ELECTRICAL MACHINES
(MECH 3133)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) The e.m.f. induced in the armature of the shunt generator is 600V. The armature resistance is 0.1ohm. If the armature current is 200A, the terminal voltage will be
(a) 640 V (b) 620 V (c) 600 V (d) 580 V.

(ii) If P_{core} and P_{cu} represents core loss and full load copper loss respectively, the maximum kVA delivered by transformer to the load corresponding to maximum efficiency is equal to rated kVA multiplied by
(a) $\frac{P_{core}}{P_{cu}}$ (b) $\sqrt{\frac{P_{core}}{P_{cu}}}$ (c) $\left(\frac{P_{core}}{P_{cu}}\right)^2$ (d) $\frac{P_{cu}}{P_{core}}$

(iii) For an ideal transformer the windings should have
(a) Maximum resistance on primary side and least resistance on secondary side
(b) No ohmic resistance on either side
(c) Least resistance on primary side and maximum resistance on secondary side
(d) Equal resistance on primary and secondary side.

(iv) The flux created by the current flowing through the primary winding of a transformer induces emf in
(a) Primary winding only
(b) Both primary and secondary winding
(c) Secondary winding only
(d) Transformer core only.

(v) The maximum efficiency of transformer occurs when
(a) Iron loss > Copper loss (b) Iron loss = Copper loss
(c) Iron loss < Copper loss (d) None of (a), (b) & (c).

(vi) The relationship between rotor frequency f_r, slip s and stator supply frequency f_s is given by
(a) $f_s = sf_r$ (b) $f_r = sf_s$
(c) $f_r = (1-s)f_s$ (d) $f_r = s^2f_s$.

(vii) The frequency of rotor current of a 3 phase, 4 pole 50 Hz induction motor operating at 2% slip is
(a) 2 Hz (b) 1 Hz (c) 50 Hz (d) 100 Hz

(viii) A 480MW, 3 phase Y-connected synchronous generator has a rated voltage of 20kV at a power factor of 0.8. The line current when operating at full load rated conditions
(a) 13.43 kA (b) 17.3 kA
(c) 23.25 kA (d) 27.36 kA

(ix) When synchronous generator is loaded, its terminal voltage may increase when load power factor is
(a) leading (b) lagging
(c) zero (d) unity.

(x) In synchronous motor, 'V' curves represent the variation of
(a) Armature current with maximum power developed
(b) Armature current with field current
(c) Field excitation with stalling torque
(d) Field excitation with minimum power developed.

Fill in the blanks with the correct word

(xi) Direction of rotation of motor is determined by _____ law.

(xii) The number of parallel path in case of wave winding is _____.

(xiii) If the coil pitch is less than one pole pitch, then the coil is called as _____.

(xiv) A 40kVA single phase transformer has a full load copper loss of 160W. The copper loss at 75% of full load is _____.

(xv) The slip speed of a 3 phase, 6 pole induction motor operating at 3% slip is _____.

Group - B

2. (a) Classify dc generator according to the methods of excitation. *[(CO1)(Remember/LOCQ)]*
(b) Derive the emf equation of a dc generator. *[(CO1)(Understand/LOCQ)]*
(c) A dc shunt machine connected to 250V supply, has an armature resistance of 0.12Ω and the resistance of the field circuit is 100Ω. Find the ratio of the speed as a generator to the speed as a motor, the line current in each case being 80A. *[(CO2)(Evaluate/HOCQ)]*

3 + 4 + 5 = 12

3. (a) What is armature reaction. What are the two effects of armature flux on the main flux? *[(CO2)(Remember/LOCQ)]*
(b) Draw and explain the speed / armature current characteristics and torque / armature current of a dc series and shunt motor. *[(CO2)(Understand/LOCQ)]*
(c) A lap-wound dc shunt generator having 80 slots with 12 conductors per slot generates at no load emf of 400 V when running at 1000 r.p.m. At what speed should it be rotated to generate a voltage of 210 V on open circuit. *[(CO2)(Apply/IOCQ)]*

3 + 4 + 5 = 12

Group - C

4. (a) Derive the emf equation of a single phase transformer. *[(CO3)(Remember/LOCQ)]*
   (b) Analyze the phasor diagram of a practical transformer operating under lagging power factor load. *[(CO3)(Analyze/IOCQ)]*
   (c) A 30 kVA single phase transformer has 500 primary turns and 30 secondary turns. The primary is connected to a 3300 V, 50 Hz supply. Evaluate (i) the maximum flux in the core, (ii) the secondary emf, (iii) the primary and secondary currents. *[(CO3)(Evaluate/HOCQ)]*

4 + 5 + 3 = 12

5. (a) Define voltage regulation of a transformer. Hence derive the condition at which maximum voltage regulation occurs. *[(CO3)(Remember/LOCQ)]*
   (b) A 75 kVA transformer has 500 turns on primary and 100 turns on secondary. The primary and secondary resistances are 0.4 Ω and 0.02 Ω respectively and the corresponding leakage reactances are 1.5 Ω and 0.045 Ω respectively. The supply voltage is 2200 V. Determine (i) the equivalent impedance referred to the secondary, (ii) the voltage regulation at a power factor of 0.8 lagging. *[(CO3)(Apply/IOCQ)]*
   (c) The power input to the high voltage winding of a 440/220 V single phase transformer is 80 W. Evaluate the (i) the no load current, (ii) the core loss current and (iii) the magnetizing current of the transformer, if the power factor of the no load current is 0.3 lagging and the low voltage winding is kept open. *[(CO3)(Evaluate/HOCQ)]*

4 + 5 + 3 = 12

Group - D

6. (a) Explain with necessary diagram and calculations how rotating magnetic field is produced in a 3 phase induction motor. *[(CO4)(Remember/LOCQ)]*
   (b) A 6 pole, 50 Hz, 3-ϕ induction motor has a slip of 1% at no load and 3% at full load. Evaluate: (a) synchronous speed, (b) no load speed, (c) full load speed, (d) frequency of rotor current at standstill, (e) frequency of rotor current at full load. *[(CO4)(Evaluate/HOCQ)]*
   (c) Define slip of an induction motor. Hence explain why an induction motor cannot run at synchronous speed. *[(CO4)(Analyze/IOCQ)]*

4 + 5 + 3 = 12

7. (a) Show that in a 3 phase induction motor
   $\frac{\tau_{fl}}{\tau_{max}} = \frac{2s\alpha}{s^2+\alpha^2}$
   Where τ_{fl} = full load torque, τ_{max} = maximum torque, s = full load slip of the motor, α = slip corresponding to maximum torque. *[(CO4)(Apply/IOCQ)]*
   (b) A 6 pole, 3-ϕ, 50 Hz induction motor runs on full load with a slip of 4%. Given the rotor standstill impedance per phase as (0.01 + j0.05) Ω, evaluate the available maximum torque in terms of full load torque. Also determine the speed at which the maximum torque occurs. *[(CO4)(Evaluate/HOCQ)]*

(c) Sketch the torque-slip characteristic of a 3 phase induction motor and mark salient regions on this diagram. *[(CO4)(Remember/LOCQ)]*

4 + 5 + 3 = 12

Group - E

8. (a) Derive the necessary e.m.f. equation for the synchronous generator at lagging and unity power factor. Draw necessary phasor diagrams. *[(CO5)(Understand/LOCQ)]*

(b) A 3-phase, 50 Hz, 4 pole star connected turboalternator has 54 slots with 4 conductors per slot. The pitch of the coils is 2 slots less than the pole pitch. If the machine gives 3300V between line on open circuit with sinusoidal flux distribution, determine the useful flux per pole. *[(CO5)(Apply/IOCQ)]*

6 + 6 = 12

9. (a) Why is synchronous motor not self-starting? What methods are generally used to start the synchronous motors? *[(CO6)(Remember/LOCQ)]*

(b) Sketch the equivalent circuit of a 3 phase synchronous motor and hence analyze the phasor diagram of the same under (i) lagging power factor load, (ii) leading power factor load, (iii) unity power factor load. *[(CO6)(Apply/IOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	42.70	35.43	21.87

Course Outcome (CO):

After the completion of the course students will be able to

CO1: Explain the constructional details and operating principle of the DC generator and analyze the performance under various operating conditions to solve complex electrical engineering problems.

CO2: Analyze the performance of DC motors under various operating conditions to solve complex electrical engineering problems.

CO3: Identify and analyze the problems related to performance analysis of single phase transformer reaching substantiated conclusion.

CO4: Formulate and solve the numerical problems related to three phase induction motor.

CO5: Apply the knowledge of synchronous generator to identify and analyze the problems related to performance analysis.

CO6: Implement the understanding of synchronous motor to solve complex engineering problems related to various applications.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*