MACHAKOS UNIVERSITY

University Examinations for 2023/2024 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 538: ELECTRICAL MACHINE DESIGN

DATE: **TIME:**

INSTRUCTIONS

- *This Paper Consists of FIVE Questions.*
- *Question **ONE** is **Compulsory.***
- *Attempt **ANY OTHER TWO** of the remaining **FOUR** Questions.*

QUESTION ONE (COMPULSORY) (30 MARKS)

a) No insulating material in practice satisfies all the desirable properties. Therefore, materials which satisfy most of the desirable properties must be selected. Based on the temperature withstanding ability, the insulating materials have been classified according to ISI (now BIS) – 1271, 1985, first revision. Discuss these classifications, giving specific examples in each case. (7 marks)

b) Determine the main dimensions of the armature core, number of conductors, and commutator segments for a 350kW, 500V, 450 rpm, 6pole shunt generator assuming a square pole face with pole arc 70% of the pole pitch. Assume the mean flux density to be 0.7T and ampere-conductors per cm to be 280 (7 marks)

c) A 3 phase 1,800 KVA, 3.3 KV, 50 Hz, 250 rpm, salient pole alternator has the design data in Table Q 1c).

Table Q 1 c)	
Stator bore diameter	230 cm

Gross length of stator bore	38 cm
Number of stator slots	216
Number of conductors per slot	4
Sectional area of stator conductor	86 mm^2

Using this data, determine:

(i) Flux per pole (3 marks)

(ii) Flux density in the air gap (2 marks)

(iii) Current density (2 marks)

d) A 3-phase, $350KVA$, $11/3.3KV$, $Y-\Delta$, 50Hz, 3-leg, naturally cooled (NC), 3-stepped core type transformer has a current density of $250A/cm^2$. The peak flux density in the limb is 1.2 T and it is assumed that the distance between core centers is twice the width of the core. Determine the following:

(i) Core Diameter (3 marks)

(ii) Transformer stampings and yoke height (2 marks)

(iii) Window dimensions (4 marks)

QUESTION TWO (20 MARKS)

a) Explain the Ten steps involved in the design of Commutator and Brushes of a DC Machine (10 marks)

b) A 500kW, 500V, 375 rpm, 8 pole DC generator has an armature diameter of 110 cm and the number of armature conductor is 896. Assuming single turn coils, determine the following:

(i) Diameter and Length of the Commutator (5 marks)

(ii) Commutator Losses (4 marks)

(iii) Temperature Rise of the Commutator (1 mark)

QUESTION TWO (20 MARKS)

A manufacturer catalogue has the B-H Curve for the magnetic circuit of a 440V, 6 pole, 3-phase Y-connected 50HZ induction motor shown in Table Q 3.1. Further, the machine has the particulars shown in Table Q 3.2. *Required: The magnetization current for the machine internal circuit.*

Table Q 3.1

$B(T)$	0.5	0.7	1.0	1.2	1.4	1.6
$H(AT/m)$	95	110	200	300	600	2500

Table Q 3.2	
Particular	Value
Core length	0.15m
Stator teeth length	30mm
Stator Tooth width at 1/3 height from the narrow end	7mm
Rotor Tooth width at 1/3 height from the narrow end	10.5mm
Rotor teeth length	15mm
Stator bore diameter	0.4m
Effective airgap length	0.9mm
Stator and Rotor core depth	6.5mm
Mean $60°$ length of magnetic circuit per pole pair in stator	0.25m
Mean $60°$ length of magnetic circuit per pole pair in Rotor	0.16m
Number of stator slots	72
Conductors per stator slot	8
Rotor slots	49
Stacking factor	0.9

QUESTION FOUR (20 MARKS)

a) A $500\,kVA, 6600/440V, 50Hz$, 3 phase transformer has $100\,cm$ height, $96\,cm$ length and $47\,cm$ breadth and Total losses of 7 kw. The allowable temperature rise for the tank walls is $35℃$. Tubes of 5 cm diameter are to be used and are placed 10cm apart. A clearance of 50cm is taken for the tank height and another clearance of 20cm for tank height and breadth.

i) Determine the number of tubes required for the cooling system (6 marks)

ii) Find and sketch their possible arrangement of the tubes (4 marks)

b) A 300 kVA, 6600/400V, delta-star connected core type transformer has the data shown in Table Q 4b). From first principles, determine the following at $0.8\,pf$ lag and full load

i) Equivalent series impedance referred to the primary side (8 marks)

ii) Percentage voltage regulation (10 marks)

Table Q 4b)			
Winding	Diameter (cm)		Conductor cross-sectional area (mm^2)
	Inside	Outside	
H.V	29.5	36	5.4
L.V	22	26.5	70
$Length\ of\ coils\ = 50cm, Volt/turn = 8, Resistivity\ = \frac{0.021\Omega}{m}/mm^2)$			

QUESTION FIVE (20 MARKS)

a) Derive the Output Equation of a Three Phase Synchronous Machine (4 marks)

b) A 1000KVA, 3300V, 50 Hz, 300 rpm, 3 phase alternator has 180 slots with 5 conductors per slot. Single layer winding with full pitched coils is used. The winding is star connected with one circuit per phase. If the stator bore is 2m and core length is 0.4m, determine the following:

i) Peripheral Speed (1 mark)

ii) Specific Electric Loading (4 marks)

iii) Specific Magnetic Loading (4 marks)

c) Using the same parameters in ii) and iii) in 5b) above, determine the following for a 1250KVA, 3300V, 50 Hz, 250rpm, 3 phase star connected alternator having 2 circuits per phase and 60^0 phase spread

i) Diameter(D) and Length(L) (4 marks)

ii) Actual Turns per Phase(T_{ph}) (3 marks)