MACHAKOS UNIVERSITY

University Examinations for 2021/2022

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 538: ELECTRICAL MACHINE DESIGN

DATE: 15/12/2021 **TIME: 11.00-1.00 PM**

Instructions

- *This Paper Consists of FIVE Questions.*
- *Question **ONE** is **Compulsory.** Attempt **ANY OTHER TWO** of the remaining **FOUR** Questions.*
- *All solutions must be hand written.*

QUESTION ONE (COMPULSORY) (30 MARKS)

a) *Insulating Materials for Machine Design Applications (IMMDA)* can be classified as either Solid, Liquid or Gas.

i) Discuss this classification, giving specific examples in each case (6 marks)

ii) Explain the areas of application in machine design for each category (3 marks)

b) *Computer Aided Machine Design (CAMD)* is very paramount in the practical realization of *Electrical Machine Designs and Applications (EMDA).* It involves simulation of the design specifications over a given software platform.

i) Explain the relevance of CAMD (4 marks)

ii) Explain the challenges faced in Optimal CAMD (OCAMD) (4 marks)

iii) Explain the factors considered in choosing a CAMD Software (CAMDS) (3 marks)

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

Using this data, determine the following

(i) Flux per pole (2 marks)

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

(iii) Current density (1 mark)

(iv) Size of stator slot (5 marks)

Table Q 1c)	
Stator bore diameter	230 cm
Gross length of stator bore	38 cm
Number of stator slots and teeth	216
Sectional area of stator conductor	86 mm^2
Conductors per slot	4
K_w	0.955
Flux density at a third tooth area	1.7T
Carters coefficient of the air gap	0.7
Number of ventilating ducts	4
Width of each duct	1cm
Pole arc to pole pitch	0.65
Stacking factor	0.92
Standard insulation details applies	

QUESTION TWO (20 MARKS)

a) Derive the Output Equation of a DC Machine and explain the approaches for its Solution (5 marks)

b) A 600kW, 500V 900rpm dc generator has the following specifications: Average flux density= 0.6T, Ampere-conductors per meter=35000,Ratio of pole arc to pole pitch= 0.67,Efficiency=91%,Peripheral velocity should not exceed 40m/s ,Armature mmf per pole should be below 7500A,Current per brush arm should not exceed 400A,frequency of flux reversal should not exceed 50Hz,the mmf required for the air gap is 50% of the armature mmf and the air gap contraction factor is 1.15. Explain all the assumptions made clearly and subjecting your results to design checks where possible, determine the following

i) The number of poles (2 marks)

ii) D and L (4 marks)

iii) Number of slots (3 marks)

iv) Number of armature conductors (3 marks)

v) Air gap length (3 marks)

QUESTION THREE (20 MARKS)

a) Derive the Output Equation of a Three Phase Induction Machine, defining all the symbols used (6 marks)

b) 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. Represent this B-H graphically (2 marks)

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

c) Further, the machine has the particulars shown in Table Q 3.2. Estimate the magnetization current for the machine internal circuit (12 marks)

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) Derive the Output Equation of a Three-Phase Core Type Transformer (4 marks)

b) A 300 kVA, 6600/400V, delta-star, 50Hz, 3 phase core type transformer has the data shown in Table Q.4.

Table Q 4							
Flux Density(T)	0.75	1.0	1.15	1.25	1.3	1.35	1.4
AT/m	100	105	200	400	500	1000	1500
Core Loss/Kg (W/Kg)	0.7	1.25	1.75	2.1	2.3	2.6	2.8

Further, the number of turns per phase on the HV winding is 830 while the net iron area of each limb and yoke is $260cm^2$ and $297cm^2$ respectively. The mean length of the flux path in each limb and yoke are 55 cm and 86.9 cm respectively while the density of iron is $7.55g/cm^3$.

i) Sketch the transformer section showing the *Core and Yoke* details (2 marks)

ii) Plot on the same axes, the Flux Density as a function of both AT/m and the Core Loss/Kg (4 marks)

iii) Applying the graphs plotted in 4b) above, determine the *Maximum Flux Density* in the Leg Area and the total loss in the legs (3 marks)

iv) Using the graphs plotted in 4b) above, determine the total loss in the Yoke Area (2 marks)

v) Find the no load current for the transformer steel (5 marks)

QUESTION FIVE (20 MARKS)

a) Derive the output equation of a Three Phase Synchronous Machine (6 marks)

b) A 1000 kVA, 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. Determine the Specific Electric and Magnetic Loading if the stator bore is 2 m and core length is 0.4 m. (7 marks)

c) Using the same Specific Electric and Magnetic Loadings in 5b) above, determine the diameter(D), length(L) and the actual turns per phase(T_{ph}) for a 1250 kVA, 3300V, 50 Hz, 250 rpm, 3 phase star connected alternator having 2 circuits per phase. The machines have 600 phase spread (7 marks)