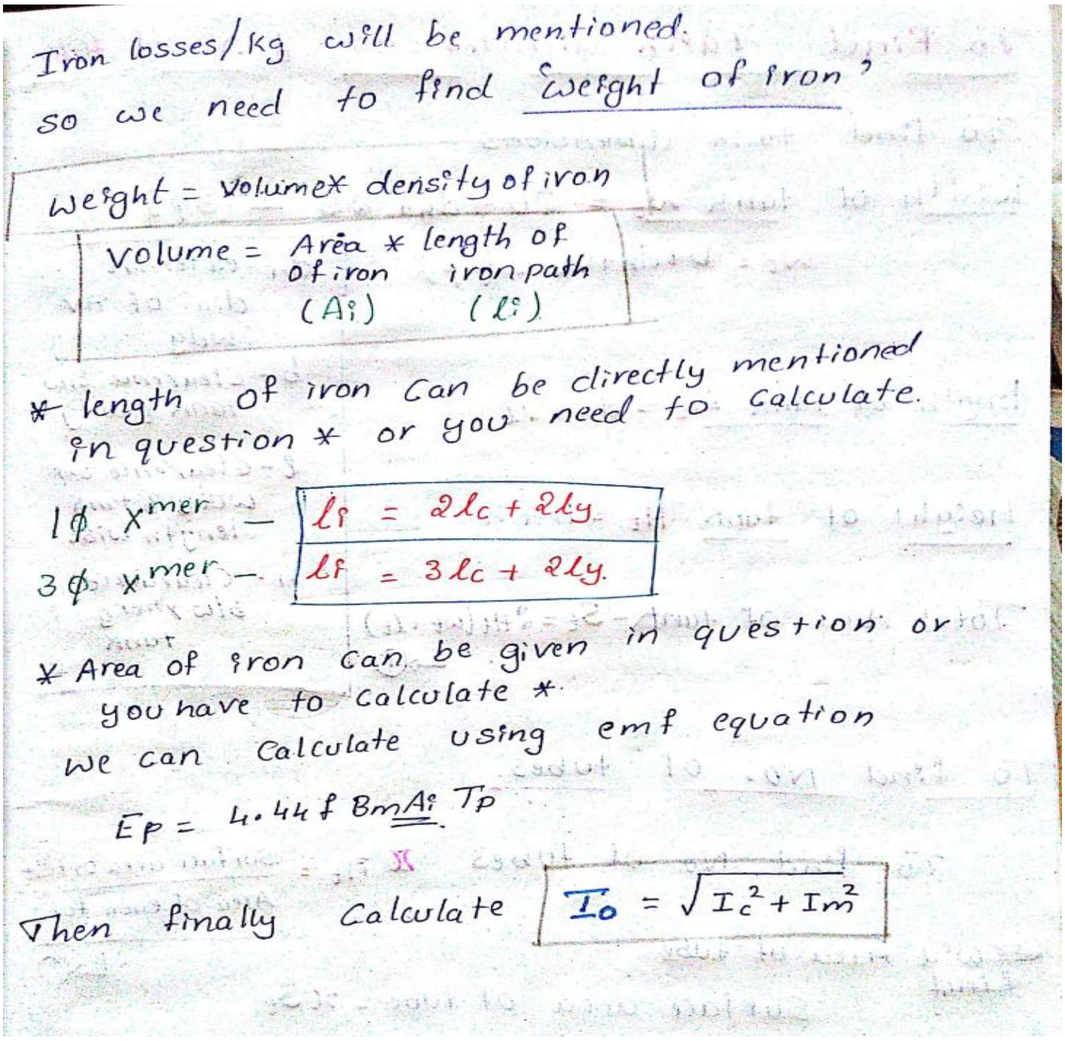
or else

$$\boxed{\frac{AT_0}{\sqrt{2}\,T_p} = I_m}$$ → Total magnetizing current if AT_0 is ampere turns total.

To find 'I_c' i, e Core lore Component

$$\boxed{I_c = \frac{\text{Iron losses}}{\text{Voltage (Primary)}}}$$

Iron losses will not be directly mentioned in watts. so we have to Calculate Iron losses in watts



Iron losses/kg will be mentioned.

so we need to find 'weight of iron'

weight = volume $\times$ density of iron

volume = Area of iron (Ai) $\times$ length of iron path (li)

* length of iron can be directly mentioned in question * or you need to calculate.

1ϕ xmer — $l_i = 2l_c + 2l_y$

3ϕ xmer — $l_i = 3l_c + 2l_y$

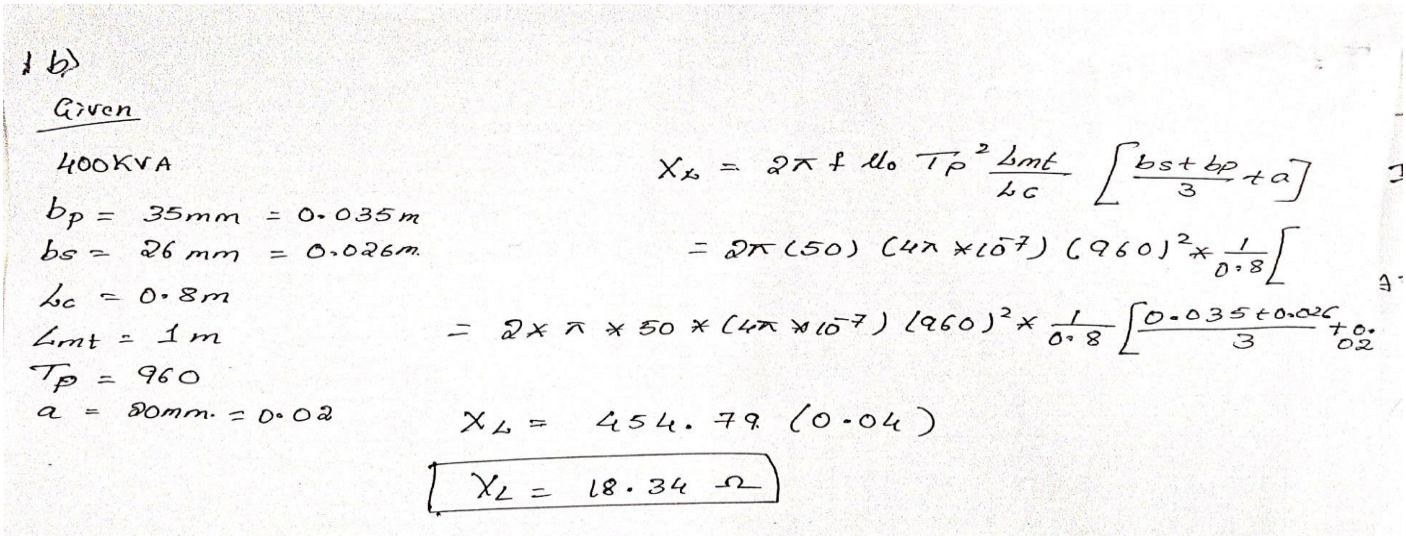
* Area of iron can be given in question or you have to calculate *

we can calculate using emf equation

$E_p = 4.44 f B_m A_i T_p$

Then finally Calculate $\boxed{I_0 = \sqrt{I_c^2 + I_m^2}}$

Q1.b1



1 b)

Given

400 KVA

$b_p = 35mm = 0.035m$

$b_s = 26mm = 0.026m$

$L_c = 0.8m$

$L_{mt} = 1m$

$T_p = 960$

$a = 20mm = 0.02$

$$X_L = 2\pi f \mu_0 T_p^2 \frac{L_{mt}}{L_c}\left[\frac{b_s + b_p}{3} + a\right]$$

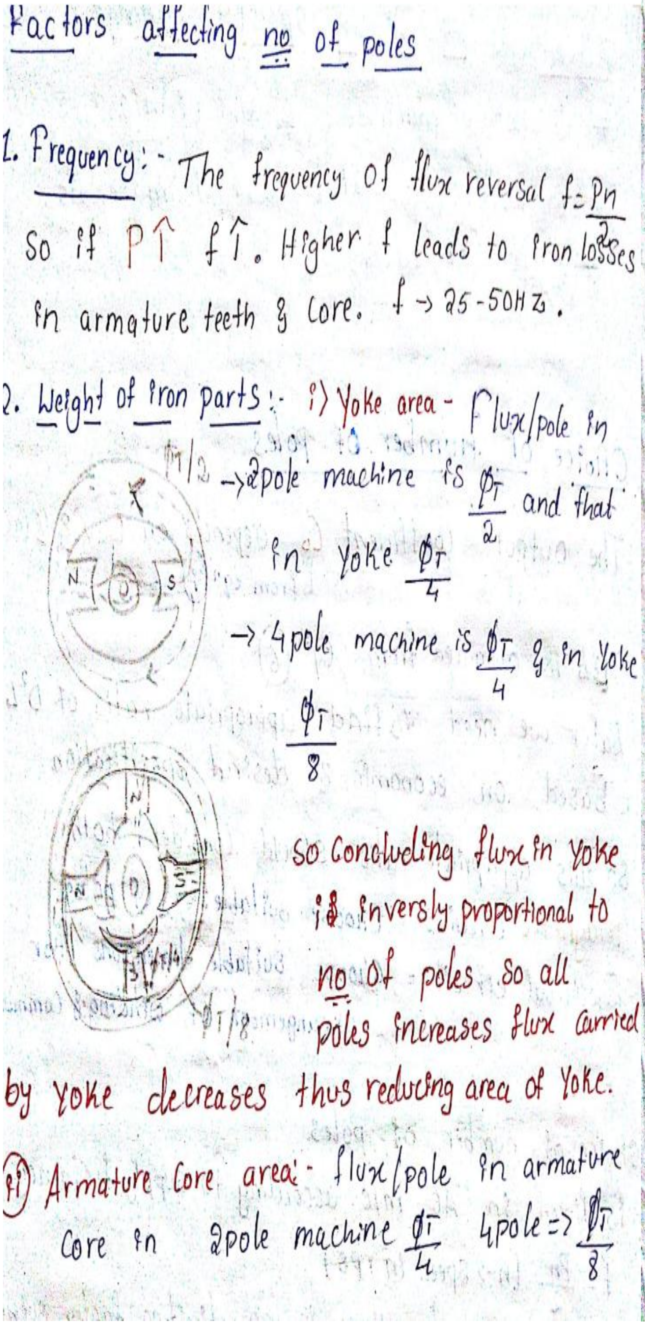
$$= 2\pi(50)(4\pi \times 10^{-7})(960)^2 \times \frac{1}{0.8}\left[\right.$$

$$= 2 \times \pi \times 50 \times (4\pi \times 10^{-7})(960)^2 \times \frac{1}{0.8}\left[\frac{0.035 + 0.026}{3} + 0.02\right.$$

$$X_L = 454.79\,(0.04)$$

$$\boxed{X_L = 18.34\ \Omega}$$

Q2.



Factors affecting no of poles

1. **Frequency:-** The frequency of flux reversal $f = \frac{Pn}{2}$

So if P↑ f↑. Higher f leads to iron losses in armature teeth & core. f → 25-50Hz.

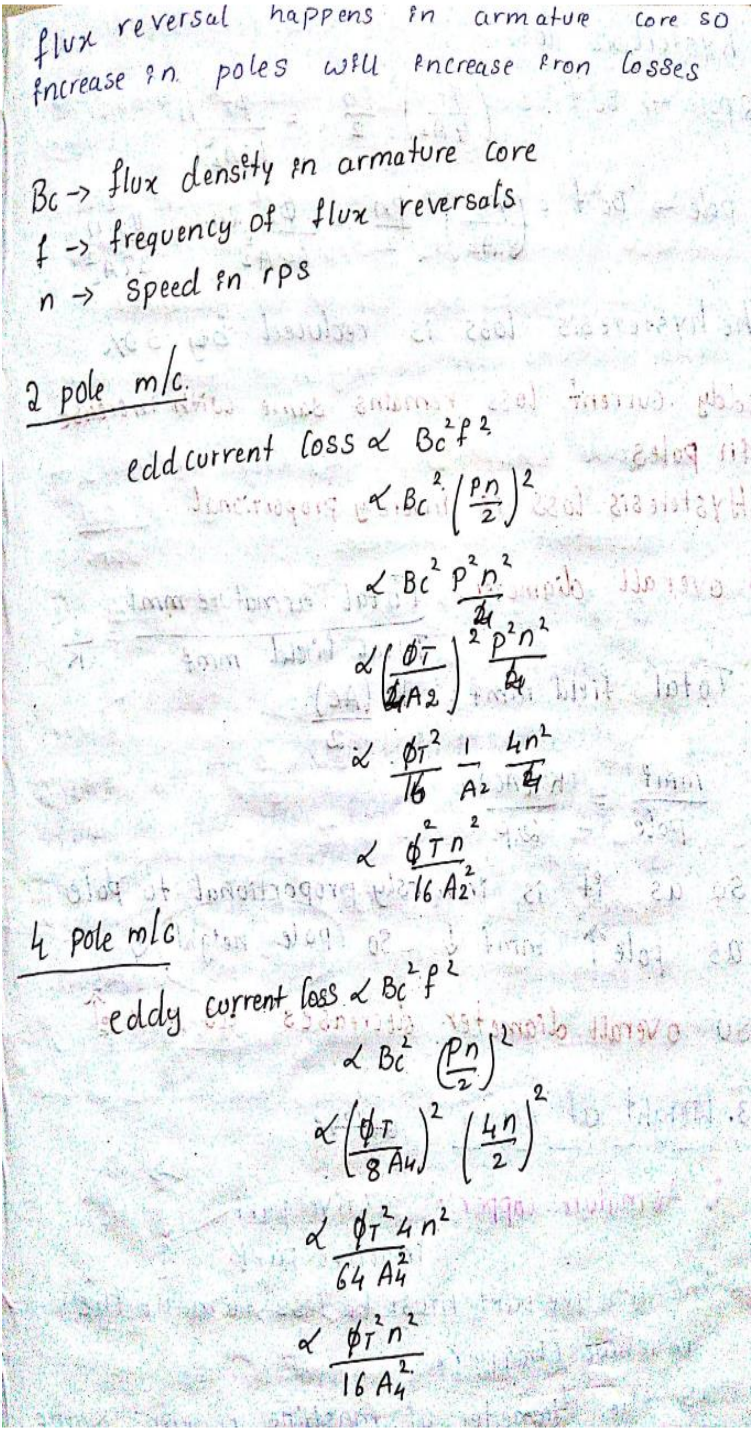
2. **Weight of iron parts:-** i) Yoke area - Flux/pole in m/c

→ 2pole machine is $\frac{\phi_T}{2}$ and that in yoke $\frac{\phi_T}{4}$

→ 4pole machine is $\frac{\phi_T}{4}$ & in Yoke $\frac{\phi_T}{8}$

So concluding flux in yoke is inversly proportional to no of poles so all poles increases flux carried by yoke decreases thus reducing area of Yoke.

ii) Armature Core area:- flux/pole in armature core in 2pole machine $\frac{\phi_T}{4}$ 4pole ⇒ $\frac{\phi_T}{8}$



flux reversal happens in armature core so increase in poles will increase iron losses

B_c → flux density in armature core
f → frequency of flux reversals
n → speed in rps

2 pole m/c.

$$\text{eddy current loss} \propto B_c^2 f^2$$
$$\propto B_c^2 \left(\frac{pn}{2}\right)^2$$
$$\propto B_c^2 \frac{p^2n^2}{4}$$
$$\propto \left(\frac{\phi_T}{4A_2}\right)^2 \frac{p^2n^2}{4}$$
$$\propto \frac{\phi_T^2}{16} \frac{1}{A_2} \frac{4n^2}{4}$$
$$\propto \frac{\phi_T^2 n^2}{16 A_2^2}$$

4 pole m/c

$$\text{eddy current loss} \propto B_c^2 f^2$$
$$\propto B_c^2 \left(\frac{pn}{2}\right)^2$$
$$\propto \left(\frac{\phi_T}{8A_4}\right)^2 \left(\frac{4n}{2}\right)^2$$
$$\propto \frac{\phi_T^2 4n^2}{64 A_4^2}$$
$$\propto \frac{\phi_T^2 n^2}{16 A_4^2}$$

hysteresis loss

2 pole → $B_c^2 f = \left(\frac{\phi_T}{4A_2}\right)^2 \frac{Pn}{2} = \frac{\phi_T^2 n}{16A_2^2}$

4 pole → $B_c^2 f = \left(\frac{\phi_T}{8A_2}\right)^2 \frac{Pn}{2} = \frac{\phi_T^2 2n}{64A_2^2} = \frac{\phi_T^2 n}{32A_2^2}$

The hysteresis loss is reduced by 50%.

eddy current loss remains same with increase in poles

Hysteresis loss is inversly proportional.

③ overall diameter:- $\frac{\text{Total armature mmf}}{\text{Total field mmf}} = \frac{1}{K}$

Total field mmf = $K\frac{(AC)}{2}$

$\frac{mmf}{pole} = \frac{K(AC)}{2.P}$

so as it is inversly proportional to pole

as pole ↑ mmf ↓ so $\boxed{\text{pole height}}$ ↓ — reason.

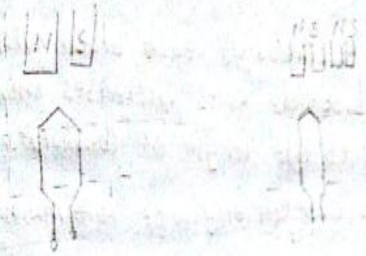
so overall diameter decreases as pole no ↑

3. Weight of Copper ~~active~~

i) Armature copper:- active part
inactive part

The inactive part must be less to make the machine cheaper.

as the diameter of machine remains Same if No of poles increases the pole pitch decreases thus decreasing the ovehang (inactive part of machine) length, so this will reduce the copper & overall length of machine



So increase in number of poles. reduces weight of copper and also overall length of machine is reduced.

ⓑ Field copper:- As we have previously seen the field mmf is inversly proportional to poles, for two poles the area of crossection of each pole is more, while that of 4 pole is less, so the total field copper decreases with increase in number of poles., as increase in pole number decreases the pole height also.

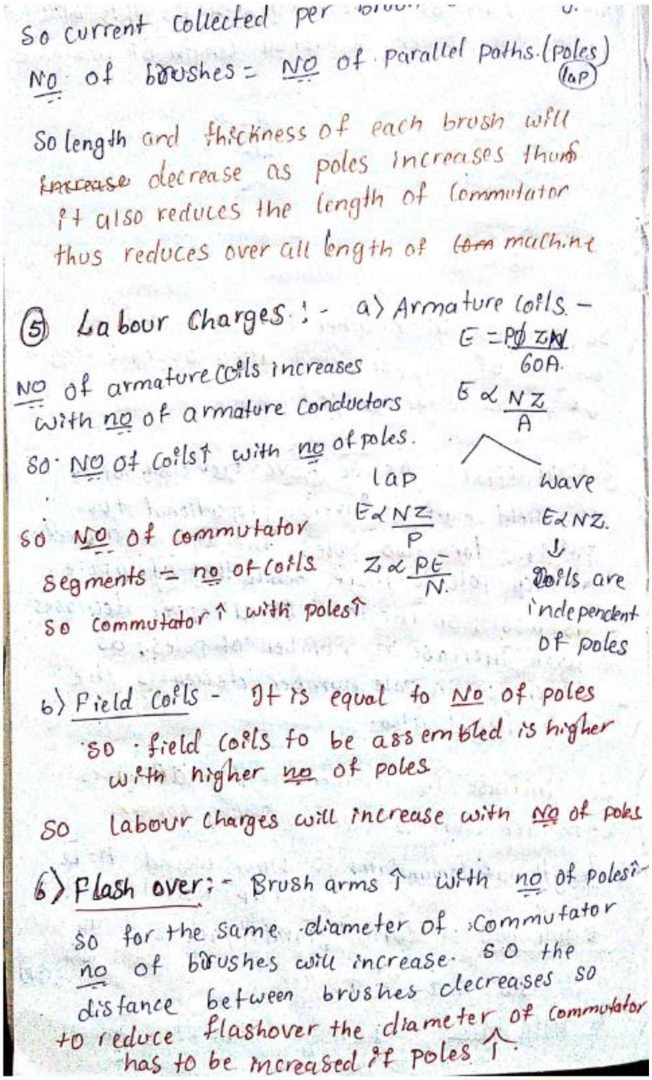
So increase in number of poles decreases both armature & field winding copper.

4. length of Commutator :- Wave wound A = 2
Lap wound A = P.

2 pole m/c :- current / parallel path $I_z = \frac{I_a}{2}$ (∵ A=P)

$I_b = 2I_z = I_a$.

4 pole m/c. $I_z = \frac{I_a}{4}$. $I_b = 2I_z = \frac{I_a}{2}$



So current collected per

NO of brushes = NO of parallel paths. (poles) (lap)

So length and thickness of each brush will ~~increase~~ decrease as poles increases thus it also reduces the length of commutator thus reduces over all length of ~~com~~ machine

⑤ Labour Charges :- a) Armature coils. -

$E = \frac{P\phi ZN}{60A}$

NO of armature coils increases with no of armature conductors

$E \propto \frac{NZ}{A}$

so NO of coils↑ with no of poles.

lap

$E \propto \frac{NZ}{P}$

$Z \propto \frac{PE}{N}$

wave

$E \propto NZ.$

↓

coils are independent of poles

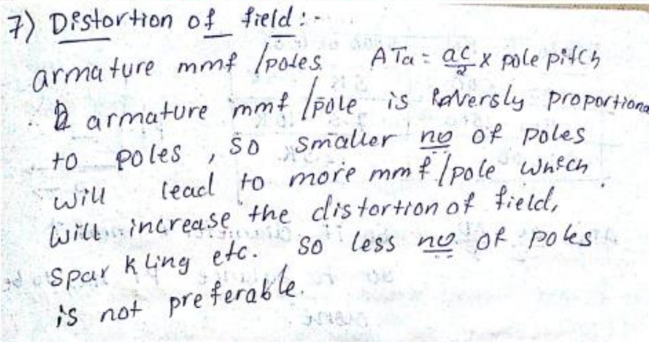
so NO of commutator segments = no of coils

so commutator ↑ with poles↑

b) Field coils - It is equal to NO of poles so field coils to be assembled is higher with higher no of poles

So labour charges will increase with NO of poles

6) Flash over:- Brush arms ↑ with no of poles↑ so for the same diameter of commutator the no of brushes will increase. so the distance between brushes decreases so to reduce flashover the diameter of commutator has to be increased if poles ↑.

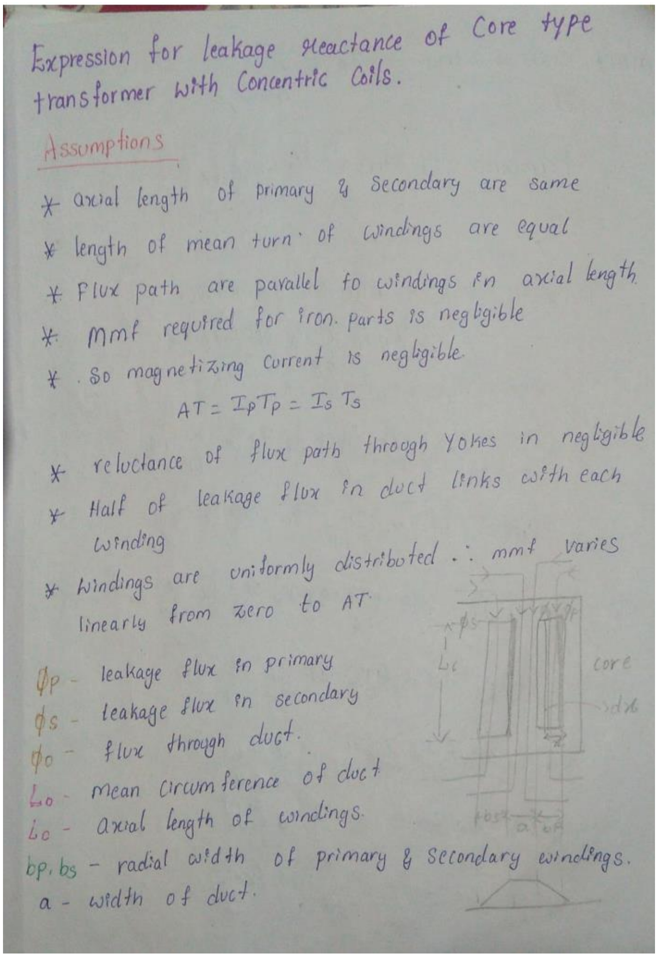


7) Distortion of field:-

armature mmf /poles $AT_a = \frac{ac}{2} \times$ pole pitch

∴ armature mmf /pole is inversly proportional to poles, so smaller no of poles will lead to more mmf /pole which will increase the distortion of field, sparking etc. so less no of poles is not preferable.

Q3.



Expression for leakage reactance of Core type transformer with Concentric Coils.

Assumptions

- * axial length of primary & Secondary are same
- * length of mean turn of windings are equal
- * Flux path are parallel to windings in axial length
- * mmf required for iron parts is negligible
- * So magnetizing current is negligible

$$AT = I_p T_p = I_s T_s$$

- * reluctance of flux path through Yokes in negligible
- * Half of leakage flux in duct links with each winding
- * Windings are uniformly distributed ∴ mmf varies linearly from zero to AT

ϕ_p - leakage flux in primary

ϕ_s - leakage flux in secondary

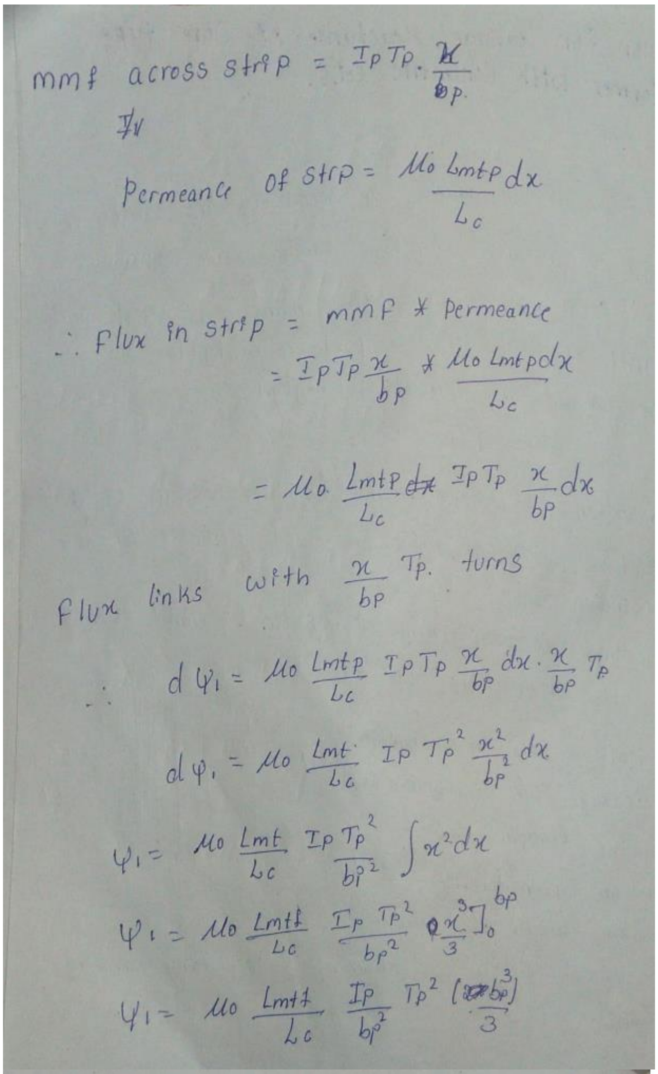
ϕ_0 - flux through duct.

L_0 - mean circumference of duct

L_c - axial length of windings.

b_p, b_s - radial width of primary & secondary windings.

a - width of duct.



mmf across strip $= I_p T_p \cdot \frac{x}{b_p}$

$\cancel{\Psi}$

Permeance of strip $= \frac{\mu_0 L_{mtp}\, dx}{L_c}$

$\therefore$ Flux in strip = mmf * Permeance

$$= I_p T_p \frac{x}{b_p} * \frac{\mu_0 L_{mtp}\, dx}{L_c}$$

$$= \mu_0 \frac{L_{mtp}}{L_c} \cancel{dx}\, I_p T_p \frac{x}{b_p} dx$$

Flux links with $\frac{x}{b_p} T_p$. turns

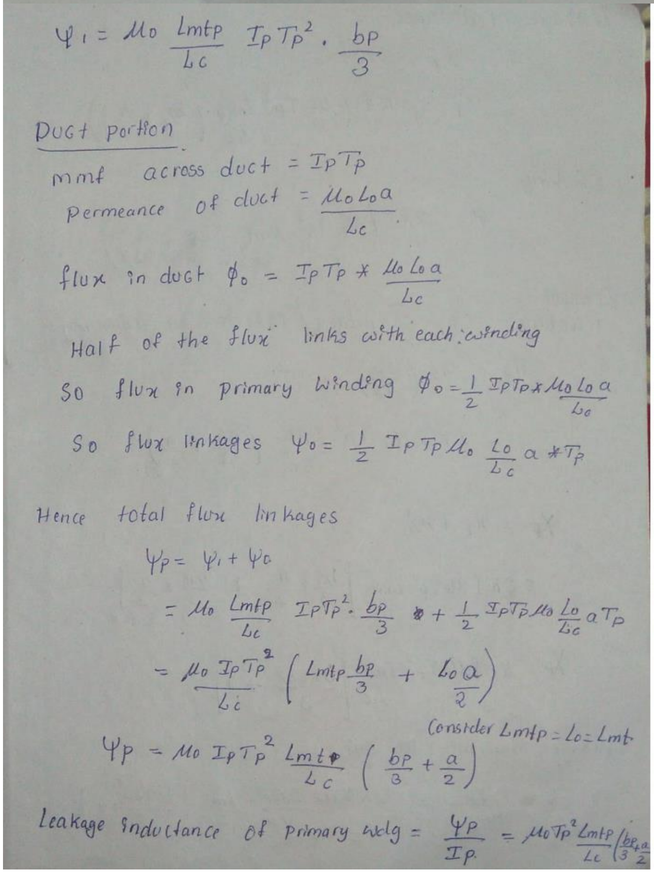
$$\therefore d\psi_1 = \mu_0 \frac{L_{mtp}}{L_c} I_p T_p \frac{x}{b_p} dx \cdot \frac{x}{b_p} T_p$$

$$d\psi_1 = \mu_0 \frac{L_{mt}}{L_c} I_p T_p^2 \frac{x^2}{b_p^2} dx$$

$$\psi_1 = \mu_0 \frac{L_{mt}}{L_c} \frac{I_p T_p^2}{b_p^2} \int x^2 dx$$

$$\psi_1 = \mu_0 \frac{L_{mt}}{L_c} \frac{I_p T_p^2}{b_p^2} \left[\frac{x^3}{3}\right]_0^{b_p}$$

$$\psi_1 = \mu_0 \frac{L_{mt}}{L_c} \frac{I_p}{b_p^2} T_p^2 \left(\frac{b_p^3}{3}\right)$$



$$\psi_1 = \mu_0 \frac{L_{mtp}}{L_c} I_p T_p^2 \cdot \frac{b_p}{3}$$

<u>Duct portion</u>

mmf across duct $= I_p T_p$

Permeance of duct $= \frac{\mu_0 L_0 a}{L_c}$

flux in duct $\phi_0 = I_p T_p * \frac{\mu_0 L_0 a}{L_c}$

Half of the flux links with each winding

So flux in primary winding $\phi_0 = \frac{1}{2} I_p T_p * \frac{\mu_0 L_0 a}{L_c}$

So flux linkages $\psi_0 = \frac{1}{2} I_p T_p \mu_0 \frac{L_0}{L_c} a * T_p$

Hence total flux linkages

$$\psi_p = \psi_1 + \psi_0$$

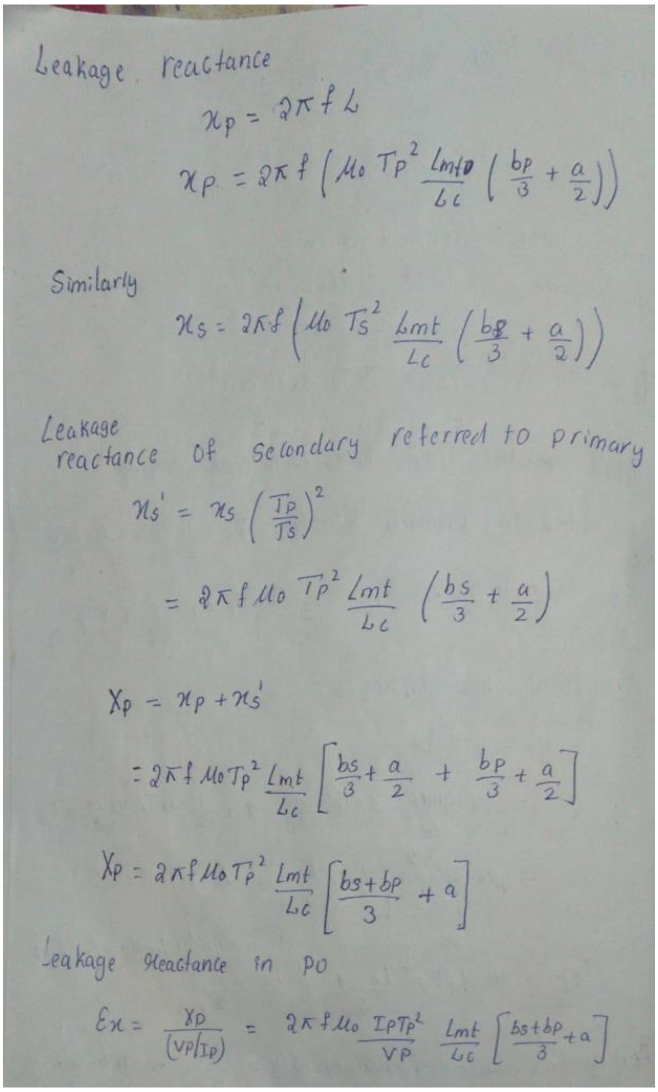
$$= \mu_0 \frac{L_{mtp}}{L_c} I_p T_p^2 \cdot \frac{b_p}{3} + \frac{1}{2} I_p T_p \mu_0 \frac{L_0}{L_c} a T_p$$

$$= \frac{\mu_0 I_p T_p^2}{L_c} \left(L_{mtp} \frac{b_p}{3} + \frac{L_0 a}{2} \right)$$

Consider $L_{mtp} = L_0 = L_{mt}$

$$\psi_p = \mu_0 I_p T_p^2 \frac{L_{mt}}{L_c} \left(\frac{b_p}{3} + \frac{a}{2} \right)$$

Leakage inductance of primary wdg $= \frac{\psi_p}{I_p} = \mu_0 T_p^2 \frac{L_{mtp}}{L_c} \left(\frac{b_p}{3} + \frac{a}{2}\right.$



Leakage reactance

$$x_p = 2\pi f L$$

$$x_p = 2\pi f \left(\mu_0 T_p^2 \frac{L_{mtp}}{L_c} \left(\frac{b_p}{3} + \frac{a}{2} \right) \right)$$

Similarly

$$x_s = 2\pi f \left(\mu_0 T_s^2 \frac{L_{mt}}{L_c} \left(\frac{b_s}{3} + \frac{a}{2} \right) \right)$$

Leakage reactance of secondary referred to primary

$$x_s' = x_s \left(\frac{T_p}{T_s} \right)^2$$

$$= 2\pi f \mu_0 T_p^2 \frac{L_{mt}}{L_c} \left(\frac{b_s}{3} + \frac{a}{2} \right)$$

$$X_p = x_p + x_s'$$

$$= 2\pi f \mu_0 T_p^2 \frac{L_{mt}}{L_c} \left[\frac{b_s}{3} + \frac{a}{2} + \frac{b_p}{3} + \frac{a}{2} \right]$$

$$X_p = 2\pi f \mu_0 T_p^2 \frac{L_{mt}}{L_c} \left[\frac{b_s + b_p}{3} + a \right]$$

Leakage Reactance in PU

$$\varepsilon_x = \frac{X_p}{(V_p/I_p)} = 2\pi f \mu_0 \frac{I_p T_p^2}{V_p} \frac{L_{mt}}{L_c} \left[\frac{b_s + b_p}{3} + a \right]$$

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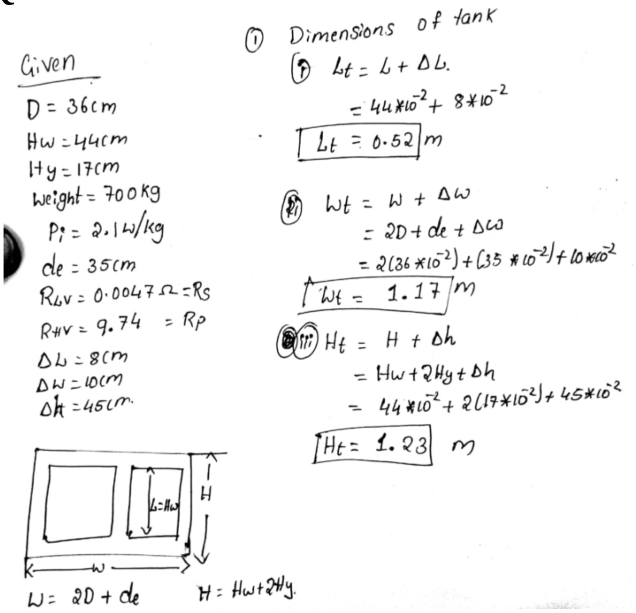
Q4.



Given

$D = 36cm$
$H_w = 44cm$
$H_y = 17cm$
weight = 700kg
$P_i = 2.1 W/kg$
$d_e = 35cm$
$R_{LV} = 0.0047 \Omega = R_s$
$R_{HV} = 9.74 = R_p$
$\Delta L = 8cm$
$\Delta W = 10cm$
$\Delta h = 45cm$

$W = 2D + d_e$ $\quad H = H_w + 2H_y$

① Dimensions of tank

(i) $L_t = L + \Delta L$

$= 44*10^{-2} + 8*10^{-2}$

$\boxed{L_t = 0.52}\ m$

(ii) $W_t = W + \Delta W$

$= 2D + d_e + \Delta W$

$= 2(36*10^{-2}) + (35*10^{-2}) + 10*10^{-2}$

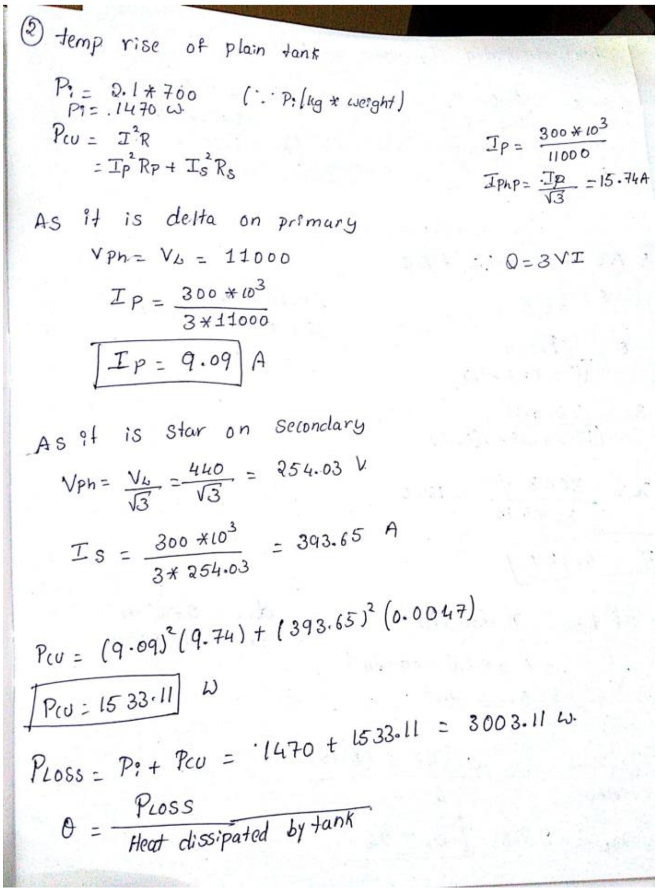
$\boxed{W_t = 1.17}\ m$

(iii) $H_t = H + \Delta h$

$= H_w + 2H_y + \Delta h$

$= 44*10^{-2} + 2(17*10^{-2}) + 45*10^{-2}$

$\boxed{H_t = 1.23}\ m$



② temp rise of plain tank

$P_i = 2.1 * 700$ $\quad$ ($\because P_i$/kg * weight)
$P_i = 1470\ W$

$P_{cu} = I^2R$

$= I_p^2 R_p + I_s^2 R_s$

$I_p = \frac{300*10^3}{11000}$

$I_{php} = \frac{I_p}{\sqrt{3}} = 15.74A$

As it is delta on primary

$V_{ph} = V_L = 11000$ $\quad \because Q = 3VI$

$I_p = \frac{300*10^3}{3*11000}$

$\boxed{I_p = 9.09}\ A$

As it is star on secondary

$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{440}{\sqrt{3}} = 254.03\ V$

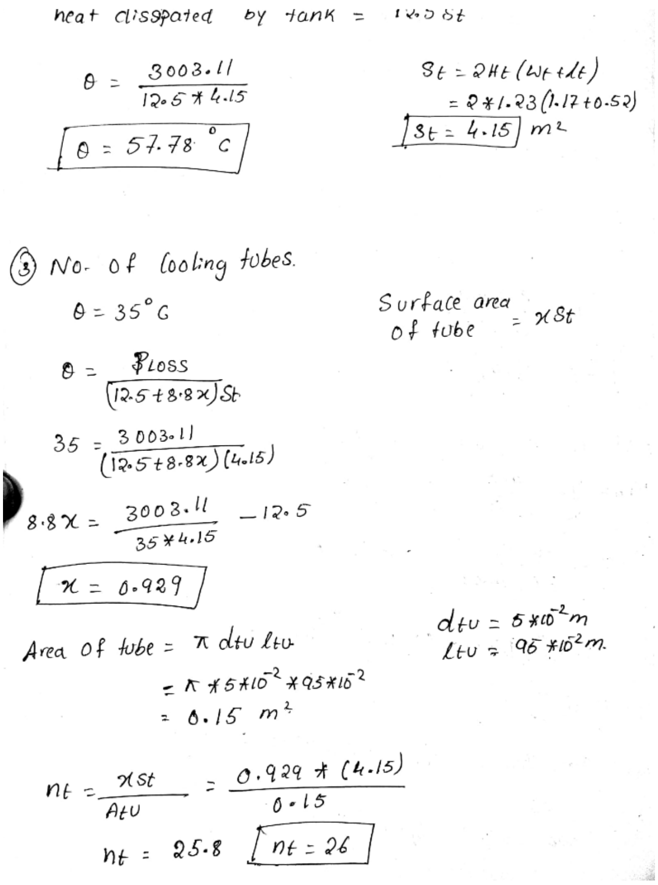
$I_s = \frac{300*10^3}{3*254.03} = 393.65\ A$

$P_{cu} = (9.09)^2(9.74) + (393.65)^2(0.0047)$

$\boxed{P_{cu} = 1533.11}\ W$

$P_{LOSS} = P_i + P_{cu} = 1470 + 1533.11 = 3003.11\ W.$

$\theta = \frac{P_{LOSS}}{\text{Heat dissipated by tank}}$



heat dissipated by tank = 12.5 St

$\theta = \frac{3003.11}{12.5 * 4.15}$

$\boxed{\theta = 57.78\ ^\circ C}$

$S_t = 2H_t(W_t + L_t)$

$= 2*1.23(1.17+0.52)$

$\boxed{S_t = 4.15}\ m^2$

③ No. of cooling tubes.

$\theta = 35^\circ C$

Surface area of tube $= x S_t$

$\theta = \frac{P_{LOSS}}{(12.5 + 8.8x)S_t}$

$35 = \frac{3003.11}{(12.5+8.8x)(4.15)}$

$8.8x = \frac{3003.11}{35*4.15} - 12.5$

$\boxed{x = 0.929}$

Area of tube $= \pi d_{tu} l_{tu}$

$= \pi * 5*10^{-2} * 95*10^{-2}$

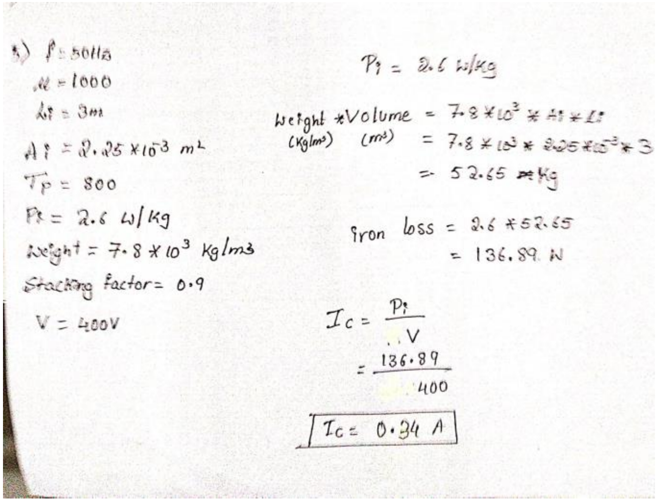
$= 0.15\ m^2$

$d_{tu} = 5*10^{-2} m$
$l_{tu} = 95*10^{-2} m.$

$n_t = \frac{x S_t}{A_{tu}} = \frac{0.929 * (4.15)}{0.15}$

$n_t = 25.8$ $\quad \boxed{n_t = 26}$

Q5.



5) $f = 50Hz$
$N = 1000$
$L_i = 3m$
$A_i = 2.25*10^{-3}\ m^2$
$T_p = 800$
$P_i = 2.6\ W/Kg$
weight = $7.8*10^3\ Kg/m^3$
Stacking factor = 0.9
$V = 400V$

$P_i = 2.6\ W/kg$

Weight * Volume $= 7.8*10^3 * A_i * L_i$
(Kg/m³) (m³)
$= 7.8*10^3 * 2.25*10^{-3} * 3$
$= 52.65\ Kg$

Iron loss $= 2.6 * 52.65$
$= 136.89\ W$

$I_c = \frac{P_i}{V}$

$= \frac{136.89}{400}$

$\boxed{I_c = 0.34\ A}$

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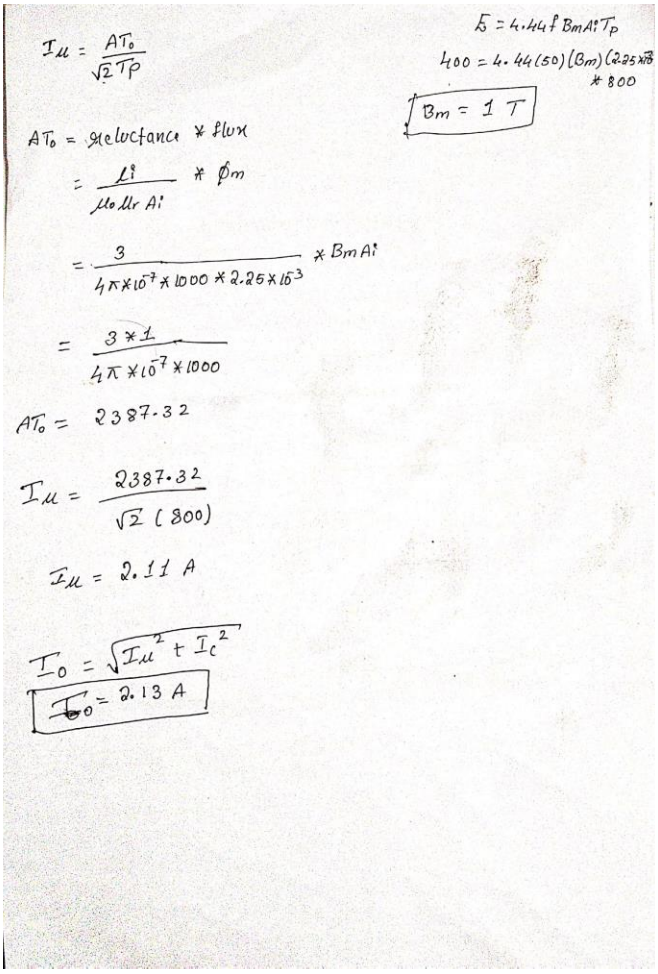


$E = 4.44 f B_m A_i T_p$

$400 = 4.44(50)(B_m)(2.25 \times 10^{-3}) * 800$

$\boxed{B_m = 1\ T}$

$I_\mu = \frac{AT_0}{\sqrt{2} T_p}$

AT_0 = reluctance * flux

$= \frac{l_i}{\mu_0 \mu_r A_i} * \phi_m$

$= \frac{3}{4\pi \times 10^{-7} \times 1000 * 2.25 \times 10^{-3}} * B_m A_i$

$= \frac{3 * 1}{4\pi \times 10^{-7} \times 1000}$

$AT_0 = 2387.32$

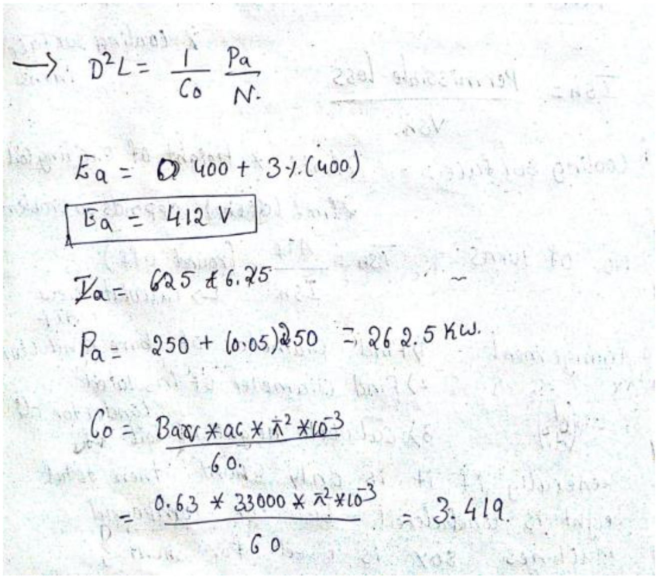
$I_\mu = \frac{2387.32}{\sqrt{2}(800)}$

$I_\mu = 2.11\ A$

$I_0 = \sqrt{I_\mu^2 + I_c^2}$

$\boxed{I_0 = 2.13\ A}$

Q6.



$\rightarrow D^2 L = \frac{1}{C_0} \frac{P_a}{N}$

$E_a = 400 + 3\%(400)$

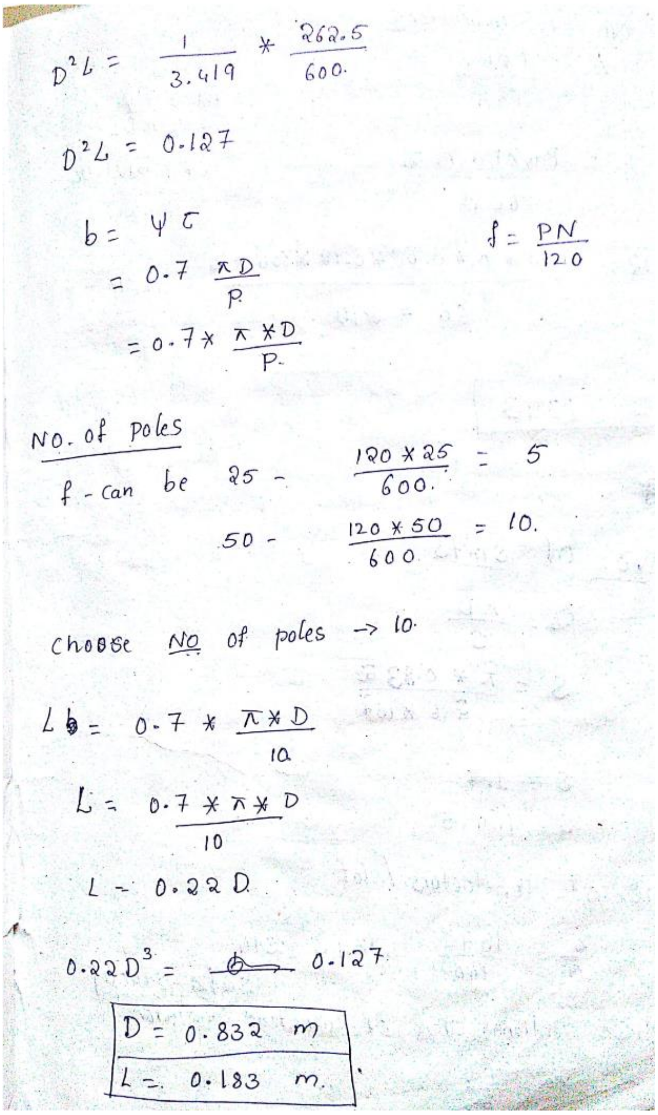
$\boxed{E_a = 412\ V}$

$I_a = 625 \angle 6.75$

$P_a = 250 + (0.05)250 = 262.5$ KW.

$C_0 = \frac{B_{av} * ac * \pi^2 * 10^{-3}}{60}$

$= \frac{0.63 * 33000 * \pi^2 * 10^{-3}}{60} = 3.419$



$D^2 L = \frac{1}{3.419} * \frac{262.5}{600}$

$D^2 L = 0.127$

$b = \psi \tau$

$f = \frac{PN}{120}$

$= 0.7 \frac{\pi D}{P}$

$= 0.7 \times \frac{\pi * D}{P}$

No. of poles

f - can be 25 - $\frac{120 * 25}{600} = 5$

50 - $\frac{120 * 50}{600} = 10$.

choose No of poles → 10.

$L = 0.7 * \frac{\pi * D}{10}$

$L = \frac{0.7 * \pi * D}{10}$

$L = 0.22 D$

$0.22 D^3 = 0.127$

$\boxed{D = 0.832\ m}$

$\boxed{L = 0.183\ m.}$

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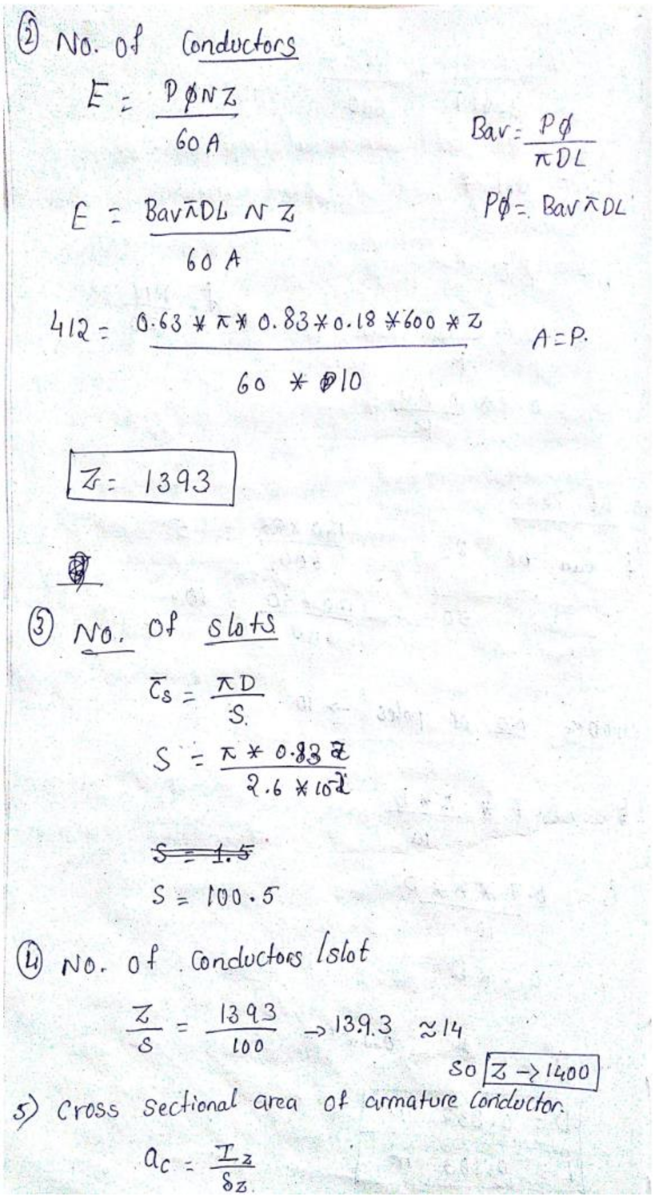


② No. of Conductors

$$E = \frac{P\phi N Z}{60A}$$

$$B_{av} = \frac{P\phi}{\pi D L}$$

$$P\phi = B_{av}\pi D L$$

$$E = \frac{B_{av}\pi D L\, N Z}{60A}$$

$$412 = \frac{0.63 * \pi * 0.83 * 0.18 * 600 * Z}{60 * 10}$$

$A = P.$

$$\boxed{Z = 1393}$$

③ No. of slots

$$\tau_s = \frac{\pi D}{S}$$

$$S = \frac{\pi * 0.83}{2.6 * 10^{-2}}$$

~~S = 1.5~~

$S = 100.5$

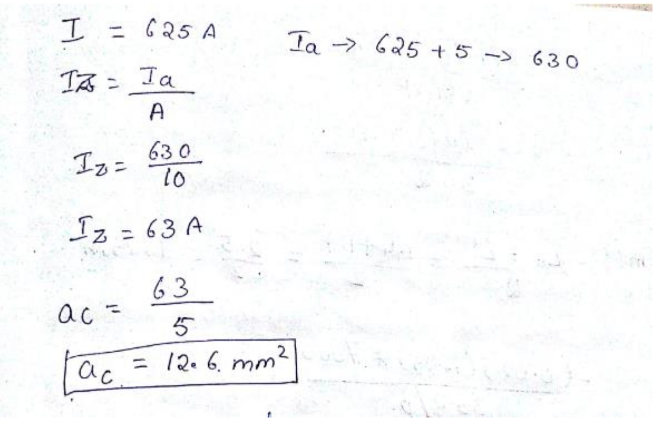
④ No. of conductors /slot

$$\frac{Z}{S} = \frac{1393}{100} \rightarrow 139.3 \approx 14$$

so $\boxed{Z \rightarrow 1400}$

5) Cross sectional area of armature conductor

$$a_c = \frac{I_z}{\delta_z}$$



$I = 625\ A$ $\quad I_a \rightarrow 625 + 5 \rightarrow 630$

$$I_z = \frac{I_a}{A}$$

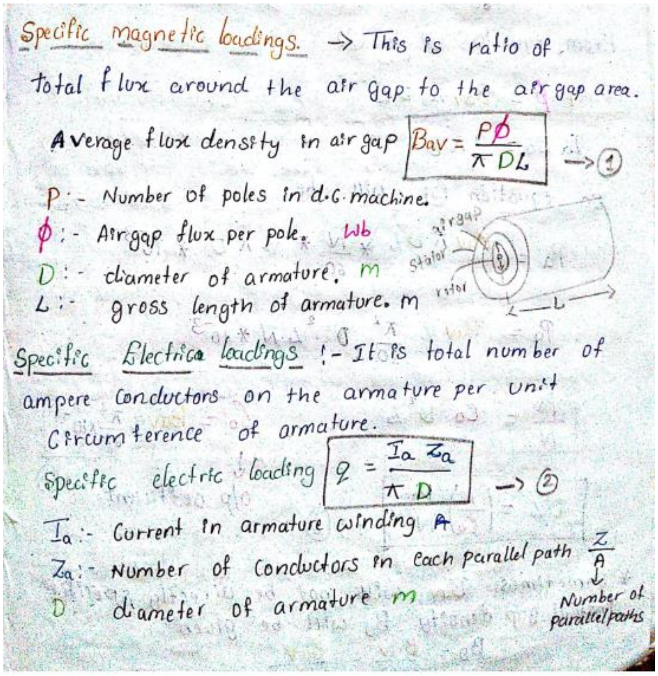
$$I_z = \frac{630}{10}$$

$I_z = 63\ A$

$$a_c = \frac{63}{5}$$

$$\boxed{a_c = 12.6\ mm^2}$$

Q7 a.



Specific magnetic loadings. → This is ratio of total flux around the air gap to the air gap area.

Average flux density in air gap $\boxed{B_{av} = \frac{P\phi}{\pi D L}} \rightarrow$ ①

P :- Number of poles in d.c. machine.

ϕ :- Airgap flux per pole. Wb

D :- diameter of armature. m

L :- gross length of armature. m

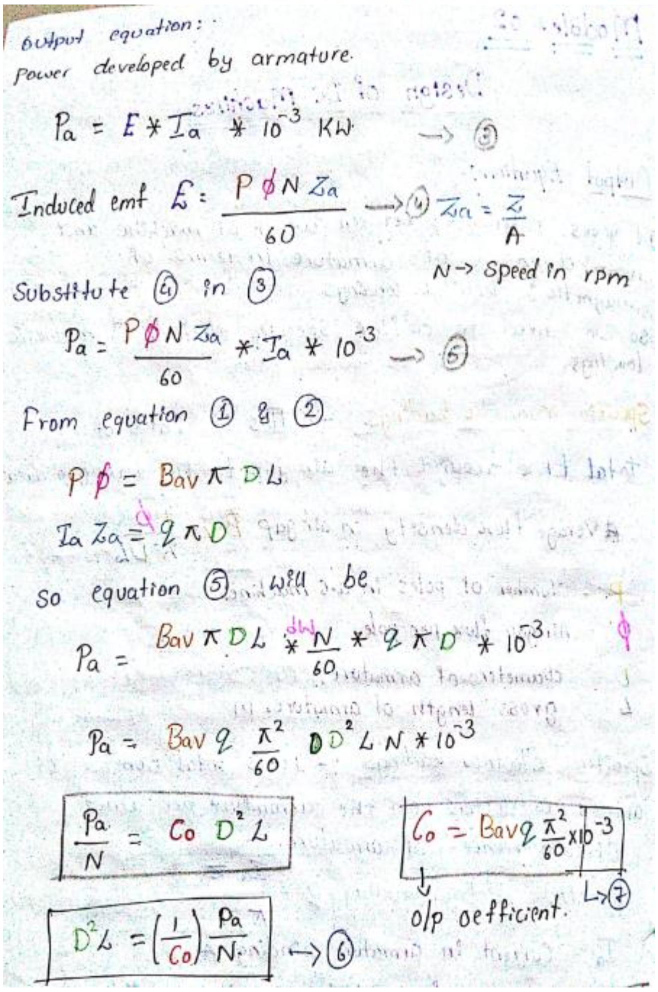
Specific Electrical loadings :- It is total number of ampere conductors on the armature per unit circumference of armature.

Specific electric loading $\boxed{q = \frac{I_a Z_a}{\pi D}} \rightarrow$ ②

I_a :- Current in armature winding A

Z_a :- Number of conductors in each parallel path $\frac{Z}{A}$ ↓ Number of parallel paths

D :- diameter of armature m



Output equation:

Power developed by armature.

$$P_a = E * I_a * 10^{-3}\ KW \rightarrow ③$$

Induced emf $E = \frac{P\phi N Z_a}{60} \rightarrow$ ④ $\quad Z_a = \frac{Z}{A}$

N → Speed in rpm

Substitute ④ in ③

$$P_a = \frac{P\phi N Z_a}{60} * I_a * 10^{-3} \rightarrow ⑤$$

From equation ① & ②

$$P\phi = B_{av}\pi D L$$

$$I_a Z_a = q\pi D$$

So equation ⑤ will be

$$P_a = B_{av}\pi D L * \frac{N}{60} * q\pi D * 10^{-3}$$

$$P_a = B_{av}\, q\, \frac{\pi^2}{60} D^2 L N * 10^{-3}$$

$$\boxed{\frac{P_a}{N} = C_o D^2 L} \qquad \boxed{C_o = B_{av}\, q\, \frac{\pi^2}{60} \times 10^{-3}} \rightarrow ⑦$$

↓ o/p oefficient.

$$\boxed{D^2 L = \left(\frac{1}{C_o}\right)\frac{P_a}{N}} \rightarrow ⑥$$

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Q7. b

Choice of Specific Loadings

Both magnetic and electrical loadings play a important role in design of dc machine.

These loadings also depend on certain factors which are listed below:-

Choice of average gap density (Specific magnetic loadings)

i) Flux density in teeth:- Flux density at root of teeth should not be > 2.2T. if mmf increases field Copper loss will increase. Iron losses will also increase at higher flux density.

ii) Frequency:- frequency of reversals $f = \frac{Pn}{2}$ if this is higher, it will increase iron losses in both armature & field. We should not use ~~Frequency reversals increases with increase in flux density~~ high Bav in f↑ machine.

iii) Size of machine:-

In a well designed machine we have max. flux density in teeth Compared to air gap. so we have to relate B_t & B_{av}.

Flux over one slot pitch $= \frac{P\phi}{S}$

* The max. Valve of flux density occurs at Smallest tooth width.

For smaller machines the variation in tooth width is seen, so as B_t increases to maintain the ratio B_{av} must be reduced

∴ Smaller machines have lower specific magnetic loadings.

Disadvantages due to higher Specific magnetic loading.

* Increased noise, iron loss, copper loss
* mmf requirement is more, so no load current is more
* Higher tooth flux density (B_t)
* Increased temperature due to losses.
* Saturation of magnetic parts.

Choice of Ampere Conductors per metre (Specific Electrical loadings)

Factors that influence AC/m

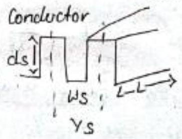
Temperature rise limit:-

$$ac = \frac{I_a Z_a}{\pi D} = \frac{I_a Z_a/s}{\pi D/s} = \frac{I_z Z_s}{Y_s}.$$

$$I^2R \text{ loss} = I_a^2\left(\frac{\rho L}{a_z}\right)$$ in slot portion of each conductor

$$= I_a^2 \frac{\rho l}{Z}$$ in each conductor

$$= \frac{Z_s I_a^2 \rho L}{a_z}$$ each solt



Heat dessipating Surface $= Y_s L$

$$\text{Loss dessipated } q = \frac{\text{loss}}{\text{surface}} = \frac{Z_s I_a^2 \rho L}{a_z Y_s L}$$

$$= \frac{I_a^2 Z_a \rho}{Y_s a_z}$$

$$ac = \frac{I_a Z_s}{Y_s}$$

1) Temperature rise → Insulating material plays an important role Semi closed machines are good.

2) Speed of machine:- with good ventilation more 'ac' can be used

3) Voltage:- Larger space is required for insulation So less space for conductors

4) Armature reaction:- as 'ac' increases conductor's mmf increase, which inturn increases field mmf hence cost is increased.

5) Commutation: $ac = \frac{I_z Z}{\pi D}$ small D & higher Z for higher ac (reason (inductance

⑥ Size of machine :·

Area of each slot = height of slot * width of slot

$d_s * w_s$

Total area of all slots = $S d_s w_s$

$= \frac{\pi D}{y_s} d_s w_s S_f$

Total area of conductors = $Z a_s$

$= Z(I_z/\delta) \cancel{a_s}$

$\frac{I_z}{a_s} = \delta \quad ac = \frac{I_z Z}{\pi D}$

$= ac \frac{\pi D}{\delta} \cancel{a_s}$

$$\pi D \frac{ac}{\delta} = \frac{\pi D}{y_s} d_s w_s S_f$$

$$ac = \delta \frac{\pi D}{y_s} d_s S_f w_s$$

~~ac =~~

Disadvantages due to higher specific electrical loading

* Increased field excitation, ↑ field cu loss.
* ↑ armature copper loss.
* ↑ reactance voltage ↓ commutation.
* ↑ temperature.
* reduced overload capacity

Advantages of higher specific loadings

* ↓ size of machine, weight of m/c
* lower overall cost, cost of materials
* volume of m/c