Menoufiya University *Faculty of Engineering* *Shebin El-Kom* *First Semester Examination* *Academic Year: 2013-2014*	Minufiya University	*Year:2014* *Department: Electrical Engineering* *Subject:Design of Electrical Machines* *Time Allowed: 3 hours* *Date: 13/1/2014*

Allowed Tables and Charts: None

Answer the following questions ***(25 Marks)***

Question (1), Transformers

(a) Prove that the transformer - leakage reactance is given by,

$$X_{eq1} = 2\pi f \mu_o W_1^2 \frac{\ell_{mt}}{L_c}\left(a' + \frac{b_1 + b_2}{3}\right)$$

where f is the frequency, W_1 is the number of primary turns per phase, ℓ_{mt} is the length of mean turn, L_c is the height of winding, a' is the separation between *l.v.* and *h.v.* windings, b_1 is width of the primary winding and b_2 is the width of the secondary winding.

(b) Calculate the following for *a 25 kVA, 11000/433 V, 50 Hz, 3 – phase, delta/star, core type, oil immersed, natural cooled distribution transformer:* (i) the diameter of the circumscribing circle, maximum width, window dimensions, and distance between centers of adjacent centers if the shape of core section is cruciform with $E_t = 2.25\,V$ and, $B_m = 1\,\mathrm{T}$, $K_w = 0.18$, $J = 2.3\ A/mm^2$ and $L = 2.5w$, (ii) total width, height and depth of the transformer core if the yoke is rectangular and $A_{yi} = 1.2A_i$ and $k_i = 0.9$, (iii) the per unit resistance if $\rho = 0.021\ \Omega \cdot mm^2/m$, the inner and outer diameters of low voltage winding are 138 mm, and 156.2 mm respectively, and inner and outer diameters of high voltage winding are 186.2 mm and 239 mm respectively, (iv) the per unit reactance if $\ell_{mt} = 592\,mm$, $L_c = 253\,mm$ and $a' = 15\,mm$, (v) the instantaneous radial force on *h.v. winding* under short circuit conditions.

Question (2), DC – Machines ***(25 Marks)***

Find suitable values for the number of poles, armature diameter, length of the armature core, slots of *a 1000-kW, 500-V, 300-rpm,* dc-generator fitted with interpoles and 5 ventilating ducts of 9 mm each, assuming an average flux density over the armature periphery of 0.7 T, ampere conductors per meter of the armature periphery of 40,000, the full load efficiency is 94%, the pole face is square, ΔV = 2% from the terminal voltage, $\frac{S}{2p} \geq 9$ and α' = 0.7. Find also the flux density at one third from the narrow end of armature teeth if the slot depth and width are 50 mm and 11 mm respectively, and the iron factor $k_i = 0.9$. Voltage between two adjacent commutator segments should not exceed 15 V at no load.

Question (3), Induction Machines **(25 Marks)**

(a) *Derive the output equation of ac machines.*

(b) *A 2.2 kW, 400 V, 3 – phase, 50 Hz,* 4 – pole, squirrel cage induction motor is to be started by a star/delta starter and having an efficiency and power factor of 0.8 and 0.825 respectively at full load and there is no ventilating ducts, find: (i) the stator diameter and length if $B_{av} = 0.44\_T$, $ac = 21000\_A/m$, ratio $L/\tau_p = 1.5$ starting your calculations with $k_w = 0.955$, (ii) number of turns per phase, and number of conductors per slot if $q_1 = 2$, (iii) the fixed winding factor if the coils are chorded by one slot, the conductor – cross sectional area, slot area if $J_1 = 4\_A/mm^2$ and the slot - space factor is 0.4, (iv) the stator outside diameter if $h_{s1} = 21\_mm$, $k_i = 0.9$ and $B_{c1} = 1.2\_T$, and (v) the rotor resistance per phase referred to the stator side and full – load slip neglecting the rotational losses if $S_2 = 22$, $J_b = J_e = 6\_A/mm^2$, $\rho = 0.021\_\Omega.mm^2/m$, $\ell_b = 165\_mm$, and $D_e = 76\_mm$.

Question (4), Synchronous Machines **(25 Marks)**

(a) *Draw an equivalent circuit to the synchronous machine in case of sub-transient and transient conditions.*

(b) A *30,000 kVA, 11 kV, 3000 rpm, 50 Hz, 3* – phase alternator having $B_{av} = 0.55$ *T*, $ac = 54000$ *A/m*, $k_w = 0.955$, neglecting air gap - length find: (i) the main dimensions if the peripheral speed is about *130 m/s*, (ii) the number of turns and conductors per slot if q = 5 and the stator employs single-circuit, single - layer winding, (iii) k_{eav} , k_{eov}, and R_{ac} if $\ell_{mt} = 2L + 2.5\tau_p + 0.06kV + 0.2\_m$, the current density $J_c = 3\ A/mm^2$, $b_c = 30\ mm$, $b_s = 40\ mm$ and each conductor is divided into 6 strips, (iv) F_a, F_f, A_{cuf}, S_2, τ_{s2}, a_f, Z_f, Z_{s2}, W_f, *and* G_{cuf} *if* $F_f \approx 2\ F_a$, $J_f = 2.5\ A/mm^2$ and $\ell_{mf} = 2L + 2.3\tau' + 0.24\_(m)$, $\tau' = 2\tau_p/3$, assuming $\rho = 0.021\_\Omega.mm^2/m$ and the exciter voltage = 220 V where 80% of this voltage is applied to the field winding and 20% is kept in reserve, (v) the order of slot harmonics, skewing angle to eliminate the lower order and its effect on the higher order.

Good Luck Every One

This exam measures the following ILOs

Question number	***1***	***2***	***3***	***4***
Skills	*a14-4, b13-4, c2-1, c10-1, c16-1*	*a14-1, b13-1, c2-1, c10-1, c16-1*	*a14-3, b13-3, c2-1, c10-1, c16-1*	*a14-2, b13-2, c2-1, c10-1, c16-1*