



UNIVERSITY COLLEGE TATI (UC TATI)

FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BMT 3013
COURSE	: ELECTRICAL MACHINE
SEMESTER / SESSION	: 02 – 2023/2024 Flexible
DURATION	: 3 HOURS

Instructions:

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

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

THIS BOOKLET CONTAINS 6 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

- a) List **four (4)** types of the losses that occur in practical transformer. (4 marks)
- b) A transformer basically is very simple static (or stationary) electro-magnetic passive electrical device that works on the principle of Faraday's law of induction by converting electrical energy from one value to another.
- Draw the electrical model of an ideal transformer. (2 marks)
 - Describe how the voltage is induced in secondary side. (2 marks)
- c) A single phase 1500 VA, 240/120 V, and 40 Hz transformer has been tested and the results of these two tests were given in the **Table 1**.

Table 1

Measure	Short circuit test	Open circuit test
Voltage	$V_{sc} : 50 \text{ V}$	$V_{oc} : 100 \text{ V}$
Current	$I_{sc} : 6.5 \text{ A}$	$I_{oc} : 2.8 \text{ A}$
Power	$P_{sc} : 50 \text{ W}$	$P_{oc} : 30 \text{ W}$

Calculate :

- The value of the equivalent reactance and resistance of the (3 marks) transformer referred to the high voltage side.
- The value of R_c and X_M on the primary side. (5 marks)
- Draw the transformer equivalent circuit referred to the high (2 marks) voltage side complete with values
- The efficiencies of the transformer when supplying a half-load (4 marks) and full-load, with the power factor of 0.9 lagging for both conditions.
- Compare the efficiencies of the transformer under half-load (3 marks) and full-load condition.

QUESTION 2

- a) Explain the function of armature winding and field winding in synchronous machine. (4 marks)
- b) Draw the power flow diagram of synchronous motor including its label. (4 marks)
- c) The full load current of a 2.3 kV, star-connected synchronous motor is 150 A at 0.7 pf lagging. The resistance and synchronous reactance of the motor are 0.6Ω and 4.5Ω per phase respectively. With an assumption that the mechanical stray-loss to be 50 kW, calculate the:
- i. Excitation emf, E_a (4 marks)
 - ii. Torque angle, δ (2 marks)
 - iii. Shaft output, P_{out} (4 marks)
 - iv. Efficiency, η (3 marks)
 - v. Phasor diagram for synchronous motor. (4 marks)

QUESTION 3

- a) Draw the per phase exact and approximate equivalent circuit of induction motor including its label (5 marks)
- b) Define the equation of slip speed and slip. (4 marks)
- c) The full load power output to 6 pole, 40 Hz three-phase induction motor is 60kW has a slip of 0.03 when operating at full load condition. Assume the stator losses equal the rotor losses and friction and windage loss 250W. Calculate:
- i. Synchronous speed (2 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 (3 marks)
 - vi. Stator power input (2 marks)
 - vii. Efficiency (2 marks)

QUESTION 4

- a) Describe armature reaction including **two (2)** main problems that caused by this reaction. (4 marks)
- b) Draw the equivalent circuit and power flow diagram for the following DC machines.
- i. DC shunt motor (3 marks)
 - ii. DC compound generator (3 marks)
 - iii. DC series motor (3 marks)
- c) A 240 V, 1500 rpm DC shunt motor has the following parameters:

Armature resistance : 0.05Ω

Field resistance : 120Ω

At half - full load condition, the line current is 65 A. The rotational losses are given as 1500 W. Calculate:

- i. The efficiency and torque of the motor under rated condition. (4 marks)
- ii. The speed of the motor if the load is reduced so that the motor draws 75A while the motor flux remain unchanged (5 marks)
- iii. The speed of motor if the load is reduced so that the motor draws 75A if flux is decrease by 10% instead of remaining constant. (3 marks)

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

TABLE OF FORMULAS

DC Motor			
Series Motor	$V_T = E_a + i_a(R_a + R_f) + V_{brush}$		$E_a = K_1 K_2 i_a \omega$
Shunt Motor	$V_T = E_a + i_a R_a$	$i_L = i_a + i_f$	$P_{in} = V_T i_L$
	$V_T = i_f R_f$		$P_m = E_a i_a$
Long Shunt Compound Motor	$V_T = E_a + i_a(R_a + R_{se}) + V_{brush}$	$i_L = i_a + i_{sh}$ $i_{sh} = \frac{V_T}{R_{sh}}$	$P_{out} = P_{in} - \sum P_{loss}$ $P_{out} = P_m - P_\mu$
Short Shunt Compound Motor	$V_T = E_a + i_a R_a + i_L R_{se} + V_{brush}$ $V_{sh} = i_{sh} R_{sh}$	$i_L = i_a + i_{sh}$ $i_{sh} = \frac{V_T - i_L R_{se}}{R_{sh}}$ $i_{sh} = \frac{E_a + i_a R_a + V_{brush}}{R_{sh}}$	$\tau_m = \left(\frac{60 P_m}{2\pi N}\right)$ $\tau_o = \left(\frac{60 P_{out}}{2\pi N}\right)$ $\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$
AC Motor			
Induction Motor	$N_s = \frac{120f}{P}$	$s = \frac{N_s - N}{N_s}$	$f_r = sf$
	$\tau_m = \left(\frac{60 P_m}{2\pi N}\right)$	$\tau_o = \left(\frac{60 P_{out}}{2\pi N}\right)$	$\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$
	$P_{in(rotor)} = P_{in(stator)} - (P_{scu} + P_c)$		$P_m = P_{in(rotor)} - P_{rcu}$
	$P_{in(rotor)} : P_{rcu} : P_m = 1 : s : 1 - s$		$P_{out} = P_{in} - \sum P_{loss} = P_m - P_\mu$
Synchronous motor	$P_{in} = \sqrt{3} V_L I_L \cos \phi$	$E_{Rph} = I_{aph} Z_s $	$Z_s = R_a + jX_s$ $Z_s = Z_s \angle \theta$
	$p.f = \cos \phi$	$P_m = P_{in} - P_{scu}$	$P_{scu} = 3 I_{aph}^2 R_a$
	$\theta = \tan^{-1} \frac{X_s}{R_s}$	$ Z_s = \sqrt{R_a^2 + X_s^2}$	$\eta = \left(\frac{P_{out}}{P_{in}}\right) \times 100\%$
	$(E_{bph})^2 = (V_{ph})^2 + (E_{Rph})^2 - 2V_{ph} E_{Rph} \cos(\theta \pm \phi)$		