**W'08 : 7 AN : EL 407 ( 1468 )**

# DESIGN OF ELECTRICAL SYSTEMS

*Time : Three hours*

*Maximum Marks : 100*

*Answer* FIVE *questions, taking* ANY TWO *from* **Group A**, ANY TWO *from* **Group B** *and* ALL *from* **Group C**.

*All parts of a question ( a, b, etc. ) should be answered at one place.*

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*Any missing or wrong data may be assumed suitably giving proper justification.*

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## Group A

1. ( *a* ) Derive the output equation of a d.c. machine. 10

( *b* ) What are the disadvantages of higher specific electric and magnetic loading ? 5

( *c* ) A 5 kW, 250 V, 4 pole, 1500 rpm d.c. shunt generator is designed to have a square pole face. The average flux density in the air gap is 0·42 $Wb/m^2$ and ampere conductors per metre is 15000. Find the main dimensions of the machine. Assume full load efficiency is 0·87 and ratio of pole arc to pole pitch is 0·66. 5

**2.** (*a*) Obtain an expression to find the maximum value of permissible core length of a d.c. machine. What is the limiting value of the armature diameter? 10

(*b*) List the factors to be considered for selecting the number of armature slots. What are the guiding factors for choice of number of armature slots? 5

(*c*) Find the armature voltage drop of a 300 kW, 500 V, 6 pole lap connected d.c. generator having 150 slots with 8 conductors per slot. Area of each conductor is 25 $mm^2$ and length of mean turn is 2·5 m. The resistivity is 0·021 Ω/m. 5

**3.** (*a*) What is a concentric winding and what are the types? 4

(*b*) Deduce the expression for emf generated in a fractional pitch concentric winding. 10

(*c*) Why should the commutator pitch in a simplex wave winding always be an integer? 4

(*d*) What is the requirement of a dummy coil? 2

**4.** (*a*) For a d.c. machine, show that for a particular temperature rise, the mmf per unit of height of field winding is proportional to under root of product of permissible loss, copper space factor, and depth of winding. 10

(*b*) Derive the calculation of resistance steps of d.c. shunt motor starter. 10

**Group B**

**5.** (*a*) Optimise the transformer design from the point of view of (*i*) minimum cost, and (*ii*) minimum loss. 12

(*b*) The ratio of flux to full load mmf in a 400 kVA, 50 Hz single phase core type power transformer is $2{\cdot}4 \times 10^{-6}$. Calculate the net iron area and the window area of the transformer. Maximum flux density in the core is 1·3 $Wb/m^2$, current density 2·7 $A/mm^2$, and window space factor 0·26. Also, calculate the full load mmf. 8

**6.** (*a*) What are the different methods of cooling of transformers? 5

(*b*) What is CTC winding? Why is it preferred? 5

(*c*) What are the functions of conservator and breather in transformer? 5

(*d*) Why is transposition done in helical windings? 5

**7.** (*a*) Which is the type of rotor construction recommended for induction motor with high value starting torque? 5

(*b*) What is overload capacity of induction motor? Comment on selection of values of overload capacity of induction motor. What is the impact if the a.c. value is higher? 8

(*c*) What afe the effects of space harmonics? 4

(*d*) What is the function of a frame in induction motor? 3

**8.** (*a*) Find the main dimensions of a 15 kW, 3-phase, 400 V, 50 Hz, 2810 rpm squirrel cage induction motor having an efficiency of 0·88 and a full load power factor of 0·9. Assume that specific magnetic loading = 0·5 $Wb/m^2$; specific electric loading = 25000 A/m. Take the rotor peripheral speed as approximately 20 m/s at synchronous speed. Derive the necessary equations used. 15

(*b*) Which factor should be considered when estimating length of the air gap of induction motor? Why should the air gaps be as small as possible? 5

## Group C

**9.** Answer the following in brief : 2 x 10

(*i*) What is diversity factor in a power distribution system?

(*ii*) What are the advantages of ring main distribution system?

(*iii*) Why does skewing lower the power factor and overload capacity of induction motor?

(*iv*) What is the condition of maximum efficiency of a d.c. machine?

(*v*) What is a three-winding transformer?

(*vi*) What types of mechanical forces develop in transformer windings?

(*vii*) Why are the electrical mechines with large dimensions more efficient?

(*viii*) Why do small machines have lower specific magnetic loading?

(*ix*) How would you reduce the armature reaction in a d.c. generator?

(*x*) What is the role of peripheral speed on choice of $D$ and $L$ in an electrical machine?

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## Group A

1. (*a*) What are the guiding factors for selection of number of poles in a d.c. machine? 6

(*b*) Calculate the diameter and length of armature for a 7·5 kW, 4 pole, 1000 r.p.m., 220 V d.c. shunt motor. Given : Full load efficiency = 83%; maximum gap flux density = 0·9 $Wb/m^2$; specific electric loading = 30,000 amp conductors/m; and field form factor = 0·7. Assume that the maximum efficiency occurs at full load and the field current is 2·5% of rated current. The pole face is square. 8

(*Turn Over*)

(c) What are the criteria for choice of ampere conductors per metre in context of d.c. machine design? 6

2. (a) What are the factors to be considered for selecting core length and armature diameter for a d.c. machine design. 6

(b) Determine the main dimensions, number of poles and the length of air gap of a 600 kW, 500 V, 900 r.m.p. d.c. generator. Assume average gap density as $0{\cdot}6\,Wb/m^2$ and ampere conductors per metre as 35000. The ratio of pole pitch to pole arc is 1·34 and the efficiency is 91%. Following are the design constraints : Peripheral speed $\not>$ 40 m/s; frequency of flux reversals $\not>$ 50 Hz; current per brush arm $\not>$ 400 A; and armature m.m.f. per pole $\not>$ 7350 A. The m.m.f. required for air gap is 50% of armature m.m.f. and gap contraction factor is 1·15. 10

(c) Justify that flux per pole is reduced due to armature reaction in a d.c. machine. 4

3. (a) Discuss various aspects of commutator design in a d.c. machine. 6

(b) State briefly the considerations that determine the maximum rating of a d.c. machine armature of a given diameter. Determine the maximum rated output that can be obtained from a 375 r.p.m. lap wound d.c. generator without exceeding a peripheral speed of 40 m/s, an average e.m.f of 70 V in each conductor and an electric loading of 45,000 ampere conductors per metre circumference. 14



4. (a) Discuss how apparent and real flux densities in the teeth of d.c. machine are related. 8

(b) The following particulars refer to the shunt field coil for a 440 V, 6 pole, d.c. generator; mmf per pole = 7000 A; depth of winding = 50 mm; length of inner turn = 1·1 m; length of outer turn = 1·4 m, loss radiated from outer surface excluding ends = $400\,W/m^2$; space factor = 0·62; resistivity = 0·02 ohm/m and $mm^2$. Calculate (i) the diameter of the wire, (ii) length of coil, (iii) number of turns, and (iv) exciting current. Assume a voltage drop of 20% of terminal voltage across the field regulator. 12

## Group B

5. (a) Derive an output equation of a three-phase transformer. 8

(b) Calculate approximate overall dimensions for a 200 kVA, 3000/400 V, 50 Hz 3-phase core type transformer. The following data may be assumed : e.m.f. per turn = 9; maximum flux density = $1{\cdot}3\,Wb/m^2$; current density = 2·5 $Amp/mm^2$; window space factor = 0·3, and overall height = overall width. Assume a four-stepped core and 90% stacking factor. 12

6. (a) What are different methods of cooling for a transformer? 5

(*b*) How does heat dissipation take place from the tank surface of a transformer? 5

(*c*) The tank of a 300 kVA, 3-phase, oil immersed self-cooled transformer is 145 cm in height and 55 cm × 115 cm in plan. The full load loss to be dissipated is 5·5 kW. Find the number and disposition of cooling tubes necessary in order to limit the temperature rise of the tank walls to 35°C. The tube are of 5 cm diameter and may be assumed to have an average length of 100 cm and speed 8 cm apart between centres. Draw the arrangement of tubes completely. 10

7. (*a*) Derive an output equation of an induction motor in terms of specific electric and magnetic loadings. 4

(*b*) How are stator base diameter (m) and stator length (m) of an induction motor related with each other for best power factor? 3

(*c*) Discuss the deciding factors for consideration of an air gap of an induction motor. 3

(*d*) Determine the main demensions, number of radial ventilating ducts, number of stator slots and number of terms per phase of a 3·7 kW, 400 V, 3-phase, 4-pole 50 Hz squirrel cage induction motor to be started by a star-delta starter. Also, work out the winding details. 10



8. (*a*) Explain the effects of harmonic fields in design consideration of a squirrel cage rotor of an induction motor. 6

(*b*) A 15 kW, 400 V, 3-phase, 50 Hz, 6-pole induction motor has a diameter of 0·3 m and length of core 0·12 m. The number of slots (stator) is 72 with 20 conductors/slot. The stator is delta-connected. Calculate the value of magnetizing current per phase of the length of air gap is 0·55 m. The gap contraction factor is 1·2. Assume the mmf required for iron parts to be 35% of the air gap mmf. Coil span is 11 slots. 10

(*c*) Discuss the effect of dispersion coefficient on maximum power factor of an inductor motor. 4

## Group C

9. Answer the following in brief : 2 × 10

(*i*) Deep bars are used for the rotors of squirrel cage induction motor — why?

(*ii*) Why inductor motor should not have a small number of slots per pole per phase?

(*iii*) Why leakage coefficient in a loaded machine has a larger value as compared to that in an unloaded machine?

(*iv*) Why are soft magnetic materials preferred for the construction of core of the electromagnets?

(*v*) What are two main advantages (distinct) of double layer winding?

(*vi*) Why are equalizer connections used in simplex lap winding?

(*vii*) Why is the core made multistepped in transformers?

(*viii*) What is recommended value of minimum electric strength of transformer oil as per IS 335-1972?

(*ix*) Why should the value of flux density of a distribution transformer be kept low?

(*x*) Why is a higher value of armature conductors (a.c.) per meter is preferred in a semi-closed (d.c) machine?

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### Group A

**1.** (*a*) What are the characteristic of the material(s) used in making rheostats? Explain. 5

(*b*) A copper bar, 1·2 cm in diameter, is insulated with micanite tube which fits tightly around the bar and into the rotor slot of an induction motor. The micanite tube is 1·5 mm thick and its thermal resistivity is 8 ohm-m. Calculate the loss that will pass from copper bar to iron, if a temperature difference of 25° C is maintained between them. The length of the bar is 20 cm. 10

(c) The resistivity of ferric-chromium-aluminium alloy is $5\cdot1 \times 10^{-8}$ ohm-m. A sheet of the material is 15 cm long, 6 cm wide and 0·014 cm thick. Determine resistance between (i) opposite ends, and (ii) opposite sides. 5

2. (a) Prove that in a d.c. machine, the volume of active material is proportional to torque of the machine. 5

(b) Determine the main dimensions, number of poles and the length of air gap of a 600 kW, 500 V, 900 rpm of a d.c. generator. Assume average gap density as 0·6 Wb/m² and ampere conductors per metre as 3500. The ratio of pole arc to pole pitch is 0·67 and the efficiency is 91 per cent. The peripheral speed should not exceed 40 m/s and the armature m.m.f. per pole should be below 7500 A. The m.m.f. required for air gap is 50 per cent of armature m.m.f. and gap contriction factor is 1·15. 15

3. (a) What are the types of d.c. windings? With a suitable example, explain them and also mention and mark different types of winding pitches. 10

(b) Find whether the following simplex lap windings are symmetrical or not? 5×2

(i) 4 poles, 26 slots, 26 coils.

(ii) 6 poles, 37 slots, 37 coils.

4. (a) Deduce a general expression for the nth harmonic m.m.f. distribution of 3 phase a.c. machines. Hence, write the fundamental, third, fifth and seventh harmonic expressions. 15

(b) Deduce the design procedure of series field of the d.c. machine. 5

**Group B**

5. (a) Show that the output of a three-phase core type transformer is

$$Q = 5\cdot23\, f B_m H d^2 H w \times 10^{-3} \text{kVA}$$

where $f$ = frequency in Hz, $B_m$ = maximum flux density in Wb/m², $d$ = effective diameter of core in m, $H$ = magnetic potential gradient in limb in A/m, $Hw$ = height of limb (window) in m. 10

(b) Determine the dimensions of core and yoke for a 200 kVA, 50 Hz single-phase core type transformer. A cruciform core is used with distance between adjacent limbs equal to 1·6 times the width of core laminations. Assume voltage per turn 14 V, maximum flux density 1·1 Wb/m², window space factor 0·32, current density 3 A/mm², and stacking factor 0·9. 10

6. (a) Transformers rated for larger outputs must be provided which means to improve the conditions of heat dissipation. This may be done by providing corrugations, tubing or radiators. Design the tank with tubes for three-phase core type transformer. 10

(b) Derive an expression for the leakage inductance per limb of the windings of a single-phase transformer referred to the primary side in terms of the relevant quantities. 10

7. (a) Express the relation between $D$ and $L$ (with usual meaning) for best power factor from the viewpoint of total permeance for leakage flux path of an induction motor. 10

(b) How can the starting torque of three-phase induction motor be improved by using (i) double cage rotor, and (ii) deep bar rotor? 5 × 2

8. (a) What are the points to be considered for fixing the location of distribution transformer? Explain them. 5

(b) Following data were collected from the daily load curves of a power system during a year:

| *Load*, kW | *Duration*, hr |
|---|---|
| 15,000 | 87 |
| 12,000 and over | 876 |
| 10,000 and over | 1,752 |
| 8,000 and over | 2,628 |
| 6,000 and over | 4,380 |
| 4,000 and over | 7,000 |
| 2,000 and over | 8,760 |

Construct the annual load duration curve and find the load factor of the system. 10

(c) Discuss the procedure for design of a distributor. 5

**Group C**

9. Answer the following in brief: 2 × 10

(i) How do a good load factor and a good diversity factor help to keep overall cost of generation low?

(ii) What are the advantages of a doubly fed distributor over single fed distributor?

(iii) Give the advantages and uses of lap and wave windings.

(iv) Why are interpole windings connected in series with the armature circuit?

(v) Why is a starter necessary for d.c. motor?

(vi) Explain the heating time constant of transformers.

(vii) Draw the shape and size of rotor slots for squirrel cage rotor (closed and semi-enclosed type).

(viii) Write the classes of insulating materials with assigned temperature.

(ix) What are different types of losses of d.c. machine and write the expression of efficiency.

(x) What are the informations obtained from circle diagram of three-phase induction motor?

## S'10:7AN:EL 407 (1468)

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### Group A

1. (*a*) Derive the output equation for a d.c. machine. 5

   (*b*) What are the advantages and disadvantages of highly specific magnetic loading ? 3 + 3

   (*c*) Find the diameter and length of armature of a 4-pole, 10 kW, 220V, 1000 rpm d.c. shunt motor. Assume suitable data. 9

2. (*a*) A 400 V d.c. shunt motor has armature resistance of 0·5 ohm. Find the values of resistance elements of starter to limit maximum current to 100 A and ratio of maximum current to minimum current to 1·5. 8

(*b*) What are the factors to be taken into account in selecting the number of poles in the design of d.c. machine. Discuss. 6

(*c*) Distinguish between lap and wave windings for d.c. machines. 6

**3.** A synchronous machine stator has 90 slots and 8 poles. Prepare a table showing various slot positions for one repeatable basic section of the winding. Write the phases to which the coils in various slots belong. Choose a suitable coil span. Show the interconnection of coils. 20

**4.** (*a*) Find the breadth factor for a three-phase winding for a machine having 9 slots per pole and 60° phase groups. 6

(*b*) A synchronous machine has 180 slots and is rated at 50 Hz and 600 rpm. If coil span is 15 slots, find the pitch factor. 6

(*c*) How would you select the number of slots in the design of d.c. machine ? Discuss. 8

### Group B

**5.** (*a*) Derive the output equation for a three-phase core-type transformer. 8

(*b*) Find the main dimensions ( core diameter, window area, distance between adjacent cores, overall height, overall width) of a 200 kVA, 6600/440V 50 Hz, three-phase core-type transformer. Assume suitable data. Use three stepped core. 12

**6.** Write short notes on the following : 5 × 4

(*i*) Design of feeders and distributors

(*ii*) Design of domestic wiring

(*iii*) Load factor and diversity factor

(*iv*) Design of transformer tank.

**7.** (*a*) The yearly load duration curve of a power plant is a straight line. The maximum load is 30 MW and minimum load is 20 MW. Plant capacity is 35 MW. Find (*i*) plant capacity factor, (*ii*) load factor, and (*iii*) utilization factor. 3 × 3

(*b*) The load on a power plant on a typical day is as under : 5 + 6

| Time : | 12-5 AM | 5-9 AM | 9AM-6PM | 6-10 PM | 10-12 PM |
|---|---|---|---|---|---|
| Load, MW : | 20 | 40 | 80 | 100 | 20 |

Plot chronological load curve and load duration curve.

**8.** (*a*) Estimate the stator bore diameter and length for a 7·5 kW, three-phase, 400V, 50 Hz 4 pole delta-connected squirrel cage induction motor. Assume suitable data. 10

(*b*) How would you select rotor bar current and rotor bar area of three-phase induction motor ? 6

(*c*) List the types of transformers as per cooling methods. 4

### Group C

**9.** Choose the best alternative for the following : 1 × 20

(*i*) If connected load is 40 MW, maximum demand is 20 MW and total energy in a year is $4{\cdot}36 \times 10^7$ units, the demand factor is

(*a*) 2

(*b*) 2/3

(*c*) 1/2

(*d*) 1/3.

(*ii*) The minimum permissible size of aluminium cable for lighting circuits is

(*a*) 1·2 $mm^2$

(*b*) 1·5 $mm^2$

(*c*) 2·2 $mm^2$

(*d*) 3·5 $mm^2$.

(*iii*) The purpose of earthing the electric appliances is to

(*a*) provide safety against shock

(*b*) ensure that appliance works properly

(*c*) ensure that appliance gets full voltage

(*d*) All of the above.

(*iv*) The illumination level in the living room of a residential house should be about

(*a*) 50 lux

(*b*) 300 lux

(*c*) 150 lux

(*d*) 25 lux

(*v*) The material, commonly used for insulation in HV cables, is

(*a*) lead

(*b*) rubber

(*c*) paper

(*d*) iron.



(*vi*) A permeable substance is one

(*a*) which is a strong magnet

(*b*) through which magnetic lines of flux can pass very easily

(*c*) which is a good conductor.

(*d*) which can behave as an insulator.

(*vii*) If the area of hysteresis loop of a material is large, the hysteresis loss in this material is

(*a*) small

(*b*) large

(*c*) zero

(*d*) Any one of the above.

(*viii*) The thickness of lamination is about

(*a*) 2 mm

(*b*) 5 mm

(*c*) 0·5 mm

(*d*) 0·1 mm.

(*ix*) The yoke of a d.c. machine

(*a*) must be made of magnetic material

(*b*) should preferably be made of magnetic material.

(*c*) is always made of non-magnetic material

(*d*) can be of any material.

(*x*) A d.c. generator has six poles. A brush shift of 6° actual means a brush shift of

(*a*) 6° electrical
(*b*) 18° electrical
(*c*) 36° electrical
(*d*) 2° electrical.

(*xi*) Modern starters used in d.c. shunt motors

(*a*) are manual
(*b*) use time delay relays
(*c*) use back emf relays
(*d*) either (b) or (c) above.

(*xii*) A 10 kVA, 200/400 V single-phase transformer is operating with secondary open circuits. The input current will be about

(*a*) 2 A
(*b*) 10 A
(*c*) 20 A
(*d*) 50 A.

(*xiii*) It is necessary that magnetic circuit of a transformer is close. This is done to ensure

(*a*) high efficiency
(*b*) good regulation
(*c*) good regulation and high efficiency
(*d*) good regulation and high power factor.

(*xiv*) The full load efficiency of a large size power transformer is about

(*a*) 0·75
(*b*) 0·85
(*c*) 0·9
(*d*) 0·98.

(*xv*) The breadth factor for a three-phase a.c. winding is about

(*a*) 0·96
(*b*) 0·85
(*c*) 0·7
(*d*) 0·5.

(*xvi*) Under blocked rotor conditions, the frequency of rotor currents in a 50 Hz three-phase induction motor is

(*a*) very low
(*b*) very high
(*c*) 50
(*d*) about 50.

(*xvii*) For a 20 kW, three-phase, 400 V induction motor, the no load current is about

(*a*) 100 A
(*b*) 40 A
(*c*) 10 A
(*d*) 2 A.

(*xviii*) A 50 Hz three-phase induction motor has a full-load speed of 1440 rpm. The number of poles of the motor is

(*a*) 4
(*b*) 6
(*c*) 8
(*d*) 12.

(*xix*) If $P$ is number of poles; $L$, the length of core ; and $D$, the internal diameter of stator of a three-phase, 50 Hz induction motor, then to obtain good power factor,

(*a*) $D = 0{\cdot}135\, P\sqrt{L}$
(*b*) $D = 1{\cdot}35\, P\sqrt{L}$
(*c*) $D = 1{\cdot}35\, PL$
(*d*) $D = 0{\cdot}135\, PL$.

(*xx*) In design of transformer tank, the heat dissipation by convection is taken as

(*a*) 6.5 $W/m^2/{}^\circ C$
(*b*) 6.5 $W/cm^2/{}^\circ C$
(*c*) 12.5 $W/m^2/{}^\circ C$
(*d*) 12.5 $W/cm^2/{}^\circ C$.

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**Group A**

**1.** (*a*) Prove, from the first principle, that for a rotating machine output in volt-ampere is given by $C_0D^2$ Ln. Discuss, in detail, why the output coefficient $C_0$ changes with size and type of machine. Here $D$ is the armature diameter, *m*; $L$, the stator core length, *m*; and *n*, the speed in r.p.s. 10

(*b*) A 350 kW, 500 V, 450 r.p.m, 6-pole d.c. generator is built with an armature diameter of 0·81 m and a core length of 0·32 m. The lap wound armature has 660 conductors. Calculate specific electric and magnetic loadings. 6

(c) What are the disadvantages of selecting higher values of specific electric loading and magnetic loadings? 4

2. (a) Discuss the factors to be considered for selecting a suitable value for armature diameter of a d.c. machine. 4

(b) Determine suitable values for number of poles, the armature diameter, and armature length for a 1000 kW, 500 V, 300 r.p.m. d.c. generator. Assume average gap density as 10,000 gauss, specific magnetic loading as 400 amp-cond/cm. 10

(c) Discuss the grinding factors for choice of number of poles in case of design of a d.c. machine. 6

3. (a) Explain effect of 'armature reaction' pertaining to design of a d.c. machine, and how is the effect of armature reaction reduced? 6

(b) A 4-pole d.c. generator supplies a current of 140 A. It has 480 armature conductors (i) lap connected, and (ii) wave connected. The brushes are given an actual lead of 10 deg. Calculate the cross and demagnetizing mmf per pole in each case. The field winding is shunt connected and takes a current of 10 A, and find the number of extra shunt field turns to neutralize the demagnetization. 9

(c) What are various constraints for armature design for a d.c. machine? 5

4. (a) Explain the necessity of a starter in d.c. machine and discuss the basic principle employed in the design of a starter for a d.c. series motor. 5

(b) Find the number of sections (steps) and the resistance of each section for a starter of a 300 V d.c. series motor which has a total resistance of 0·12 ohm. The limiting values of current, during starting are 300 A and 226 A, and the corresponding values of the flux are in the ratio of 1·124 : 1. 10

(c) Explain, in terms of the speed-current and torque-current characteristics, the advantages of the series motor for haulage purpose. 5

## Group B

5. (a) Derive an output equation for voltage per turn; $V_t = C\sqrt{kVA}$ for a 1-$\phi$ transformer and discuss significance and factors upon which constant '$C$' depends, and effect of the type of transformer upon the factor '$C$' also. 8

(b) Determine the main dimensions of the core (four-stepped core) for a 250 kVA, 6600/415 V, 50 Hz, 3-phase transformer with star-connected winding. Assume the data as: $V_t$ (voltage per turn) = 9; maximum flux density = 1·25 Wb/m$^2$; $A_i = 0{\cdot}62\, d^2$; window space factor = 0·27, ratio of height of window to width of window = 2; and current density = 200 A/cm$^2$. 12

6. Discuss the following with respect to transformer design: 4 × 5

(a) Significance of iron cost and copper cost

(b) Significance of stepping of the core

(c) Comparison between core and shell-type transformer

(d) Comparison between power and distribution

7. (*a*) What are various types of cooling systems used for transformer cooling ? 5

(*b*) The tank of a 1250 kVA natural cooled and oil immersed transformer has the dimensions length, breadth, and height as 155 cm × 65 cm × 185 cm, respectively. The full load losses to be dissipated are : Core loss = 3.75 kW and copper loss = 15 kW. Assuming an average length of (cooling) tubes as 100 cm and diameter of 5 cm, find a suitable arrangement of the tubes to limit the temperature rise of the tank walls to 50 deg. 15

8. (*a*) Derive an output equation for a three-phase induction motor. 6

(*b*) Discuss how does the value of output coefficient '$C_0$' depends upon the choice of specific electrical loading and specific magnetic loading. 4

(*c*) Determine the main dimensions, number of radial ventilating ducts, number of stator slots, and the number of turns per phase of a 3·7 kW, 400 V, 3-phase, 4 pole, 50 Hz squirrel cage induction motor to be started by a star-delta starter. Also, work out the winding details. Assume air flux density in the gap = 0·45 Wb/m²; Amp.cond/m = 23000; $\eta$ = 85%; power factor = 0·84; machine rated at 3·7 kW with 4 poles; winding factor = 0·955; and stacking factor = 0·9. 10

**Group C**

9. Answer the following in brief : 10 × 2

(*i*) As long as no current flows through the armature conductors, there is no armature reaction, why ?

(*ii*) How the electric loading ($I_a Z_a$) remains same in the armatures of two d.c. machines although the conductor current $I_a$ has changed in two machines ?

(*iii*) Why are the brushes in d.c. machines staggered ?

(*iv*) Why are the equalizer rings not necessary in case of simple wave winding in d.c. machine ?

(*v*) For large (rated) d.c. machines, lap winding with equalizer rings is adopted. Justify.

(*vi*) The windings in a core-type transformer are more susceptible to damage under short circuit conditions than the windings of a shell type transformer.

(*vii*) Why are three winding transformers built with a tertiary winding, being an additional winding.

(*viii*) Why is high content of silicon preferred in core steel of a transformer ?

(*ix*) Compare rotors of squirrel cage and slip ring induction motor particularly for design point of view.

(*x*) Semi-enclosed slots are usually preferred for induction motors, why ?

**S'12:7AN:EL 407 (1468)**

**DESIGN OF ELECTRICAL SYSTEMS**

*Time : Three hours*

*Maximum Marks : 100*

*Answer* FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

*All parts of a question ( a,b,etc.) should be answered at one place.*

*Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.*

*Any missing or wrong data may be assumed suitably giving proper justification.*

*Figures on the right-hand side margin indicate full marks.*

**Group A**

1. (*a*) Explain the term 'output coefficient' in design of d.c. machines. 4

   (*b*) Find (*i*) output coefficient, (*ii*) diameter and length of armature, (*iii*) number of armature conductors, (*iv*) number of armature slots for a 4 pole, 220 V, 10 kW, 1000 rpm d.c. shunt motor. Make suitable assumptions. 16

2. (*a*) Differentiate between single layer and double layer windings. Which one is preferred for armature winding and why ? 8

   (*b*) Show (*i*) layout for first 4 poles, (*ii*) complete interconnection of coils for an 8 pole 90 slot fractional slot a.c. winding. 12

( *Turn Over* )

3. (*a*) Explain the terms 'breadth factor' and 'pitch factor'. Derive their equations. 8

(*b*) Bring out the effect of armature reaction in a.c. machines for lagging and leading power factors. 6

(*c*) Find the breadth factor for an a.c. machine having 9 slots per pole and 60° phase spread in a 3 phase winding. 6

4. Discuss the following in brief: 6 + 6 + 8

(*a*) Design of load hose

(*b*) Causes and elimination of harmonics

(*c*) Skin effect and eddy current losses in a.c. machines.

## Group B

5. Explain the following in transformer design: 6 + 8 + 6

(*a*) Window space factor and its choice

(*b*) Calculation of main dimensions of transformer tank

(*c*) Transformer winding reactances

6. (*a*) Compute the main dimensions of core and window for a 1250 kVA, 33/6·6 kV, 50 Hz, 3 phase core-type transformer. Make suitable assumptions of design data. 14

(*b*) Briefly discuss the different types of windings used in transformers., 6

7. Find the following for a 30 kW, 440 V, 3 phase, 4 pole, 50 Hz, delta-connected cage induction motor: 10 + 4 + 3 + 3

(*i*) Main dimensions of stator frame

(*ii*) Number of stator winding turns

(*iii*) Number of stator slots

(*iv*) Number of stator conductors per slot.

Assume suitable data.



8. (*a*) Figure 1 shows a distribution system. The resistances of different sections are shown. Load at point C is 25 A at unity power factor and load at point D is a motor load drawing current *I* at unity power factor. If voltage at point A is 275 V and at C is 255 V, find motor current *I* and voltage at point D. 10

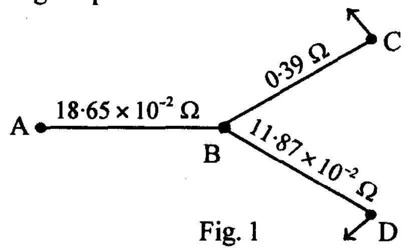


Fig. 1

(*b*) What is a load duration curve ? Discuss its use. 5

(*c*) Discuss in brief the design of domestic wiring. 5

## Group C

9. Explain the following in brief: 10 × 2

(*i*) Diversity factor.

(*ii*) Location of distribution transformer.

(*iii*) Calculation of no load current of three-phase induction motor.

(*iv*) Calculation of losses in a transformer.

(*v*) Determination of number of cooling tubes for a transformer.

(*vi*) Choice of number of poles in a d.c. machine.

(*vii*) Design of rheostat

(*viii*) Commutator windings

(*ix*) Starter for d.c. motor.

(*x*) Advantages of fractional slot winding.

**W'12 : 7AN : EL407 (1468)**

## DESIGN OF ELECTRICAL SYSTEMS

*Time : Three hours*

*Maximum Marks : 100*

*Answer* FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

*All parts of a question (a, b, etc.) should be answered at one place.*

*Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.*

*Any missing or wrong data may be assumed suitably giving proper justification.*

*Figures on the right-hand side margin indicate full marks.*

### Group A

1. (*a*) A 150 kW, 230 V, 500 rpm, d.c. shunt motor has a square field coil. Find number of poles, main dimensions, and air gap length of the motor. Assume the average gap density over the pole are as 0·85 Wb/m$^2$ and ampere conduction per metre as 29,000. The rates of width of pole body to pole pitch is 0·55 and the ratio of pole arc to pole pitch is 0·7. Efficiency of the motor is 91 %. Assume that the mmf required for air gap is 55% of the armature mmf and the air gap contraction factor is 1·15. 10

   (*b*) Discuss the factors affecting the specific loading in the context of design of d.c. machine. 4

   (*c*) Determine suitable values for the number of poles, the armature diameter and armature length for a

1000 kW, 500 V, 300 rpm, d.c. generator. Assume average air gap density as 10000 gauss and specific magnetic loading as 400 A-cond/cm. 6

**2.** (*a*) Following particulars refer to the shunt field coil for a 400 V, 6-pole, d.c. generator : MMF/pole = 7000 A, depth of winding = 50 mm, length of inner turn = 1·1 m, length of outer turn = 1·4 m, loss radiated from outer surface excluding ends = 400 $W/m^2$, space factor = 0·62, resistivity = 0·02 ohm/m and $mm^2$. Calculate (*i*) diameter of the wire, (*ii*) length of the coil, (*iii*) number of turns, and (*iv*) exciting current. 8

(*b*) Discuss effects of slots and ventilating ducts upon reluctance of the air gap for d.c. machines. 6

(*c*) Explain apparent and real flux densities in the teeth pertaining to d.c. machine. How are these two densities related ? 6

**3.** (*a*) What are various aspects of commutator design ? Explain in sequential steps. 4

(*b*) Field coils (cylindrical) of a 4-pole, 400 V, d.c. shunt motor are required to produce 5700 A-T/pole. The mean length of the turn is 0.66 m, while the winding depth is 4 cm. Heat is dissipated at the rate of 1000 $W/m^2$ after outside cylindrical surface of the coil. Calculate the (*i*) dimensions of the coil, (*ii*) size of the conductor, and (*iii*) number of turns. Assume the diameter of the conductor along with the insulation to be 0·175 mm greater than the base conductor. The specific resistance at the working temperature is 2 μΩ-cm. 10

(*c*) How does leakage flux affect the design parameters of rotating machines in general. 6

**4.** (*a*) Explain, in terms of the speed-current and torque current characteristics, the advantages of the series motor for haulage purpose. 6

(*b*) The starter for a 460 V d.c. series motor preferred for haulage purpose has a 5 resistance sections and the current limits during starting are 120 A and 156 A. The resistance of this series motor is 0·19 ohm, and between these current limits this flux changes by 10 percent. Find the resistance of each section. 8

(*c*) Explain armature reaction in d.c. machines and how does it affect in performance evaluation of d.c. machines. 6

## Group B

**5.** (*a*) Derive an equation for output voltage per turn, $V_t = C\sqrt{kVA}$ and discuss significance of the factor '*C*' used in the expression of $V_t$ and also the factor upon which '*C*' depends. 6

(*b*) Determine the main dimensions of the four-stepped core force 250 kVA, 6600/415 V, 50 Hz, three-phase transformer with star-connected winding. Assume the following data : Approximate voltage per turn, $V_t = 9$, maximum flux density = 1·25 $Wb/m^2$, iron area ($A_i$) = 0·62 $d^2$ (*d* is the diamter of circumscribing circle), window space factor = 0·27, ratio of height of window-to-width of window = 2, and current density = 250 $A/cm^2$. 10

(*c*) Explain the significance of iron cost and copper cost in transformer design. 4

**6.** (*a*) Estimate the no-load current of a 400 V, 50 Hz, single-phase transformer with the following particulars : Length of the mean magnetic path = 200 cm, gross cross-section = 100 cm², joints are equivalent to 0·1 mm air gap, $B_m = 0{\cdot}7$ Wb/m², magnetizing force corresponding to 0·7 Wb/m² is 2·2 AT/cm, and specific loss corresponding to 0·7 Wb/m² is 0·5 W/kg. Assume stacking factor of 0·9. 8

(*b*) What do you understand by leakage reactances of core-type transformer ? Derive an expression for total reactance of transformer (per phase) referred to primary side. 6

(*c*) Differentiate between power transformer and distribution transformer with particular reference to core design. 6

7. (*a*) Derive an expression for output equation of an a.c. machine. 6

(*b*) What are the factors influencing the choice of specific magnetic loading and specific electric loading with reference to design of a.c. machines. 6

(*c*) Determine the main dimension number of radial ventilating ducts, number of stator slots and the number of turns per phase of a 3·7 kW, 400 V, 3-phase, 4-pole, 50 Hz, squirrel cage induction motor to be started by a star/delta starter. Also, work out the winding details. 8

8. (*a*) Prove that the voltage drop diagram for a uniformly loaded distributor fed at one end is a parabola. 6

(*b*) Explain 'skin effect' and 'proximity effect' emphasising on effective resistance and reactance after conductor. 4

(*c*) A 2-core distributor cable AB is 400 m long and supplies an uniformly distributed lighting load of 1 A/m. There are concentrated loads of 120 A, 72 A, 48 A and 120 A at 40 m, 120 m, 200 m and 320 m, respectively from the end *A* as shown in Fig. 1. The cable has a resistance of 0·15 ohm/km run. Determine the position of the lowest-run lamp and its voltage when the cable is fed at 250 V from both ends *A* and *B*. 10

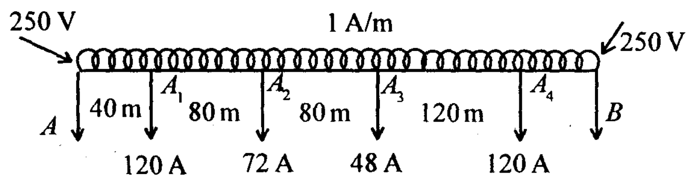


Fig. 1

## Group C

9. Answer the following in brief : 10 × 2

(*i*) The charge distribution on a conical-shaped conductor is uniform. Justify.

(*ii*) The charge on an isolated conductor resides at the surface of the conductor. Why ?

(*iii*) Direct-on-line starters are not suitable for starting large d.c. motors. Explain.

(*iv*) Why is the yoke of generator made of cast iron ?

(*v*) Why are carbon brushes generally used in d.c. generators ?

(*vi*) Residual magnetism is the essential prerequisite for starting d.c. series generator. Why ?

(*vii*) If in a transformer the secondary turns are doubled and at the same time the primary voltage is reduced by half, the secondary voltage will *not* change. Why ?

(*viii*) The short-circuit current can continuously flow through power transformers without causing any damage to it. Why ?

(*ix*) Why is hydrogen cooling preferred for turbo alternators of more than 50 MW rating ?

(*x*) State the reason why air gaps should be kept to a minimum of length and maximum of cross-section.

# W'13: 7 AN: EL 407 (1468)

## DESIGN OF ELECTRICAL SYSTEMS

*Time : Three hours*

*Maximum Marks : 100*

*Answer* FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

*All parts of a question ( a,b,etc.) should be answered at one place.*

*Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.*

*Any missing or wrong data may be assumed suitably giving proper justification.*

*Figures on the right-hand side margin indicate full marks.*

### Group A

**1.** (*a*) Define specific magnetic loadings ($B_{av}$) and specific electric loadings (a. c.), and obtain an expression for the 'output coefficient' for a d.c. machine. 9

(*b*) What are commutating poles ? Why are they used ? Why are these poles wound with series turns and tapered ? 6

(*c*) The diameter and length of a 500 kW, 500 V, 455 rpm, 6-pole d.c. generator are 84 cm and 35 cm, respectively. If it is lap wound with 660 conductors, estimate the specific magnetic loadings and specific electric loadings. 5

**2.** (*a*) Derive an expression for the minimum number of commutator segments required in a d.c. machine. 10

(*b*) Following design data pertains to a 90 kW, 1500 rpm, d.c. motor :

Average air gap flux density, $B_{av} = 0{\cdot}5$ Wb/m$^2$
Pole arc/pole pitch, $\psi = 0{\cdot}65$
Armature diameter, $D = 40$ cm
Armature length, $L = 20{\cdot}42$ cm
Length of air gap, $l_g = 4$ mm
No. of ducts, $n_d = 1$
Width of duct, $W_d = 10$ mm
Carters' coefficients :
$K_{cd} = 0{\cdot}35$ for ducts
$K_{cs} = 0{\cdot}39$ for slots
Number of slots, $S = 40$
Width of open type of slot, $W_s = 11.5$ mm

Estimate the mmf required for the air gap. 10

3. (*a*) Explain the guiding factors for selection of armature slots of a d.c. machine. 10

(*b*) Discuss the factors which must be considered in the choice of the number of poles for a d.c. machine. 10

4. (*a*) Prove that power developed by the armature ($P_a$) of a d.c. machine is given by

$$P_a = \frac{P(1+2\eta)}{3\eta} \text{ for small motors}$$

$$P_a = \frac{P(1+2\eta)}{3\eta} \text{ for small generators}$$

under the assumption that friction, windage and iron losses amount to one-third of the total losses. ( $P$ and $\eta$ stand for power output and efficiency, respectively.) 10

(*b*) Write briefly on ventilation and cooling of d.c. machines. 10

## Group B

5. (*a*) Describe the method of estimating the magnetising current of an induction motor. 15

(*b*) Why is a short gap length so important to the operation of an induction motor ? 5

6. (*a*) Show that the end ring current of a squirrel cage induction motor is given by $S_r I_b / \pi P$, where $S_r$ = number of rotor slots, $I_b$ = rotor bar current, and $P$ = number of poles. 10

(*b*) Show that the gross core area of a 3-stepped core is approximately 85 % of the area of circumscribing circle. 10

7. (*a*) What are the simplifying assumptions made in the derivation of a formula for leakage reactance calculation in a three-phase core type transformer. 10

(*b*) A 1000 kVA, 3300/433 V, 50 Hz, delta/star, three-phase core type transformer has the following data :

Width of h.v. winding, $b_p = 32$ mm
Width of l.v. winding, $b_s = 25$ mm
Height of coils, $L_c = 600$ mm
Length of mean turns, $L_{mt} = 1.184$ m
H.V. winding turns, $T_h = 198$ and the width of duct between h.v. and l.v. windings = 15 mm

Calculate the leakage reactance of the transformer referred to h.v. side. Derive the formula used. 10

8. (*a*) Prove that, for a single-phase transformer,

(*i*) voltage per turn, $E_t = K\sqrt{Q}$, where $K$ = a constant and $Q$ = kVA rating of the transformer. 7

(*ii*) $Q = 2.22 f \Phi_m K_w A_w \delta$. The symbols have their usual meanings. 7

(*b*) What are the functions of transformer oil ? 6

**Group C**

9. (A) Give the answer in a single word/sentence : 10 × 1

(*i*) Why are the interpoles of a d.c. machine tapered ?

(*ii*) Which is the best suited material for commutator segment ?

(*iii*) A dummy coil is used in the armature of a d.c. machine. Is the machine lap or wave wound ?

(*iv*) When a d.c. motor produces maximum output power ?

(*v*) What is the most economical method of electrical braking ?

(*vi*) A shell type transformer has reduced magnetic leakage. Is the statement true or false ?

(*vii*) Why is the yoke cross-section of a transformer made large ?

(*viii*) When will you recommend radial ventilating system ?

(*ix*) For what purpose grain-oriented laminated steel are used in a transformer core ?

(*x*) How the p.f. of a synchronous motor is changed keeping the shaft load undisturbed ?

(B) Choose the most appropriate answer for the following : 10 × 1

(*i*) Helical coils are very well suited for

(*a*) HV winding of small rating transformers.

(*b*) HV winding of large rating transformers.

(*c*) LV winding of large rating transformers.

(*d*) All of the three above.

(*ii*) What is the arrangement of windings in a core-type single-phase transformer ?

(*a*) Half LV inside and half HV outside on each core limb.

(*b*) LV on one core limb and HV on the other.

(*c*) Sandwiched LV and HV discs on each core limb.

(*d*) Half HV inside and half HV outside on each core limb.

(*iii*) A transformer, having constant flux and constant current density designed for minimum cost, must satisfy the following relation :

(*a*) Iron loss = Copper loss

(*b*) Weight of iron = weight of copper

(*c*)

$$\frac{\text{Weight of Iron}}{\text{Weight of copper}} = \frac{\text{Specific cost of copper}}{\text{Specific cost of iron}}$$

(*d*)

$$\frac{\text{Weight of Iron}}{\text{Weight of copper}} = \frac{\text{Specific cost of iron}}{\text{Specific cost of copper}}$$

(*iv*) When compared with power transformer, a distribution transformer has

(*a*) low percentage impedance and high copper to iron loss ratio.

(*b*) high percentage impedance and high copper to iron loss ratio.

(*c*) high percentage impedance and low copper to iron loss ratio.

(*d*) low percentage impedance and low copper to iron loss ratio.

(*v*) The percentage of silicon in silicon-steel for transformer core is normally

(*a*) less than 1 %.

(*b*) 2 %.

(*c*) 4 %.

(*d*) 8 %.

(*vi*) Air gap at the pole tips of a d.c. machine is kept more than at the centre of the pole mainly to reduce

(*a*) reactance voltage.

(*b*) effect of armature reaction.

(*c*) losses in armature core.

(*d*) noise of the machine.

(*vii*) Air gap of a polyphase induction motor is kept small to

(*a*) reduce the possibility of crawling.

(*b*) reduce the noise.

(*c*) reduce magnetising.

(*d*) obtain high starting torque.

(*viii*) High frequency transformers are

(*a*) aluminium core.

(*b*) iron.

(*c*) copper core

(*d*) air core.

(*ix*) Induction generator delivers power at

(*a*) lagging p.f.

(*b*) leading p.f.

(*c*) unity p.f.

(*d*) zero p.f.

(*x*) An example of a motor having short-time duty is found in

(*a*) centrifugal pumps.

(*b*) crane drives.

(*c*) drilling machines.

(*d*) All of the three above.

**S'14: 7AN: EL407 (1468)**

## DESIGN OF ELECTRICAL SYSTEMS

*Time : Three hours*

*Maximum Marks : 100*

*Answer* FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

*All parts of a question ( a,b,etc.) should be answered at one place.*

*Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.*

*Any missing or wrong data may be assumed suitably giving proper justification.*

*Figures on the right-hand side margin indicate full marks.*

### Group A

1, (*a*) Derive an expression for current carrying capacity of wire made of constantan, given specific heat dissipation $\lambda$ as 20 W/m$^2$ – °C and $\rho$ for constantan is 0·5 ohm/m and mm$^3$. Assume maximum permissible temperature rise ($\theta$) of 100 °C. 7

(*b*) Design a constantan wire (of nearest 15 SWG) rheostat to carry 10 A and to dissipate 1000 W continuously. (Given mandrel diameter = 20 mm, maximum length of coil = 300 mm, turns/m = 275 and length of each turn = 73 mm for 15 SWG.) 7

(*c*) Classify insulating materials on the basis of temperature that these materials will withstand and their use in electrical machines. 6

**2.** (*a*) A slot, 20 mm wide, has five layers of solid copper conductors, each 14 mm wide and 8 mm deep. Determine the eddy current loss ratio for each layer and the average loss ratio in five layers taken together. Also, find critical depth of minimum loss and the loss ratio for this depth. The frequenciy is 50 Hz. 8

(*b*) How is eddy current loss produced in rotating electrical machines ? Suggest remedial measures to reduce this loss in the machines. 6

(*c*) Derive an expression for 'critical depth' of single conductor placed in slot for eddy current loss in rotating machines. 6

**3.** (*a*) Derive an expression for voltage per turn ($V_t = C\sqrt{kVA}$) in a core-type single-phase transformer and also discuss significance and factors upon which $C$ depends. 6

(*b*) Explain magnetic loading and electric loading with respect to a single-phase core-type transformer. 4

(*c*) Determine the core and yoke dimensions for a 250 kVA 50 Hz, single-phase core-type transformer. There are 15 V/turn. The window space factor = 0·33 per cent current density = 3 A/mm$^2$ and maximum flux density = 1·1 Wb/m$^2$. The distance between the centres of the square section core is twice the width of the core. 10

**4.** (*a*) Determine main dimensions '*D*' and '*L*' of a 15 kW, 440 V, 1500 r.p.m., d.c. shunt motor with commutating poles, type thyristor drive, class '*B*' insulation. Efficiency is not less than 88 percent. Forced air cooling may be assumed. 8

(*b*) Derive an output equation for d.c. machine. What are the factors effecting specific loading and magnetic loading in a d.c. machine ? 7

(*c*) What are the factors to be considered for 'choice of number of poles' in design of the d.c. machine ? 5

## Group B

**5.** (*a*) Determine the approximate diameter and length of the rotor core, the number of slots and the number of conductors for a 15 h.p. 400 V, 3-phase, 4-pole, 1425 r.p.m. induction motor. Adopt a specific magnetic loading of 0·45 Wb/m$^2$ and a specific electric loading of 230 ac/cm. Assume that a full load efficiency of 85 percent and a full load power factor of 0·88 will be observed. 12

(*b*) Explain the effect of output coefficient '*G*' and '$D^2L$'-product on induction motor design, where $D$ = stator bore diameter (m) and $L$ = stator length (m). 8

**6.** (*a*) A 25 h.p., 400 V, 50 c/s, three-phase wound rotor induction motor has the following data :

| | |
|---|---|
| Rotor resistance per phase (including connections to starter) | = 0·2 ohm |
| Full load rotor $I^2R$ loss (total) | = 750 W |
| Friction and windage losses | = 350 W |

Assuming that the starting current is not to exceed 1·25 times full-load current, work out the steps in a 4-step rotor resistance starter for the above motor. 12

(*b*) Show that, with an auto transformer starter, the starting current ($I_{stt}$) from the main supply and the starting torque ($T_{stg}$) are reduced to ($\chi^2$) times corresponding values with direct-on-line (DOL) starting of cage motors. 8

7. (*a*) What are the parameters affected (changed) with change of frequency in a transformer ? Explain in detail. 4

(*b*) A 40 Hz transformer is to be used on a 50 Hz system. Assuming Steinmetz's coefficient as 1·6 and losses at lower frequency 1·2%, 0·7% and 0·5 % for $I^2R$, hysteresis and eddy current, respectively. Calculate the (*i*) losses on 50 Hz for the same supply voltage and current and (*ii*) output at 50 Hz for the same total losses as on 40 Hz. 10

(*c*) Develop an expression for magnetizing V-A/kg for a transformer. Also, explain how magnetizing current ($I_m$) can be determined with the help of this expression. 6

**8.** (*a*) For a 1000 kVA, 6600/440 V, 50 Hz, three-phase delta/star, core-type, oil immersed natural cooled (ON) transformer, the design data of the transformer are : Distance between centres of adjacent limbs = 0·47 m, outer diameter of h.v. winding = 0·44 m, height of frame = 1·24 m, core loss = 3·7 kW and $I^2R$ loss = 10·5 kW. Design a suitable tank for the transformer. The average temperature rise of oil should not exceed 35 °C. The specific heat dissipation from the tank wall is 6 W/m²-°C and 6·5 W/m²-°C due to radiation and convection, respectively. Assume that the convection is improved by 35 %. 12

(*b*) Explain thermal rating of transformer. 4

(*c*) During a temperature rise test at full load on a 100 kVA transformer, temperature recorded was 60 °C after one hour and 72 °C after two hours. Find the time for which the transformer may safely be loaded to 200 kVA. Ambient temperature is 40 °C and full-load copper-loss (at 100 kVA) is twice the iron-loss. 4

**Group C**

**9.** Explain the following in brief : 10 × 2

(*i*) Materials used for rheostats

(*ii*) Comment on insolation.

(*iii*) Hydrogen cooling – an advantageous cooling

(*iv*) Magnetic leakage and leakage coefficient.

(*v*) Real and apparent flux densities

(*vi*) Conditions for symmetry for two-layer closed winding

(*vii*) Significance of iron cost and copper cost in transformer

(*viii*) Importance of leakage reactance in induction machine design

(*ix*) Basic difference in distribution and loss transformers

(*x*) Methods for transformer cooling