This question paper has 4 pages.
Instructions to Candidates :
This paper contains **4** Sections, and each section has **2** Questions.
Attempt **5** questions from the 4 sections, at least **1** question from each section.
All sections must be attempted.
Each question carries **20 marks**.

Constants :
$\varepsilon_o = 8.85 \times 10^{-12}$ F/m
$\mu_o = 4\pi \times 10^{-7}$ H/m

Section A:

A1.

(a) A 4-pole dc generator is wound with 600 conductors in its armature. The flux per pole is 24×10^{-3}Wb when it is running at 840 rpm. The current in each conductor is 50A. Calculate total current, emf, and electrical power generated in the armature if the conductors are connected as follows:
(i) Wave winding
(ii) Lap winding.

(12 marks)

(b) A 100kW, shunt excited dc generator has a field resistance of 200Ω. When the generator is delivering a rated output power, the terminal voltage is 500V and the generated emf is 525V. Find
(i) The armature resistance (4 marks)
Calculate, when the terminal voltage is set to 520V,
(ii) The generated emf if the output is reduced to 60% of rated output
(4 marks)

A2.

(a) Explain, with aid of diagrams, what is the meaning of armature reaction of a dc machine. (4 marks)

(b) State three methods to eliminate the effect of armature reaction.
(3 marks)

(c) Explain why the dc series motor is usually used for traction purpose.
(3 marks)

(d) A 220V, dc series motor takes 22A when it runs 1200 rpm. Armature resistance is 0.08Ω, series field resistance is 0.22Ω. Find the motor speed in rpm if a 10Ω external resistance is connected in parallel with the armature but the developed torque is kept constant.
Assume a linear magnetization curve.

(10 marks)

Section B:

B1 A 1.1 kVA, 220/440V, 50Hz, single-phase transformer has the following test results:

	Voltage	Current	Power	Measure at
Open Circuit Test (high volt side open)	220V	1.0A	100W	low volt side
Short Circuit Test (low volt side shorted)	60V	3A	162W	high volt side

(a) Find the transformer parameters, $R_{eq(low)}$, $X_{eq(low)}$, R_c and X_m referred to the low volt side.

(4 marks)

(b) Find the input voltage in phasor at low voltage side when the output voltage is kept at 400V, full load 0.8 power factor lagging.

(4 marks)

(c) Find the total losses of the transformer when it is operated at full load 0.8 power factor lagging.

(4 marks)

(d) Find the full load efficiency of the transformer when it is operated at full load 0.8 power factor lagging.

(4 marks)

(e) Find maximum efficiency of the transformer operated at 0.8 power factor.

(4 marks)

B2.

(a) In a 5kVA single-phase transformer, the number of turns in primary is 3000 and the number of turns in secondary is 200. The primary winding is connected to a 220V, 50Hz supply. Calculate:

(i) The secondary voltage on no load (1 marks)

(ii) The approximate values of the primary and secondary currents on full load

(1 marks)

(iii) The maximum value of the flux (1 marks)

(iv) If the supply frequency is changed to 60Hz, repeat (i), (ii) and (iii) above.

(3 marks)

(b) State two advantages of a two-winding transformer over an auto-transformer.

(4 marks)

(c) Draw the winding circuit and phasor diagram of a 3-phase transformer connected in Dy11. (10 marks)

Section C:

C1.

(a) State three starting methods for a 3-phase cage induction motor. (3 marks)

(b) Explain why the 3-phase induction motor in part (a) needs these starting methods. (3 marks)

(c) Draw a typical torque-slip characteristics of a 3-phase cage induction motor. (3 marks)

(d) A 3-phase, 11.19kW, 380V, four-pole, 50Hz, 1440rpm induction motor delivers full output power to a load connected to its shaft. The windage friction loss of the motor is 700W.

(i) Determine the mechanical power. (2 marks)

(ii) Determine the air-gap power. (2 marks)

(iii) Determine the rotor copper loss. (2 marks)

(e) The frequency of the emf induced in the rotor of a 3-phase, 6-pole, induction motor is found to have 180 cycles/min. The motor is connected to a 50Hz, 440V supply, calculate:

(i) The speed of the motor (2 marks)

(ii) The percentage slip of the motor (3 marks)

C2. A 100kW, 3-phase, 380V, 50Hz, 4-pole, star-connected induction motor has the following test results:

	Voltage	Current	Power	Frequency
No Load Test	380V	40A	2000W	50 Hz
Lock Rotor Test	60V	120A	6000W	50 Hz

The stator resistance is 0.05Ω/phase.

The motor is delivering full load output and connected up to a 380V supply. Use the approximate equivalent circuit.

(i) Find the R_c and X_m of the magnetising branch elements. (4 marks)

(ii) Find the R_2' and X_{eq} of the equivalent circuit of the motor. (4 marks)

(iii) Find the full load current if the full load power factor and efficiency of the motor are both 0.8. (4 marks)

(iv) Find the full load slip if the mechanical loss is negligible. (8 marks)

Section D:

D1.

(a) Sketch, with aid of circuit connection, a typical open circuit characteristic and a short circuit characteristic of a synchronous generator. (4 marks)

(b) Describe, using the result (a), how to determine the synchronous impedance for the synchronous generator. (4 marks)

(c) A 3-phase, 33kVA, 380V, 50Hz, star-connected 4-pole synchronous generator has a synchronous reactance of 1Ω/phase and synchronous resistance of 0.5Ω/phase. The core loss is 1kW at 50Hz and full load condition. The field current is adjusted to give 380V at no load. Draw per phase phasor diagrams and hence determine the terminal voltage if the generator is loaded to rated current with:

(i) 0.8 power factor lagging (4 marks)

(ii) unity power factor (4 marks)

(iii) The full load efficiency at unity power factor is 90%, find the friction and winding loss of the generator (4 marks)

D2.

(a) State two types of rotor construction for 3-phase synchronous generators. (2 marks)

(b) State which type in (a) is suitable for high speed application. (2 marks)

(c) Sketch the diagram to show the construction of the type in (b). (2 marks)

(d) A three-phase, star-connected synchronous generator has a synchronous reactance of 4Ω/phase. The synchronous resistance is neglected. It is excited to give a line to line voltage of 11000V on open circuit. If its excitation current remains unchanged, keeps at open circuited condition, determine the terminal voltage when supplying a load current of 500A at 0.7 power factor leading. (10 marks)

(e) Explain the effect of power factor (unity, leading and lagging) on the excitation of a three-phase synchronous generator when its terminal voltage is fixed. (4 marks)

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