UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2021

Module Number: EE3303 **Module Name: Electric Machines(N/C)**

[Three Hours]

[Answer **all questions**, each question carries **10 marks**]

Q1. a) i) State two advantages of using electromagnets in electric machines instead of permanent magnets.

ii) Explain how the hysteresis loss and the eddy current loss occur in magnetic cores.

iii) The total core loss for a given magnetic core is found to be 4.65 kW at 50 Hz. Keeping flux density constant, the frequency of the supply is raised to 60 Hz. Calculate the eddy current loss and the hysteresis loss at 50 Hz and 60 Hz, if the total core loss increased to 6 kW at 60 Hz.

[5.0 Marks]

b) The iron magnetic core shown in Figure Q1 has a thickness of 5 cm. Its left-side leg has a winding with 100 turns and right-side leg has an air gap of 0.5 mm. Take the relative permeability of iron as 4200 and the permeability of free space as $4\pi \times 10^{-7}$ Wb/A-t.m. Assume that fringing effect in the air gap increase the effective cross-sectional area of the air gap by 4 %.

i) Calculate the total reluctance of the flux path.

ii) Determine the flux densities in each section of the core for a current (I) of 5 A.

iii) Discuss how flux flow in the core would vary with the current I.

[5.0 Marks]

Q2 a) i) State three characteristics of an ideal transformer.

ii) Briefly explain why high voltage winding is wrapped and wound top of the low voltage winding in transformer construction.

iii) Draw a conservator tank type oil immersed transformer and name five main components.

[4.0 Marks]

b) A single phase 250/500 V, 60 Hz transformer is tested to determine its equivalent circuit parameters. The open-circuit test is performed on the low voltage side of the transformer and the short-circuit test is performed on the high voltage side of the transformer. Measured test data are given in Table Q2.

i) Draw the equivalent circuits of this transformer referred to its primary side and referred to its secondary side.
ii) Calculate the applied voltage, the voltage regulation and the efficiency when the output current is 5 A at 500 V and 0.8 power factor lagging.
iii) Draw the phasor diagram for part (ii).

[6.0 Marks]

Q3. a) i) What is meant by 'armature reaction' in a DC Machine?
ii) Briefly explain two methods used in DC machines to reduce the effect of armature reaction.
iii) Briefly explain why a shunt DC motor should not be started on heavy loads.
iv) From the first principles, show that internally generated voltage E_A of a separately excited DC generator can be expressed by

$$E_A = \left(\frac{pz}{2\pi a}\right) \varphi_f \omega_m$$

where all the notations have their usual meanings.

[5.0 Marks]

b) A 10 hp, 230 V shunt motor takes a line current of 25 A. The armature and the field resistances are 0.23 Ω and 150 Ω respectively. The brushes used in the motor are graphite. The core and mechanical losses are 380 W. Assume that machine operates at a constant speed of 1500 rpm and armature reaction is negligible.

i) Calculate the induced back emf in the armature.
ii) Calculate the efficiency of the motor if the stray losses are 1% of the rated output power.
iii) Determine the rated current of the motor. Assume core and mechanical losses remain the same.

[5.0 Marks]

Q4 a) i) What are the two types of rotor constructions in induction machines?
ii) Briefly explain why a three-phase induction motor is not able to run at synchronous speed.
iii) Describe the three tests used to determine the circuit parameters of a three-phase induction machine with relevant circuit diagrams.

[5.0 Marks]

b) A 400 V, 50 Hz, 1425 rpm, three-phase wye-connected induction motor has following parameters referred to the stator. Terms have their usual meanings.

$R_S = 0.34\ \Omega \qquad R'_R = 0.45\ \Omega \qquad X_S = 0.62\ \Omega \qquad X'_R = 0.52\ \Omega \qquad X_M = 34.6\ \Omega$

i) Determine the number of stator poles.
ii) Calculate the starting torque, pullout torque and rated torque of the motor.
iii) Sketch the torque speed characteristic curve indicating important speed and torque values.

Hint: Output characteristic equation of a three-phase induction motor is given by

$$T_m = \frac{3R'_R(1-s)}{s\omega_m}\left(\frac{V_{TH}^2}{(R_{TH}+\frac{R'_R}{s})^2+(X_{TH}+X'_R)^2}\right)$$

[5.0 Marks]

Q5 a) i) State three differences between round rotor type synchronous machine and a salient pole synchronous machine.
ii) State three parameters that should be synchronized when a synchronous machine is connected to the power grid.
iii) Briefly explain how the output voltage and frequency of a synchronous generator is kept at desired levels.
iv) Draw a schematic diagram of an exciter arrangement that can be used in synchronous machines to make excitation completely independent of any external power source.

[5.0 Marks]

b) A 460 V, 50 Hz, wye-connected four-pole synchronous generator has a per-phase synchronous reactance of 1.4 Ω. At full-load, the armature current is 40 A at 0.8 p.f. lagging, the friction and windage losses are 1.5 kW and core losses are 1.0 kW. The field current has been adjusted such that the no load terminal voltage is 460 V. State your assumptions and calculate the following.

i) The rotational speed of the generator.
ii) Terminal voltages of the generator if it is loaded with the rated current at 0.8 p.f. lagging, unity power factor and 0.8 p.f. leading.
iii) The efficiency of the generator at full-load and 0.8 p.f lagging.
iv) The shaft torque which must be applied by the prime mover at the full load.
v) The induced counter torque.
vi) The voltage regulation of the generator at 0.8 p.f. lagging.

[5.0 Marks]

Core thickness = 5 cm

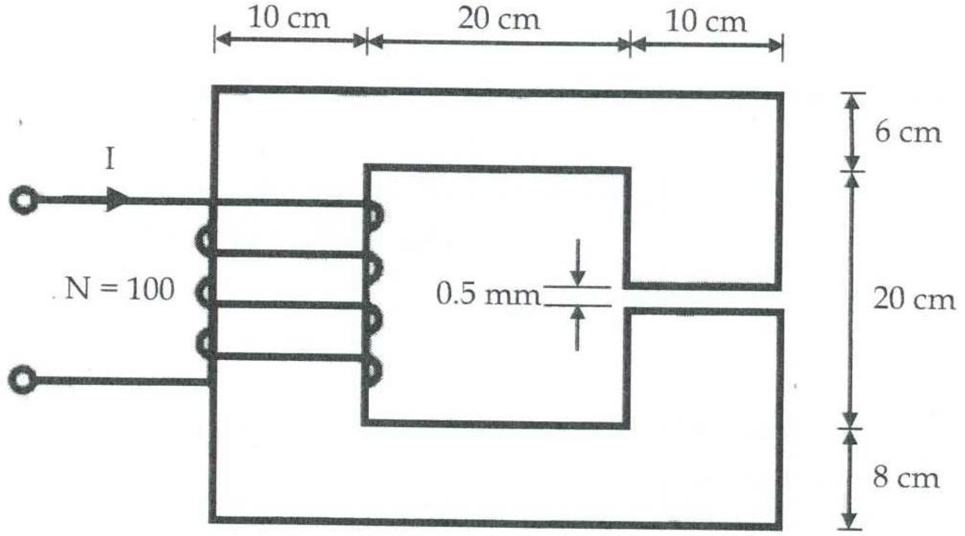

Figure Q1

Open-circuit Test (On LV side)	**Short-Circuit Test (On HV side)**
$V_{OC} = 250$ V $I_{OC} = 1$ A $P_{OC} = 80$ W	$V_{SC} = 20$ V $I_{SC} = 12$ A $P_{SC} = 100$ W

Table Q2