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**.

Section A

1) a) Name two common types of armature windings for a DC machine. (2 Marks)

b) A 100V DC supply is connected to a DC shunt motor (Ra = 0.1Ω with a rated current of 120A). At no load, the armature takes 6 amperes and runs at 1000rpm. Find:

i) the no-load loss, (3 Marks)
ii) the full load speed if armature reaction is negligible, (4 Marks)
iii) the corresponding torque for (ii), (3 Marks)
iv) the full load speed if the armature reaction reduces 5% of the shunt field flux, and (5 Marks)
v) the corresponding torque for (iv). (3 Marks)

2) a) Name different types of common DC machines. (2 Marks)
b) State the conditions necessary for the building-up of voltage in a DC shunt generator. (2 Marks)
c) Explain the function of a commutator in a DC machine. (2 Marks)
d) State the effects of armature reaction in a DC machine. (2 Marks)
e) The magnetization characteristic of a separately excited DC generator at 1200rpm is found to be $E_a = 5 + 110\ I_f$, where E_a = armature voltage (V) and I_f = field current (A).

I_f is adjusted to 1A and a 2Ω load is connected to the armature. Given the armature resistance (Ra) = 0.2Ω and the armature reaction effect can be ignored, find:

i) the quantity of $K_a\phi$, (3 Marks)
ii) the armature current, (3 Marks)
iii) the torque, and (3 Marks)
iv) the power taken by the load. (3 Marks)

Section B

3) a) Briefly explain why harmonics are present in the output current of a transformer with a sinusoidal input voltage. (4 marks)

b) A 20-kVA, 2000/200V, 50Hz single-phase transformer gives the following test results :

Open Circuit Test (HV side open)	200 V	4 A	125 W
Short Circuit Test (LV side short circuited)	60 V	10 A	280 W

i) Derive and draw the approximate equivalent circuit referring to the LV side. (12 Marks)

ii) Determine the efficiency of the transformer at full load, 0.8 p.f. lagging. (4 marks)

4) a) Draw the phasor diagram for the three transformer windings in Figure Q4 to illustrate the phase shift between primary and secondary voltages and hence determine the BSEN60076 symbol for Figure Q4. (8 marks)

b) Briefly describe the conditions for the parallel operation of the three-phase transformers. (4 marks)

c) A single phase two-winding 2000/200V, 20kVA transformer has a core loss of 150W at rated voltage excitation and the full-load copper loss is 300W at rated current. Suppose the two-winding transformer is connected as a step-up autotransfromer (2kV/2.2kV).

i) Draw diagram to show the autotransformer connection and determine the current passing through each winding sections. (4 marks)

ii) Determine the output kVA and the efficiency of the auto-transformer at full-load 0.8 p.f. lagging. (4 marks)

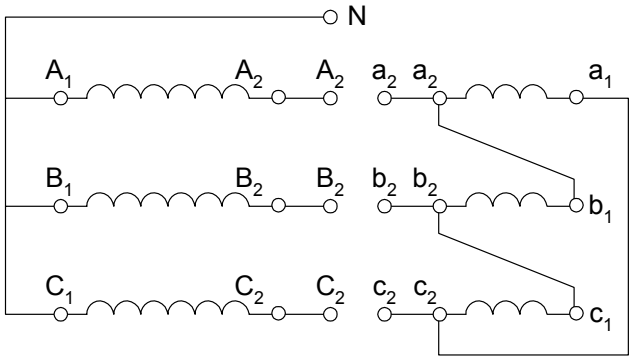

Figure Q4

Section C

5) a) Sketch the torque speed characteristic of a three-phase slip ring induction motor, and label the operating regions for generator, motor and plugging operation mode. Also, explain why the three-phase induction motor cannot develop torque when running at synchronous speed. (8 Marks)

b) Assuming that the mechanical loss of the motor is negligible, and the DC resistance between any two stator terminals is 0.1Ω, the testing results on a 3-phase, 75kW, 380V, 50Hz, 4-pole, star-connected squirrel cage induction motor is summarized as follows.

No Load Test	380V	2067W	29A
Lock Rotor Test	188V	3240W	104A

i) Derive an approximate equivalent circuit per phase for the induction motor. (6 Marks)

ii) Determine the input current and gross torque at 1455rpm. (6 Marks)

6) a) Name any three advantages or disadvantages of a 3-phase induction motor. (3 Marks)

b) What will happen if the rotor speed of an induction machine and the speed of the stator rotating magnetic field are the same? (2 Marks)

c) What are the purposes of carrying out the open-circuit and lock rotor tests? (2 Marks)

d) Name any two of the major losses in an induction motor. (2 Marks)

e) A 3-phase 380V, 6-pole, 50Hz wound rotor induction machine is star-connected in both stator and rotor windings. If the machine is running at 950rpm, find :

i) the operating slip, (2 Marks)

ii) the frequency of the induced rotor emf, and (3 Marks)

iii) the stator to rotor turns ratio, if the induced rotor phase voltage is 5.48V. (3 Marks)

iv) Now the stator terminals are shorted and the rotor is connected to a 3-phase, 380V, 50Hz supply and the motor runs at 970rpm, find the induced stator phase voltage. (3 Marks)

Section D

7) a) Name the two types of synchronous generators and state which one is for slow running power generation. (3 Marks)

b) State the characteristics of an ideal synchronous generator. (3 Marks)

c) A star connected 3-phase, 1000kVA, 10kV, 1500rpm synchronous generator has a resistance of 1.5Ω and a synchronous reactance of j15Ω per phase. The field current is adjusted to give the rated terminal voltage at open circuit. If the field current is kept unchanged, find the stator current when the machine terminals are short circuited. (6 Marks)

d) The synchronous machine in (c) is now connected to an infinite bus. The generator is adjusted to give rated current at 0.8 power factor lagging, find :

i) the excitation voltage, E_f, and (4 Marks)

ii) the percentage increase in the field current relative to the previous field current. (4 Marks)

8) a) Describe the basic construction of a 3-phase synchronous generator. (3 Marks)

b) What is the load angle of a synchronous generator? (2 Marks)

c) A 3-phase star-connected synchronous motor has the following name-plate data:

Speed	1500r.p.m.	PF	1
Voltage	6.6kV	Current	920A
Frequency	50Hz	Rating	10MW
Excitation:			
Voltage	100V	Current	5.5A

If the machine is operated at rated (full load) condition, find:

i) the number of poles, (3 Marks)

ii) the output torque, (3 Marks)

iii) the efficiency, (3 Marks)

iv) the rotational loss (assume no winding resistance loss), and (3 Marks)

v) the power loss in field circuit. (3 Marks)

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