UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

B.ENG (HONS) ELECTRICAL & ELECTRONIC ENGINEERING

SEMESTER 1 EXAMINATION - 2024/2025

ELECTRICAL MACHINES & POWER ELECTRONIC DRIVES

MODULE NO: EEE6011

Date: Monday 13th January 2025 **Time: 2:00pm – 4:30pm**

INSTRUCTIONS TO CANDIDATES:	**There are SIX questions.**
	Answer ANY FOUR questions.
	All questions carry equal marks.
	Marks for parts of questions are shown in brackets.
	Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.
CANDIDATES REQUIRE:	**Formula Sheet (attached).**

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Semester 1 Examination - 2024/2025
Electrical Machines & Power Electronic Drives
Module No. EEE6011

Question 1

a) Figure Q1a shows a ferromagnetic core whose mean path length is 40 cm. There is a small air gap 0.05 cm in the structure of the otherwise whole core. The cross-sectional area of the core is 12 cm^2, the relative permeability of the core is 4000, and the coil of wire on the core has 400 turns. Assume that fringing in the air gap increases the effective cross-sectional area of the gap by 5 percent. Given this information, find:

I. The total reluctance of the flux path (iron plus air gap); **[6 marks]**

II. The current required to produce a flux density of 0.5 tesla in the air gap, and **[3 marks]**

III. The percentage saving in power consumption if there is no air gap for the same flux density given in section II **[3 marks]**

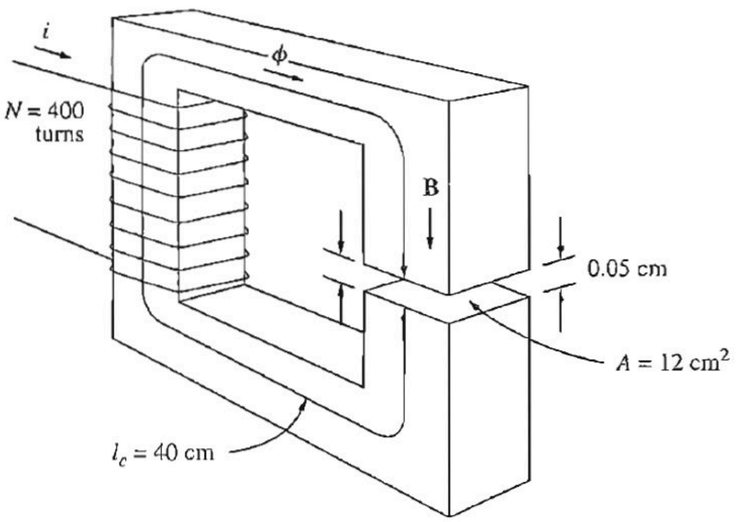

Figure Q1a magnetic circuit

Q1 continues over the page

Q1 continued

b) Answer the following questions:

I. What are the conditions to connect two three-phase transformers in parallel? **[4 marks]**

II. What is the effect of eddy current and hysteresis power loss on the function of a transformer? How do designers and manufacturers mitigate this problem? **[4 marks]**

III. The voltage regulation of a transformer is negative for a certain type of loads. Explain this case with the aid of circuit and phasor diagrams.

[5 marks]

Total 25 marks

Question 2

a) DC Generators can be classified by their magnetic field excitation methods.

Answer the following questions:

I. List the methods of magnetic field excitation; **[4 marks]**

II. Explain with the aid of diagrams how to achieve zero voltage regulation at full load. **[8 marks]**

b) A 6-pole DC machine has 53 slots with 8 conductors/slot. The magnetic flux per pole is 50 mWb, and the speed is 420 rpm. Armature current=50 A. Calculate:

I. The number of turns per coil; **[3 marks]**

II. The coil and armature voltages; **[3 marks]**

III. The coil and armature torques; **[3 marks]**

IV. The conversion power if the winding is (a) simple lap winding, (b) simple wave winding. **[4 marks]**

Total 25 marks

PLEASE TURN THE PAGE

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Semester 1 Examination - 2024/2025
Electrical Machines & Power Electronic Drives
Module No. EEE6011

Question 3.

a) What is the main purpose of no-load and locked-rotor tests in 3-phase induction motors. Explain with the aid of diagrams the method of obtaining its winding resistance and mutual inductance.
[12 marks]

b) A 480-V, 60 Hz, 50-hp,4-pole, 3-phase induction motor draws 60 A at 0.85 PF lagging. The stator copper losses and rotor copper losses are each 700 W. The friction and windage losses are 600 W, the core losses are 1800 W, and the stray losses are negligible. Find the following quantities:

I. The air-gap power P_{AG} **[2 marks]**
II. The power converted P_{conv} **[2 marks]**
III. The output power P_{out} **[2 marks]**
IV. The shaft torque **[5 marks]**
V. The efficiency of the motor **[2 marks]**

Total 25 marks

Question 4

(a) Draw the voltage, current and flux phasor diagram of a 3-phase synchronous generator loaded with inductive load. Explain the effect of armature reaction on the field flux.
[8 marks]

(b) A 3-phase, 100-hp, 440-V, star-connected synchronous motor has a synchronous impedance per phase of 0.1 +j1 ohm. The excitation and torque losses are 4 kW and may be assumed constant. Calculate:

(i) The line current and power factor; **[15 marks]**
(ii) The efficiency when operating at full load with an excitation equivalent to 400 line volts. **[2 marks]**

Total 25 marks

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Question 5

(a) Explain briefly how a single-phase induction motor can produce a revolving Flux in space. **[8 marks]**

(b) A 200 W, 110 V, 50 Hz, 4-pole, capacitor-start motor has the following equivalent circuit parameter values (in ohms) and losses:

$R_{1,main} = 2.02, X_{1,main} = 2.79\ , R_{2,main} = 4.12\ , X_{2,main} = 2.12, X_{m,,main} = 66.8$

Core loss=30 W, Friction and windage loss=18 W.

When this motor is running as a single-phase motor at rated voltage and frequency with its starting winding open and for a slip of 0.05, determine:

(i) The stator current and power factor; **[8 marks]**

(ii) Power output, speed, and torque **[6 marks]**

(iii) Efficiency **[3 marks]**

Total 25 marks

University Of Bolton
School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Semester 1 Examination - 2024/2025
Electrical Machines & Power Electronic Drives
Module No. EEE6011

Question 6

(a) Explain with the aid of drawings the relationship between speed and torque of a separately excited DC motor. Show that its speed can be controlled by changing the magnetic field **[6 marks]** and explain how a power electronic drive can be used to control the motor speed. **[6 marks]**

(b) A 50-kVA, 50 Hz, 2400:240 V single-phase distribution transformer has the equivalent circuit referred to high voltage side shown in Figure Q6b. If the load voltage is 230 V and load current is 70% of the full load current at unity power factor.

Calculate:

I. Voltage regulation **[9 marks]**

II. Efficiency **[4 marks]**

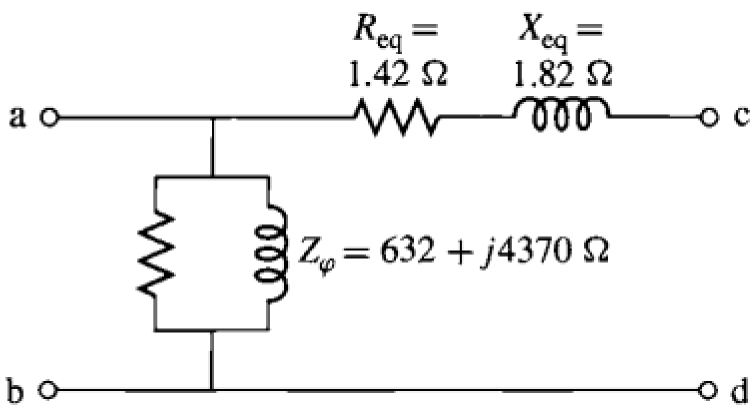

Figure Q6b Transformer Equivalent Circuit

Total 25 marks

END OF QUESTIONS

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School Of Engineering
B.Eng (Hons) Electrical And Electronic Engineering
Semester 1 Examination - 2024/2025
Electrical Machines & Power Electronic Drives
Module No. EEE6011

Formula sheet

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

DC Machines

$E=V+I_A.R_A$ (Generator voltage equation)

$E=V-I_A.R_A$ (Motor voltage equation)

$K_e=K_t=(2pCN/a)$, $E=K_e.\omega.\Phi$, $T=K_t.I_A.\Phi$

$P_{conv} = E.I_A = \omega.T$

Transformers and Induction motors

Transformer voltage ratio: $\frac{E_1}{E_2} = \frac{N_1}{N_2}$

Secondary parameters referred to primary side: $R_2' = (\frac{N_1}{N_2})^2 R_2$, $X_2' = (\frac{N_1}{N_2})^2 X_2$,

$I_2' = \frac{N_2}{N_1} I_2$, $V_2' = \frac{N_1}{N_2} V_2$, $P = \sqrt{3} V_L I_L \cos\theta$, $Q = \sqrt{3} V_L I_L \sin\theta$ $E = V + I.Z$

$slip\ \ s = \frac{n_s - n_r}{n_s}$, $P_{AG} = 3I_2^2 \frac{R_2}{s}$, $P_{conv} = 3I_2^2 R_2\left(\frac{1-s}{s}\right)$, $P_{core} = 3E_1^2 G_C$, $\tau_{in} = \frac{P_{conv}}{\omega_m}$

$$Z_f = R_f + jX_f = \frac{jX_m\left(R'_2/s + jX'_2\right)}{jX_m + \left(R'_2/s + jX'_2\right)} \qquad Z_b = R_b + jX_b = \frac{jX_m\left(R'_2/(2-s) + jX'_2\right)}{jX_m + \left(R'_2/(2-s) + jX'_2\right)}$$

University Of Bolton
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B.Eng (Hons) Electrical And Electronic Engineering
Semester 1 Examination - 2024/2025
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Synchronous machines

Voltage vector equation: E =V + I.Z

Power equations: P= $\frac{EV}{Z}\cos(\psi-\delta)-\frac{V^2}{Z}\cos(\psi)$, Q= $\frac{EV}{Z}\sin(\psi-\delta)-\frac{V^2}{Z}\sin(\psi)$

For generator

$P_{in}=\tau_{app}\omega_m$, $P_{conv}=\tau_{ind}\omega_m=3E_AI_A\cos\gamma$, $P_{out}=\sqrt{3}V_LI_Lcos\theta$

For motor the above equations will be used in the reversed order.

Motor Drives

The rotor terminals ac voltage with the open-circuit rotor voltage at standstill, $E=sE_{oc}$

The rectified output voltage E_d =1.35 E

$s=\frac{E_2}{1.35E_{OC}}$

DC Voltage developed by the inverter $E_2=1.35\ E_Tcos\alpha$

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