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

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

Open Circuit Test (LV side open)	: 2000 V	0.4 A	125 W
Short Circuit Test (HV side short circuited)	: 6 V	100 A	280 W

(i) Derive and draw the approximate equivalent circuit referring to the HV side. (12 marks)

(ii) Determine the voltage regulation at full load, 0.8 p.f. lagging. (3 marks)

(c) The efficiencies of a 10-kVA, 230/400V, 50 Hz single-phase transformer at different values of secondary load current at rated voltage, unity p.f are shown in Fig. Q1. Assuming that the core loss is constant at rated secondary voltage, determine the core loss of the transformer at rated voltage.

(5 marks)

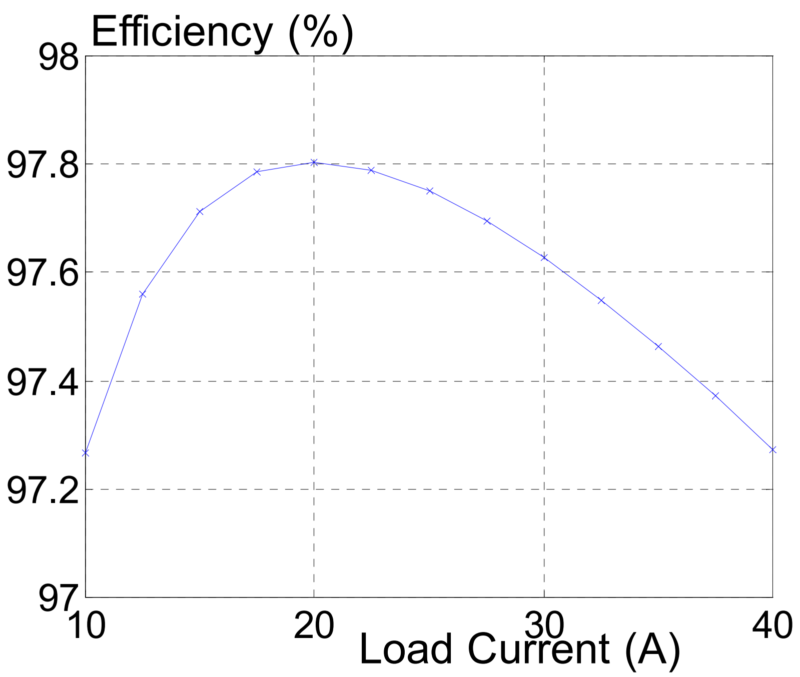

Fig. Q1

2 (a) Draw the phasor diagram for the three transformer windings in Fig. Q2 to illustrate the phase shift between the primary and secondary voltages and hence determine the BSEN60076 symbol for Fig. Q2.

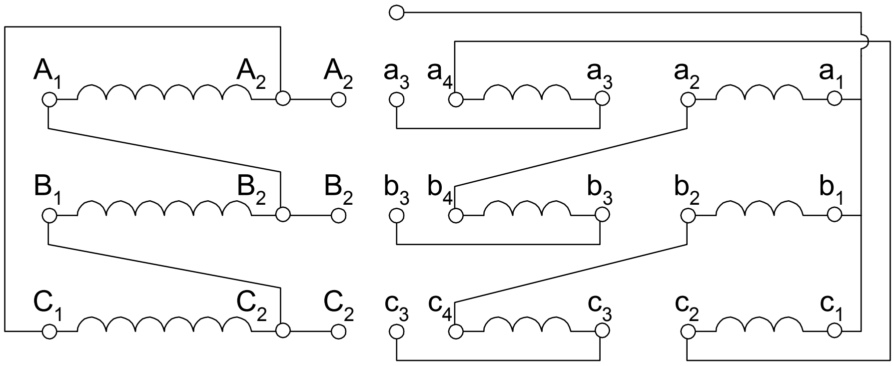

Fig. Q2

(8 marks)

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

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

(i) Sketch a diagram to show the autotransformer connection giving maximum kVA output. (2 marks)

(ii) Determine the current passing through each winding sections in (i). (4 marks)

(iii) Determine the output kVA of the auto-transformer in (i). (2 marks)

Section B

3. (a) For a separately excited two-pole dc generator, draw the diagram to illustrate how the magnetic neutral axis is shifted in presence of armature reaction. Also indicates the pole tips which the magnetic field strength are weaken or strengthened. (7 marks)

(b) The magnetizing curve of a separately excited dc generator (Fig. Q3a) driven at 1800 rpm is shown in Fig. Q3b. The armature resistance (R_a) is 0.1 Ω and the field winding resistance (R_{fw}) is 160 Ω. Neglect the rotational loss.

(i) Suppose R_{fc}=0 and a load resistor of 2Ω is connected across the terminals CD, determine armature current (I_a) and the load torque. (5 marks)

(iii) Find the value of R_{fc} for a no-load terminal voltage of 200V and the corresponding value of V_t at I_a=100A, assuming that the armature reaction at 100A is equivalent to a reduction of I_f by 0.1A. (5 marks)

(c) Briefly describe the compensating winding method to eliminate the armature reaction. (3 marks)

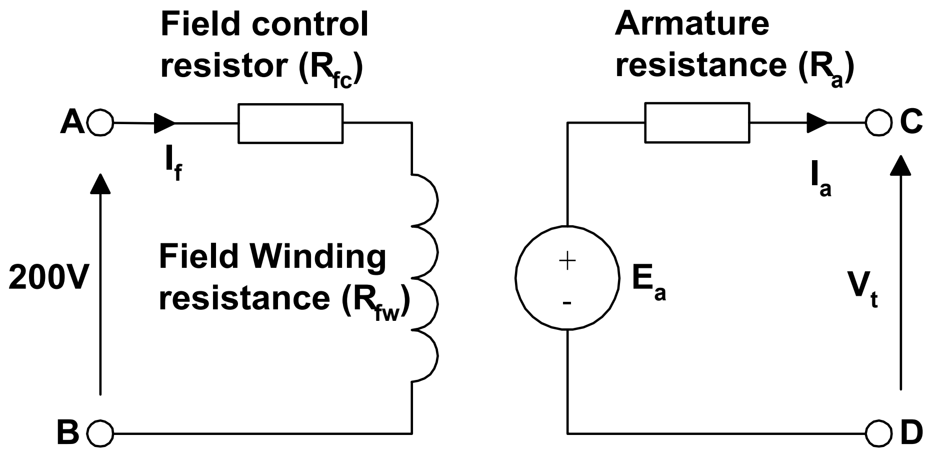

Fig. Q3a.

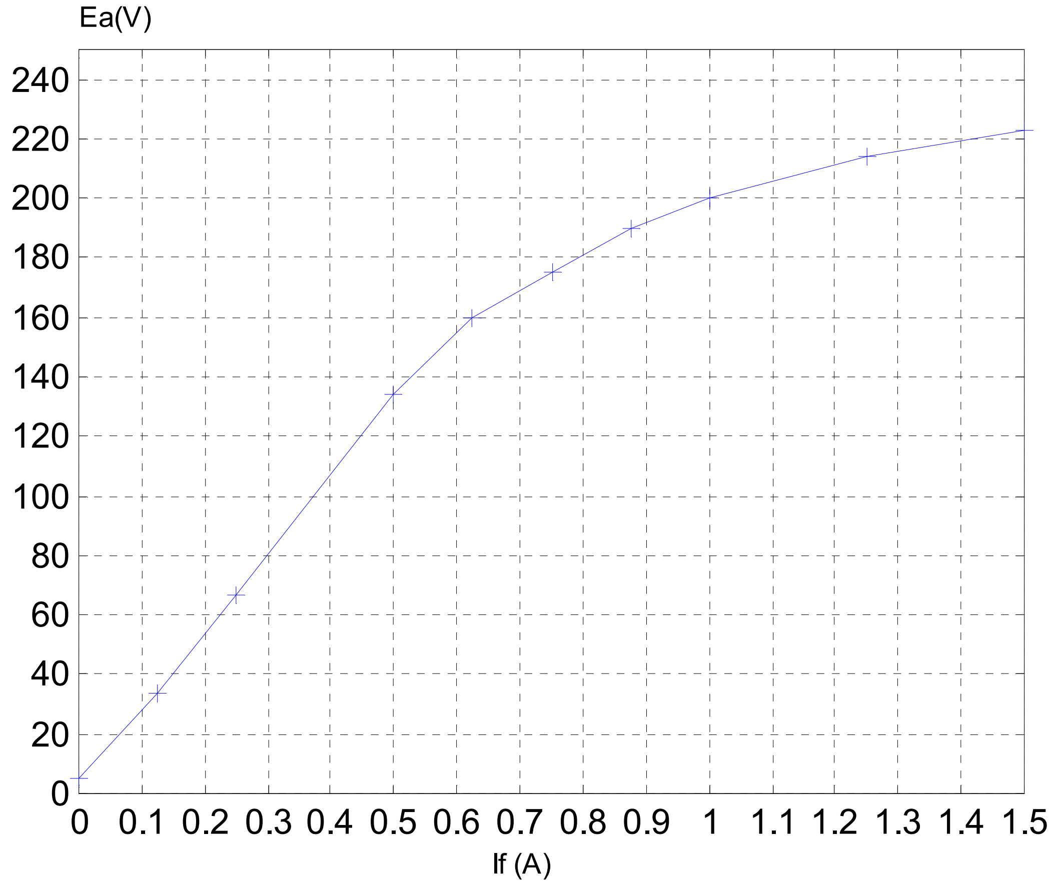

Fig. Q3b

4. (a) Briefly explain why it is undesirable to use direct on-line method to start a dc motor. Draw diagrams to illustrate the operating principle of a dc motor starter. (6 marks)

(b) Briefly describe the torque-speed characteristic of the dc shunt motor. (4 marks)

(c) The magnetization curve of a 110V, 1200 rpm, 11kW dc shunt motor at 1200 rpm is shown in Fig. Q4. The field winding resistance and armature resistance are 75Ω and 0.12Ω respectively. The field winding is connected in series with a field control resistor R_{fc}. The dc motor runs at 1200 rpm and E_a=V_t=110V at no-load. Neglect the rotational and windage loss.

(i) Find the field current and the value of the field control resistor, R_{fc}, at no-load condition. (2 marks)

(ii) Find the speed, torque and efficiency of the motor at rated armature current of 100A. Assuming that the flux is reduced by 5% of the value at no-load due to armature reaction. (4 marks)

(iii) Find the starting torque if the starting armature current is to 150A, assuming that the armature reaction is equivalent to a reduction of field current by 0.1A if I_a=150A.

(4 marks)

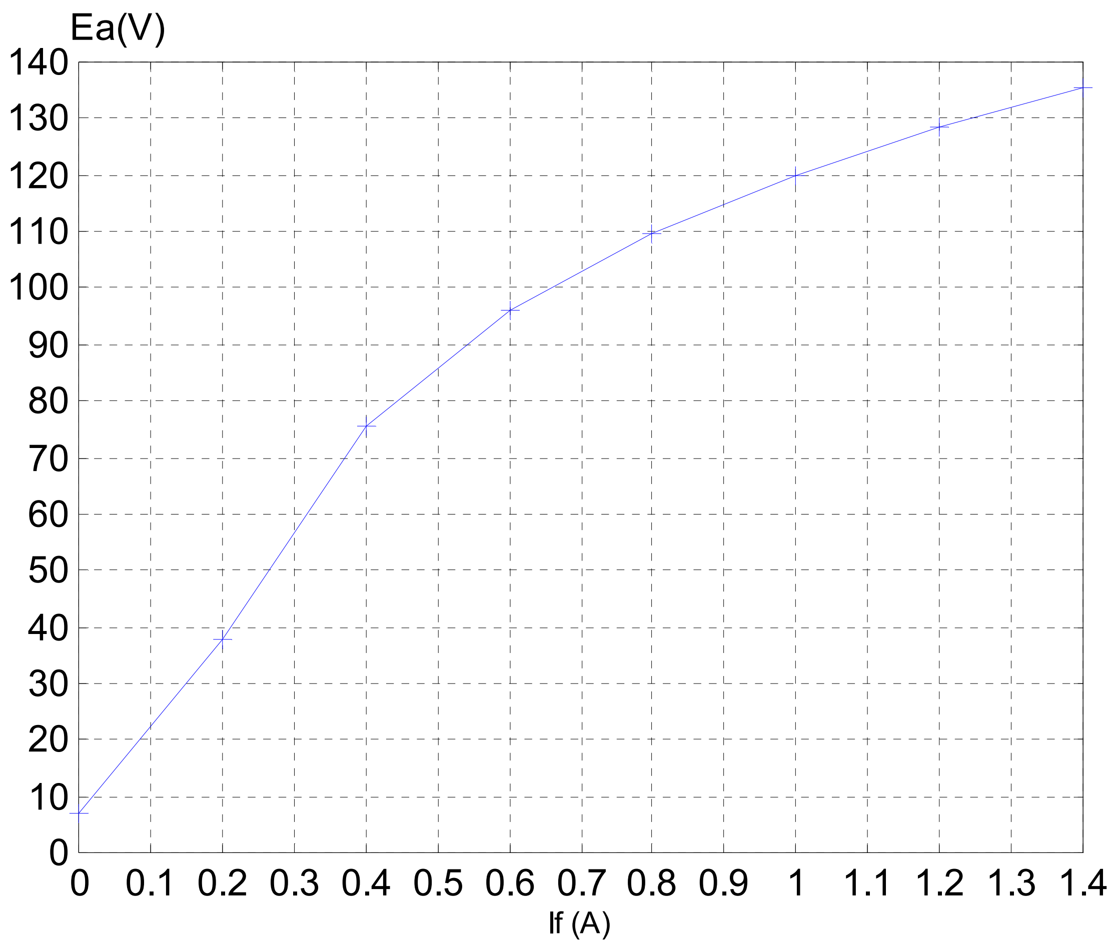

Fig. Q4

Section C

5. (a) Apart from using as an on-off connection, what is the other purpose of using a starter for induction motor ? (2 Marks)

   (b) Name the common types of motor starters for squirrel cage motors, also state which type of starter will you use for starting very heavy loads and explain the reason. (3 Marks)

   (c) Explain the method of resistor starting for wound rotor induction motor. (3 Marks)

   (d) A 380V, 50Hz, 6-pole, 3-Φ induction motor is taking 50KVA at 0.8 power factor, and is running at a slip of 3%. Given the stator and rotational losses are 1kW and 3kW respectively. Find:
   (i) The rotor copper losses, (3 Marks)
   (ii) The shaft power, (3 Marks)
   (iii) The efficiency and (3 Marks)
   (iv) The shaft torque. (3 Marks)

6. (a) A three phase, star-connected, 6-pole, 380V, 50Hz wound-rotor induction motor has an output of 15kW. The frequency of the emf induced in the rotor is 90 cycles/minute, the friction and windage torque is 16 Nm and the stator losses are 800W. Find the input power and efficiency of the motor. (6 marks)

   (b) A three phase, star-connected 6-pole, 380V, 50Hz, wound-rotor induction motor with negligible stator resistance, rotor resistance of 0.1Ω/phase and standstill reactance of 0.5Ω/phase, find
   (i) The speed for maximum torque
   (ii) The value of the external rotor-starter resistor to obtain maximum torque on starting.
   (iii) The ratio of the torque at 960rpm to the maximum torque. (10 marks)

   (c) Briefly explain and sketch diagram to illustrate how the value of the external rotor-starter resistor affects the torque speed characteristic of the induction motor in (b). (4 marks)

Section D

7. (a) Briefly describe the advantages and disadvantages of using
   (i) Salient pole synchronous generator (5 marks)
   (ii) Cylindrical rotor synchronous generator. (5 marks)

   (b) A three phase 150MW, 0.85 p.f., 50Hz star-connected synchronous generator has synchronous reactance of 1.072Ω per phase and the armature resistance is negligible. Find the excitation emf and the voltage regulation if the generator supplies full-load output at 0.8 p.f. lagging at a terminal voltage of 13kV. (10 marks)

8. (a) Suppose a three phase synchronous generator is connected to an infinite bus bar with fixed voltage. Draw the phasor diagrams to illustrate whether the synchronous generator is over or under excited if the load has (i) unity power factor (ii) leading power factor (iii) lagging power factor. (6 marks)

   (b) The results of the open circuit test and short circuit test of a three phase, 100MVA, 11 kV, 50Hz star-connected synchronous generator are shown in Fig. Q8. The armature resistance of the generator is 0.2Ω per phase. The generator supplies power to load of 15MVA, 0.8 p.f. lagging at rated voltage.

   (i) Using graphical method, determine the unsaturated synchronous reactance of the synchronous generator in ohms. (7 marks)
   (ii) Find the excitation emf, the field current and voltage regulation. (7 marks)

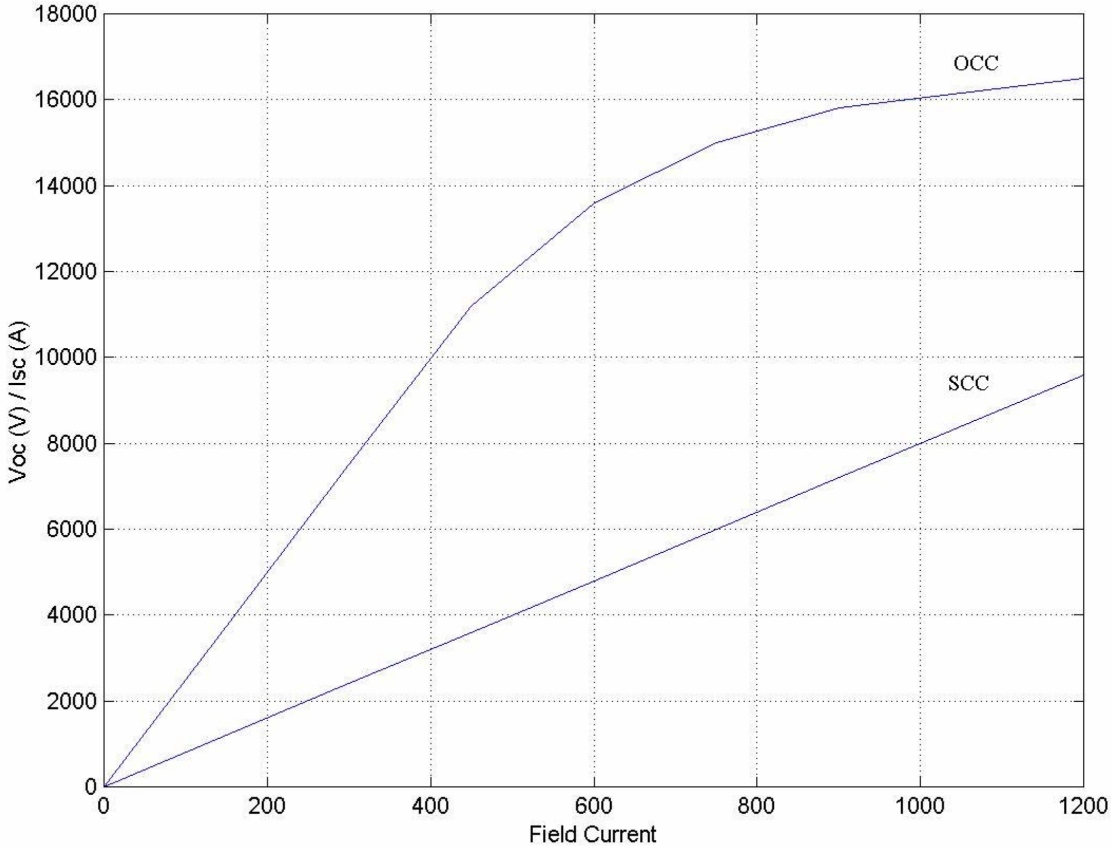

Fig. Q8 - *Note: Voc is the line to line voltage in kV

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