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UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE TATI (UC TATI)

FINAL EXAMINATION QUESTION BOOKLET

COURSE CODE	: DEE 3103
COURSE	: ELECTRICAL MACHINE
SEMESTER/SESSION	: 1-2024/2025
DURATION	: 3 HOURS

Instructions:

1. This booklet contains 4 questions. Answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise up your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

THIS BOOKLET CONTAINS 8 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

a) State **two (2)** comparisons between dc motor and dc generator. (4 marks)

b) Figure 2 show the commutation action in a dc machine. Describe the process based on Figure 2. (12 marks)

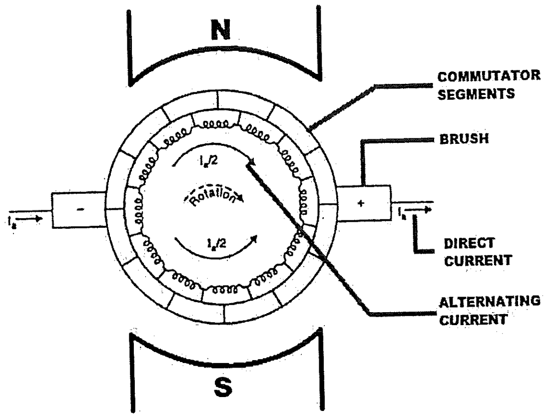

Figure 2

c) A voltage of 220 V is applied to the armature of shunt DC motor results in full load line currents of 20A. Assume that armature and field resistance are 0.6Ω and 440Ω respectively. Assuming the stray losses is 132 W at full load speed of 750rpm.

Calculate:

i. The armature current of the motor (4 marks)
ii. The back e.m.f of the motor (3 marks)
iii. The mechanical power and mechanical torque (3 marks)
iv. The output power and torque (2 marks)
v. The motor efficiency (2 marks)

QUESTION 2

a) Define transformer (4 marks)

b) The measurement test has been conducted on 1500VA 230/115-V single phase transformer to determine the parameter of the transformer. The results of the test have been given as:

Open-Circuit (OC) Test	Short-Circuit (SC) Test
P_{OC} = 30W	P_{SC} = 20.1W
V_{OC} = 230V	V_{SC} = 13.2V
I_{OC} = 0.45A	I_{SC} = 6.52A

All data given were taken from the primary side of transformer.

i. Calculate the equivalent circuit of this transformer referred to high voltage side. (15 marks)

ii. Produce equivalent circuit referred to high voltage side and insert all the values in it. (3 marks)

iii. Determine the approximate value of secondary voltage at full load of 0.8 lagging power factor, when primary supply is 230V. (5 marks)

vi. Determine voltage regulation of the transformer using equivalent circuit. (3 marks)

QUESTION 3

a) State how the direction of induction motor can be reversed. (3 marks)

b) Describe **four (4)** comparisons of induction motor and synchronous motor. (8 marks)

c) There are two types of rotor construction used for induction motors. Briefly explain:

i. Squirrel cage rotor (3 marks)
ii. Slip ring rotor (2 marks)

d) The full load output power to 8 pole, 50 Hz three-phase induction motor is 50kW and has a slip of 0.04 when operating at full load conditions. Assume the stator losses equal the rotor losses. The friction and windage loss are 100W.

Calculate:

i. Synchronous speed (1 marks)
ii. Rotor speed (2 marks)
iii. Mechanical power developed by the motor. (2 marks)
iv. Rotor copper losses (3 marks)
v. Rotor power input (2 marks)
vi. Stator power input (2 marks)
vii. Efficiency (2 marks)

QUESTION 4

a) List **three (3)** differences between servo and stepper motor (6 marks)

b) Describe the synchronous reluctance motor (4 marks)

--End of question--------------------------------------

TABLE OF FORMULAS

Transformer	
$a = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$	$E = 4.44fN\Phi_m$
$VA = V_1I_1 = V_2I_2$	$pf = \cos\theta$
$R_2{}' = a^2R_2$	$X_2{}' = a^2X_2$
$R_{01} = R_1 + R_2{}'$	$X_{01} = X_1 + X_2{}'$
$Z_{01} = R_{01} + jX_{01}$	$Z_{SC} = \left(\frac{V_{SC}}{I_{SC}}\right)\angle\theta_{SC}$
$I_C = I_{OC}\cos\theta_{OC}$	$I_m = I_{OC}\sin\theta_{OC}$
$R_C = \frac{V_{OC}}{I_C}$	$X_m = \frac{V_{OC}}{I_m}$
$R_c{}' = a^2R_c$	$X_m{}' = a^2X_m$
$V.R = \frac{V_{NL} - V_{FL}}{V_{NL}} \times 100\%$	$V.R = \frac{V_{FL} - V_{NL}}{V_{FL}} \times 100\%$
$V.R = \frac{V_{SC}\cos(\theta_{SC} \mp \theta_{pf})}{V} \times 100\%$	$V.R = \frac{I_1[R_{01}\cos\theta_{pf} \pm X_{01}\sin\theta_{pf}]}{V_1} \times 100\%$
$\eta_{FL} = \frac{VA\cos\theta}{VA\cos\theta + P_{sc} + P_{oc}} \times 100\%$	$\eta_{(load\ n)} = \frac{nVA\cos\theta}{nVA\cos\theta + n^2P_{sc} + P_{oc}} \times 100\%$
$P_{OC} = V_{OC}I_{OC}\cos\theta_{OC}$	$P_{SC} = V_{SC}I_{SC}\cos\theta_{SC}$
$V_1\angle 0° = (I_1\angle \mp \theta_{pf})(R_{01} + jX_{01}) + aV_2$	

DC Machines				
DC Generator	$E = \frac{\emptyset PNZ}{60A}$	Lap type: $E = \frac{\emptyset NZ}{60}$	Wave type: $E = \frac{\emptyset PNZ}{120}$	
DC Motor	$E_b = K_1K_2i_a\varpi$			
Series Motor	$V_T = E_b + i_a(R_a + R_f) + V_{brush}$			$P_{in} = V_Ti_L$ $P_m = E_bi_a$ $P_{out} = P_{in} - \sum P_{loss}$ $P_{out} = P_m - P_\mu$
Shunt Motor	$V_T = E_b + i_aR_a$ $V_T = i_fR_f$	$i_L = i_a + i_f$		
Long Shunt Compound Motor	$V_T = E_b + i_a(R_a + R_{se}) + V_{brush}$	$i_L = i_a + i_{sh}$ $i_{sh} = \frac{V_T}{R_{sh}}$		

Short Shunt Compound Motor	$V_T = E_b + i_a R_a + i_L R_{se} + V_{brush}$ $V_{sh} = i_{sh} R_{sh}$	$i_L = i_a + i_{sh}$ $i_{sh} = \frac{V_T - i_L R_{se}}{R_{sh}}$ $i_{sh} = \frac{E_b + i_a R_a + V_{brush}}{R_{sh}}$	$\tau_m = \left(\frac{60P_m}{2\pi N}\right)$ $\tau_o = \left(\frac{60P_{out}}{2\pi N}\right)$ $\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$

Induction Machine

$N_S = \frac{120f}{P}$	$s = \frac{N_s - N_r}{N_s} \times 100\%$	$f_r = sf$
$\tau_m = \frac{60P_m}{2\pi N_r}$	$\tau_o = \frac{60P_{out}}{2\pi N_r}$	$\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$

$P_{in(rotor)} = P_{in(stator)} - (P_{scu} + P_c)$	$P_m = P_{in(rotor)} - P_{rcu}$
$P_{in(rotor)}: P_{rcu}: P_m = 1: s: 1 - s$	$P_{out} = P_m - P_\mu$

Synchronous Machine

Synchronous generator	$f = \frac{PN}{120}$	$E_A = K\varphi\omega$	$V_\varphi = E_A - I_A(R_A + jX_s)$	
	$P_{in} = \sqrt{3} V_L I_L \cos\theta$	$\% V.R = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100\%$	$P_{in} = P_{out} + P_{F\&W} + P_{core}$	
	$(E_{ph})^2 = (V_{ph}\cos\theta + I_a R_a)^2 + (V_{ph}\sin\theta \pm I_a X_s)^2$			
Synchronous motor	$P_{in} = \sqrt{3} V_L I_L \cos\phi$	$N_S = \frac{120f}{P}$	$E_{Rph} = I_{aph}\lvert Z_s\rvert$	$Z_s = R_a + jX_s$ $Z_s = \lvert Z_s\rvert\angle\theta$
	$p.f = \cos\phi$	$P_m = P_{in} - P_{scu}$	$P_{scu} = 3{I_{aph}}^2 R_a$	
	$\theta = \tan^{-1}\frac{X_s}{R_a}$	$\lvert Z_s\rvert = \sqrt{{R_a}^2 + {X_s}^2}$	$\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$	
	$(E_{bph})^2 = (V_{ph})^2 + (E_{Rph})^2 - 2V_{ph}E_{Rph}\cos(\theta \pm \phi)$			

DC Motor

DC Motor	$E_b = K_1 K_2 i_a \varpi$	
Series Motor	$V_T = E_b + i_a(R_a + R_f) + V_{brush}$	$P_{in} = V_T i_L$

Shunt Motor	$V_T = E_b + i_a R_a$ $V_T = i_f R_f$	$i_L = i_a + i_f$	$P_m = E_b i_a$
Long Shunt Compound Motor	$V_T = E_b + i_a(R_a + R_{se}) + V_{brush}$	$i_L = i_a + i_{sh}$ $i_{sh} = \frac{V_T}{R_{sh}}$	$P_{out} = P_{in} - \sum P_{loss}$ $P_{out} = P_m - P_\mu$
Short Shunt Compound Motor	$V_T = E_b + i_a R_a + i_L R_{se} + V_{brush}$ $V_{sh} = i_{sh} R_{sh}$	$i_L = i_a + i_{sh}$ $i_{sh} = \frac{V_T - i_L R_{se}}{R_{sh}}$ $i_{sh} = \frac{E_b + i_a R_a + V_{brush}}{R_{sh}}$	$\tau_m = \left(\frac{60P_m}{2\pi N}\right)$ $\tau_o = \left(\frac{60P_{out}}{2\pi N}\right)$ $\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$

Induction Motor

$N_S = \frac{120f}{P}$	$s = \frac{N_s - N_r}{N_s} \times 100\%$	$f_r = sf$
$\tau_m = \frac{60P_m}{2\pi N_r}$	$\tau_o = \frac{60P_{out}}{2\pi N_r}$	$\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$
$P_{in} = \sqrt{3} V_L I_L \cos\phi$	$P_{in(rotor)} = P_{in(stator)} - (P_{scu} + P_c)$	
$P_{in(rotor)} : P_{rcu} : P_m = 1 : s : 1 - s$	$P_m = P_{in(rotor)} - P_{rcu}$	$P_{out} = P_m - P_\mu$

Synchronous Motor

Synchronous motor	$N_S = \frac{120f}{P}$	$P_{in} = \sqrt{3} V_L I_L \cos\Phi$	$E_{Rph} = I_{aph}\lvert Z_s \rvert$	$Z_s = R_a + jX_s$ $Z_s = \lvert Z_s \rvert \angle\theta$
	$p.f = \cos\phi$	$P_m = P_{in} - P_{scu}$	$P_{scu} = 3{I_{aph}}^2 R_a$	
	$\theta = \tan^{-1}\frac{X_s}{R_a}$	$\lvert Z_s \rvert = \sqrt{{R_a}^2 + {X_s}^2}$	$\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$	
	$(E_{bph})^2 = (V_{ph})^2 + (E_{Rph})^2 - 2V_{ph}E_{Rph}\cos(\theta \pm \phi)$			