City & Guilds

9210-115
Level 6 Graduate Diploma in Engineering
Electrical machines and drives

Sample Paper

You should have the following for this examination • one answer book • non-programmable calculator • pen, pencil, drawing instruments	**No additional data is attached**

General instructions
- This examination paper is of **three hours** duration.
- This paper consists of **nine** questions.
- Answer any **five** questions.
- All questions carry equal marks. The maximum marks for each section within a question are shown.
- A non-programmable electronic calculator may be used but candidates **must** show sufficient steps to justify their answers.
- Drawings should be clear, in good proportion and in pencil. Do **not** use red ink.

1 a) i) Sketch the vector diagram for the terminal voltage of a cylindrical rotor synchronous machine. (4 marks)
(Assume that the armature resistance is negligible.)

ii) Derive expressions for the active power and the reactive power developed in a three-phase cylindrical rotor synchronous machine with negligible armature resistance. (4 marks)

b) Two generators G_X and G_Y are supplying a load of 5 MW with a power factor of 0.8 lagging. The two generators G_X and G_Y are operating on no load at 51.5 Hz and 51 Hz respectively with an equal slope of 1 MW/Hz.

i) Calculate the power supplied by each generator and the operating frequency of the system. (6 marks)

ii) If the load is increased by 1 MW, what would be the power produced by each generator? Calculate the operating frequency. (6 marks)

2 a) Describe the control of active and reactive power of a synchronous generator connected to an infinite bus. (6 marks)

b) The technical specifications of a Y connected three phase synchronous generator are given below.

Voltage: 480 V.
Frequency: 50 Hz.
Rated Power: 50 kVA at 0.8 lagging.
per phase synchronous reactance: 1 Ω.
Total losses: 2.5 kW.

Assume that the generator is connected to a turbine of 47 kW.

i) Construct the operating chart. (4 marks)

ii) The synchronous generator is supplying a line current of 50 A at 0.8 lagging power factor. Calculate the active and reactive power supplied by the generator. (6 marks)

iii) What is the maximum reactive power the generator can deliver when supplying 30 kW of real power? (4 marks)

3 a) Explain the difference between squirrel cage and wound rotor induction motors. (2 marks)

b) Explain what is meant by slip of an induction motor. (2 marks)

c) i) Sketch the approximate per phase equivalent circuit of a three-phase induction motor. State the assumptions made. (6 marks)

ii) Results of no-load and locked rotor tests for a 220 V, 50 Hz, three-phase star connected class B induction motor are given below.

No load test at 50 Hz
Applied voltage = 220 V, Line current = 24.0 A, Power input = 1400 W.
Locked rotor test at 12.5 Hz
Applied voltage = 24.6 V, Line current = 64.5 A, Power input = 2400 W
Per phase stator resistance is 0.12 Ω.
For class B machines,
Assume the ratio x_1 / x_2 as 0.4: 0.6.
Determine the parameters of the approximate equivalent circuit. (10 marks)

4 a) Explain the speed control of an induction motor by varying frequency and pole pair number. (4 marks)

b) Derive an expression for the electromagnetic torque developed in terms of voltage, impedances, synchronous speed and slip. (6 marks)

c) A 480 V, 20 kW, 60 Hz, 4 pole, star connected wound rotor induction motor has the following per phase parameters referred to the stator circuit.

stator resistance	= 0.75 Ω.
stator leakage reactance	= 1.25 Ω.
rotor resistance	= 0.35 Ω.
rotor reactance	= 0.45 Ω.
magnetizing reactance	= 25.5 Ω.

i) Determine the starting torque of the motor. (4 marks)

ii) What is the speed and slip at which maximum torque occurs? (4 marks)

iii) Calculate the maximum torque of the motor. (2 marks)

5 a) Explain how voltage is built up in a shunt DC generator. (4 marks)

b) i) Draw the equivalent circuit of a DC series generator and sketch the terminal voltage characteristics. (4 marks)

ii) Explain the operation of a DC series generator and how it can be used for a constant current application. (4 marks)

c) A 60 kW, 260 V separately excited DC generator has an armature resistance of 0.025 Ω. The generator delivers rated load at rated terminal voltage.

i) Find the armature current and the generated armature voltage at rated load. (4 marks)

ii) If the terminal voltage is maintained at 260 V but the output is reduced to 30 kW, find the corresponding armature voltage. (4 marks)

6 a) Identify **two** major problems caused by the armature reaction of a DC machine and explain how armature reaction affects the performance of the machine. (4 marks)

b) Derive an expression for torque-speed characteristics of a DC shunt Motor. (4 marks)

c) A 5 kW, 230 V, DC shunt motor has an armature resistance of 0.3 Ω.
Field resistance is 160 Ω. The motor draws a line current of 4 A on load at a speed of 1200 rpm.
The full load armature current is 30 A.

i) Determine the armature current at no load condition. (2 marks)

ii) Calculate the power developed by the armature at no load condition. (5 marks)

iii) Find the speed of the motor at full load condition. (5 marks)

7 a) Explain the difference between mechanical and electrical angle of a rotating electrical machine. (4 marks)

b) i) Derive expressions for the power output of a separately excited DC motor. (4 marks)

ii) A 200 V, 15 kW, DC shunt motor draws an armature current of 85 A at full load. The armature and field resistances are 0.2 Ω and 200 Ω respectively. Find the rotational losses and motor efficiency at full load. (8 marks)

c) Explain the operation of a 6/4 pole (6 stator pole and 4 rotor poles), 3phase variable reluctance stepper motor in both full step and half step modes. (4 marks)

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8 a) i) Sketch the circuit diagram of a three-phase thyristor full bridge converter. (2 marks)

ii) Explain the operation of a three-phase thyristor full bridge converter when the firing angle is 20°. (6 marks)

b) The speed of a 100 kW, 600 V, 1800 rpm, separately excited DC motor is controlled by a three phase thyristor full converter. The converter is connected to a three-phase, 460 V, 60 Hz supply. The motor parameters are given below. Assume that the converter and the power supply are ideal.

Rated armature current	= 175 A.
Armature resistance	= 0.09 Ω.
Armature inductance	= 6.50 mH.
Motor constant '$K\Phi$'	= 0.35 V/rpm.

i) Determine the no-load speed at firing angle of 20°. Assume that the armature current under no-load conditions is 15% of the rated current and is continuous. (6 marks)

ii) Calculate the firing angle to obtain the rated speed of 1800 rpm at rated motor current. (6 marks)

9 a) Explain the closed loop control of electric motors. (4 marks)

b) i) Sketch circuit diagrams of single-phase full bridge thyristor converter. (3 marks)

ii) Derive an expression for average output voltage of a single phase thyristor full bridge converter in terms of the ac supply voltage and firing angle for the controller input. (4 marks)

iii) A single-phase full bridge converter is used to control the speed of a DC motor by changing the supply voltage. The converter is connected to a 230 V, 50 Hz supply. Calculate the supply voltage when the firing angle is 30°. (5 marks)

c) Sketch the schematic circuit diagram for induction motor control incorporating a rectifier-thyristor inverter unit to provide regenerative feedback for slip power-recovery and explain its basic operation. (4 marks)