QUESTION BANK

Subject: Electrical Machine Design

Unit-I

1. Explain in brief about the HRS & CRGOS materials. 2.14 — 6 **W16**
2. Derive the relation between mechanical overload ratio and heating overload ratio. — 6 **W17**
3. Define:
   1) Heating time constant. 4.20 4.25 2) Cooling time constant (4.21)
   3) Steady state temp. rise while heating — 6 **W17**
4. Derive the expression of temperature rise of the machine when it is heated. (4.18) — 6 **S17, 6 S16**
5. Explain the following duties for electrical machines.
   i) Continuous duty 4.53
   ii) Short time duty
   iii) Intermittent duty — 6 **S17**
6. Explain various ratings of modern electric machines. Sketch the typical load, electric losses and temperature rise V/S time curves for these ratings to illustrate the answers. — 6 **S16**
7. Describe Heat – Run Test method to determine the heating time constant and final steady temp. rise of the rotating machine. — 7 **S16**
8. A transformer having temp. rise of 20ºC after 1 hour and 32ºC after 2 hours at continuous full load.
   1) What is the final steady state temp. rise on this load.
   2) If transformer is work on 50% overload how long will it takes to obtain same temp.- given that copper losses on full load equal to twice iron loss. — 7 **W17**
9. The heat run on a d. c. motor gave the following result. — 7 **W17**

Time (Minutes)	0	10	20	30	40	50
Temp. (ºC)	40	46.5	51.7	55.7	58.9	61.1

   Calculate the final steady temp. rise and the time constant of the machine. If the ambient temp. is 20ºC.

10. A machine running on steady full load gave the following temperature rise at the end of the specified intervals.

Time (hrs)	**Temp. rise (ºC)**
0.25	9.5
0.5	17.0
1.0	29.2
1.50	38.00
2.00	44.2
2.50	48.7
3.00	52.00

   Find graphically the final temp rise and heating time constant of a machine. — 7 **S17, 7 W16**

11. The rate of temp rise as measured from a temp. rise time curve of a D.C. motor is 0.0803ºC per minute and 0.0605ºC per minute when temp. rise is 20.5ºC and 28.5ºC respectively.
   Calculate:
   1) Final Steady temp. rise.
   2) Heating Time Constant — 7 **S17**
12. The temperature rise of a transformer is 30ºC after 2 hours and 45ºC after 4 hours of its operation.
   i) Calculate the maximum final temperature rise with full load on transformer and the heating time constant.
   ii) Calculate time to reach 5/6th of its final steady temperature rise.
   iii) If its temperature falls from final steady value to 55ºC in 1.5 hours when disconnected, calculate its cooling time constant. The ambient temperature is 27ºC — 7 **W16**
13. The rate of temp. rise as measured from a temp. rise time curve of a D.C. motor is 0.0803ºC per minute and 0.0605ºC per minute when temp – rise is 20.5ºC and 28.5ºC respectively. Calculate
   i) Final steady temp rise.
   ii) Heating time constant. — 7 **S16**

Unit II & III: Transformer Design

14. Describe in brief, with the help of diagrams, the different methods of cooling of transformer. 6 **S18**

15. Calculate the main dimensions of 125 kVA, 6.6 kV|400V, 50 Hz, single phase shell type transformer
Assume :
Voltage per turn = 10 V
Flux density in core = 1.1 wb/m2
Current density = 2 A/mm2
Window space factor = 0.33
Stacking factor = 0.9
Ratio of $\frac{\text{Height of window}}{\text{Width of window}}$ =3
Ratio of $\frac{\text{Depth}}{\text{Width of Central Limb}}$ = 2.5
Also calculate number of turns and area of cross-section of conductors. 7 **S18**
16. With reference to transformers, write short notes on :
i) Choice of Flux Density.
ii) Choice of Current Density. **6 S18**
17. Determine the main dimensions of the core, the number of turns and the area of conductors for a 5 kVA, 50 Hz 11000/400V, 1-phase core type distribution transformer. The net conductor area in the window is 60% of the net cross-section (square) of the iron core. Assume a flux density of 1 wb/m2, a current density of 1.4 A/mm2 and a window space factor of 0.2. The window height is 3 times its width. 7 **S18**
18. Write short notes on any three.
i) Properties of Transformer oil.
ii) Continuous and short time Rating.
iii) Classification of Insulating Material.
iv) Need of stepped core cross section. 13 **S18**
19. Write short notes on **any three.**
i) Properties of transformer oil.
ii) Off load Tap changer of transformer.
iii) Methods of cooling in case of transformer.
iv) CRGO and HRGO materials. 13 **W17**
20. A 300 kVA, 6600/400V, 50Hz delta/star 3-phase core type transformer has the following data. Width of H.V. winding = 25mm, width of L.V. winding = 16mm, Height of coils = 0.5m, length of mean turn =0.9m, H.V. winding turns = 830. Width of duct between H.V. and L.V. winding = 15mm.
i) Calculate the leakage reactance of the transformer referred to H.V. side.
ii) If the L.V. coil is split into 2 parts with one part on each side of H.V. coil, calculate the leakage reactance referred to H.V. side. Assume that there is a duct 15mm wide between H.V. winding and each part of L.V. winding. **6 S18**
21. Calculate the no-load current of a 400V, 50Hz 1-ph. core type transformer, the particulars of which are as follows. Length of mean magnetic path = 200cm, gross core section = 100cm2; Joints equivalent to 0.1mm air gap; Maximum flux density = 0.7 Tesla; Specific core loss at 50Hz and 0.7 Tesla is 0.5 watts per kg; Ampere turns 2.2 per cm for 0.7 Tesla; Stacking factor = 0.9; Density of core material = 7.5 x 103 kg/m3. **7 S18**
22. Estimate the main dimensions of core, no. of turns and cross-sectional area of conductor of primary and secondary winding of a 300kVA, 11KV / 440V, 3-ϕ, Δ /γ connected core type 50Hz distribution transformer. The following data is given.
Ratio of voltage per turn to square root of kVA rating is 0.45, winding space factor = 0.3,
Stacking factor = 0.9, Maximum flux density = 1.2 wb/m^2, current density = 2.5 A/mm^2
Hw/ww = 3, Ai = 0.6 d^2. **8 W17**
23. Derive the expression for the width of the window of a transformer for optimum output. **6 W17**
24. What is the ideal cross-section of core? Why? Derive the ratio of net core area to area of Circumscribing circle for two stepped core? **7 W17**
25. Estimate flux density, main dimensions, no. of turns and area of cross-section of conductor for 3-ϕ, Δ /γ core type distribution transformer rated at 200 kVA, 11kV/440V 50Hz, A suitable core with two steps having circumscribing circle of 0.2m diameter and leg spacing of 0.3m is available. Assume Et = 6V, δ = 2.5 A/mm2 kw = 0.29, SF = 0.9. **7 W17**
26. Derive an expression for output equation of 3ϕ transformer. **5 W17**
27. Determine main dimensions of core the no. of turns and cross section area of conductor for

5 KVA, 11000/400V, 1ϕ, 50Hz core type transformer net conductor area in window is 0.6 times net cross - section area of iron in core. Assume a square cross - section for core of flux density 1wb/m2 , current density is 1.4A/mm2 & window space factor is 0.2 height of window is 3 times it's width. 9 **W17**

28. What is ideal cross section of core? Why? Derive the ratio of net core area of circumscribing circle for two stepped core. **6 W17**
29. Calculate the core and window area of a 400 KVA, 50Hz, 1Ω , core type power transformer. Following data may be assumed.

$$\frac{\text{Weight of copper}}{\text{Ratio of weight of iron}} = \frac{G_i}{G_c} = 4$$

$$\frac{\text{Ratio of length of mean turnof copper}}{\text{Length of mean flux path}} = \frac{l_{mt}}{l_i} = 0.5$$

Maximum flux density 2 Bm =1.5wb/m
Current density = 2.24A/mm2
density of copper = gc = 8.9×10^{-3} kg /m3 and
density of Iron = gi = 7.8×10^{-3} kg /m3
Copper space factor = window space factor = kw = 0.12 **7S16**

30. Determine the main dimensions of the core no. of turns & cross sectional area of conductors in primary & secondary windings of 100 KVA, 2200/480V, 1ϕ , core type transformer to operate at 50Hz.
The following data may be assumed.
EMF per turn = 7.5 V
Maximum Flux density = 1.2wb/m2
Current density = 2.5A/mm2
Window space factor = 0.28
Ratio of effective cross sectional area of core to the square of diameter of circumscribing circle is 0.6, Ratio of $\frac{WW}{HW}$=2, stacking factor = 0.9. **8W17**
31. Calculate the overall dimension for a 200KVA, 6.6KV/440V, 50Hz, Δ/Y, core type 3 – ϕ transformer following data is given :
Voltage per turn = 8V
Current density = 2.5 A/mm2
Flux density = 1.2 wb/m2
Stacking factor = 0.9
Window space factor = 0.28
Assume two stepped core
Overall Height = limb spacing **8W16**
32. 300 KVA, 50Hz, 11 KV/440 V, 3-ϕ, Δ /γ core type transformer has following data.
Length of coil = 0.5 m
<u>LV winding</u>
Outside diameter = 0.25 m
Inside diameter = 0.2 m
Area of cross - section = 2 mm 180
No. of turns = 30
<u>HV Winding</u>
Outside diameter = 0.4 m
Inside diameter = 0.32 m
Area of cross - section = 2 mm 10
No. of turns = 1320
Calculate Pu regulation at half load and 0.8 p.f. lag. **9W17**

33. Estimate the main dimensions of core, No. of turns and cross sectional area of conductors of primary and secondary winding of a 300 KVA, 11KV/440V, 3ϕ, Δ/ Connected core

type, 50Hz, distribution transformer. The following data is given,
- Ratio of voltage per turn to square root of KVA rating is 0.45.
- Window space factor is 0.3, stacking factor is 0.9
- Maximum flux density = 2 1.2wb m , current density = 2 2.5A mm .
- Ratio of height to width of window = 3
- Ratio of net area of core to square of diameter of circumscribing circle = 0.6 **8S16**

34. Discuss OFFLOAD tap changer. 4 **W17**
35. Describe in brief, with the help of diagrams, the different methods of cooling of transformer. **6W17**
36. State and prove the design criteria that results into the minimum weight of the transformer. **5W16**
37. What is the necessity of tap changers? Explain in brief the construction and working of different tap changers. **6W16**
38. Give the design procedure for the cooling tank (with tubes) of transformer. **6W16**
39. Explain elaborately different methods of cooling of transformer. 6**W16**
40. Discuss properties of transformer oil. 4**S16**
41. State and prove the design criteria that results into the minimum weight of the transformer. **6S16**
42. A 1000 KVA, 11 KV/415 V, 50 Hz, 3ϕ, delta / star connected, core type, oil immersed 'ON' cooled transformer, has the following data :
    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, & Cu loss = 10.5 KW
    Design a suitable tank for the transformer, the average temp rise of oil should not exceed 35ºC. The specific heat dissipation from the tank walls is 6w/m2- ºC and 6.5w/m2- ºC due to radiation and convection respectively. Assume that the convection is improved by 35% due to tubes. **7W17**
43. A 15000 kVA, 33/6.6 kV, 3-ϕ, γ /Δ core type transformer has the following data
    Net iron area of each limb = 150 x 10-3m2

    Net Area of yoke = 180 x 10-3m2
    Mean length of flux path in each limb = 2.3m
    Mean length of flux path in each yoke = 1.6m
    No. of turns in HV winding = 450
    Calculate the no. load current. Use the following data. **13 W17**

Bm (wb/m2)	0.9	1.0	1.2	1.3	1.4
MMF/metre (A/m)	130	210	420	660	1300
Iron loss (W/kg)	0.8	1.3	1.9	2.4	2.9

44. Determine the main dimensions of core and yoke for 200KVA, 50Hz,1ϕ, core type transformer. A cruciform core is used with distance between adjacent limb = 1.6 times the width of core laminations. Assume voltage per turn = 14V, maximum flux density = 1.1wb/m2, kw = 0.32, current density = 3 A/mm2 and stacking factor = 0.9 Net iron area is 0.56d2 in a cruciform core where 'd' is the diameter of circumscribing circle. Also the width of largest stamping is 0.85d. **7W16**
45. Calculate the leakage reactance of transformer referred to HV side, per unit regulation of full load and 0.8 P.F. lagging, if the resistance per phase referred to HV side is 0.8Ω for a 750 KVA, 6600/400V, 50Hz, 3ϕ Δ/Y type transformer.
    Width of LV winding = 30mm
    Width of HV winding = 25mm
    Radial width of duct = 15mm between HV & LV Coil
    Length of mean turn = 1.5m
    Height of winding = 0.4m
    High voltage winding turns = 217 ` **7W16**
46. A 6600V, 60Hz, single phase transformer has a core of sheet steel. The net iron crosssectional

area is 22.6 x 10^{-3} m2 , the mean length is 2.23m and there are four lap joints.
Each lap joint takes ¼ times as much reactive mmf as is required per meter of core. If Bm =1.1 wb/m2 , Determine:
a) The number of turns on the 6600V winding and
b) The no-load current. Assume an amplitude factor of 1.52 and that for given flux density, mmf per meter = 232 A/m, specific loss = 1.76 w/kg, specific gravity of plates = 7.5. **7W16**

47. Calculate the main dimensions of a 125 KVA 6.6/0.4KV, 50Hz, 1ϕ , shell type transformer taking, voltage per turn = 10V, flux density in core = 1.1wb/m2, current density δ= 2A/mm2 , window space factor = 0.33, stocking factor = 0.9 Ratio,

$$\frac{WW}{HW} = 3, \quad \frac{D_y}{2a} = \frac{b}{2a} = 2.5$$

Also calculate the size of conductors. **7S16**

48. Estimate the per unit regulation at full load and 0.8 p.f. lagging for a 300KVA, 6600/400V, 3ϕ, Δ/γ core type xmer. The data given is

H.V. Windings	LV. windings
Outer diameter = 0.36m	Outer diameter = 0.26m
Inside diameter = 0.29m	Inside diameter = 0.22m
Area of conductor = 5.4mm2	Area of conductor = 170mm2

length of coils = 0.5m, Voltage per turn = 8V
Resistivity = ρ= 0.021x 10^{-6} Ωm **10S16**

UNIT-IV-Design of Induction Motor (Stator Design)

49. Derive an output equation of 3 phase induction motor. **6S18**
50. Explain the factors affecting choice of number of stator slots. **5S18**
51. Write short notes on selection of stator slots. **5W17**
52. Define :
1) Specific magnetic loading. 2) Specific electric loading. **6 W17**
53. 3 phase, 250HP, 400V, 50Hz, 4 pole slip ring delta connected induction motor has following data :
Efficiency = 0.92, power factor = 0.88
Current density = 3.5 A/mm2
Diameter at air gap = 395 mm
Net iron length = 316 mm
Flux per pole = 59 mwb
Flux density in stator core = 1.3 wb/m2
Calculate slot dimensions, stator copper loss and outside diameter of stator laminations.
Resistivity of copper = 2.1 x 10–8 Ωm
Maximum flux density in stator teeth = 1.7 wb/m2. **7S18**
54. Find the main dimensions, number of stator turns, size of conductor and number of stator slots of a 5 H.P., 400V, 3-phase, 50Hz, 1500 syn. r.p.m., squirrel cage induction motor, star-delta starting is used. Use the following data.
Average flux density in the air gap = 0.46 wb/m2.
Ampere conductor per meter of armature periphery = 22000.
Full load efficiency = 83%, full load power factor = 0.84 lagging.
Current density δ = 3.5 A/mm2

Stator winding factor = 0.955
Ratio of core length to pole pitch = 1.2. **8S18**

55. Estimate the main dimension, no. of stator conductors, conductor of cross section of a 100kW, 3300V, 50Hz, 12Pole, y - connected slip ring I. M. Assume Bar = 0.4 wb/m2, ac = 25000 A/m, cosϕ= 0.9, kws = 0.96, δ = 3.5 A/mm2. Choose main dimensions to give best power factor. **7 W17**
56. Estimate the main dimensions, airgap length, no. of stator slots, and cross sectional area of stator conductor for a 3 – ϕ, 20HP, 400V, 6 Pole, 50 Hz Induction Motor suitable for y-Δ starting. Assume magnetic and specific electric loading as 0.45 wb/m2 and 23000 ac/m respectively.
Ratio of core length to pole pitch is 0.85, η = 88%, P.F = 0.89 **8W17**
57. Determine main dimensions, stator slot dimension and outer diameter of stator for 100 KW, 3300 V, 50 Hz 12 pole, Y - connected slip ring Induction motor. Assume following data :
Average flux density at air = 0.4wb/m2
Conductors / metre = 25,000A/m
Efficiency = 0.9, Power factor = 0.9
Stator winding factor = 0.96
Current density = 3.5A/mm2
Choose main dimensions to give best power factor. Flux density in stator core is 1.3wb/m2. Flux density in stator teeth should not exceed 1.7 wb/m2. **13S17**
58. A 3ϕ slip ring star - connected induction motor of 120 KW operated on 2200 V, 50 Hz, data given, Bav=0.48wb/m , ac 26000 A/m2, efficiency 92%, P.F. = 0.88, Ratio of core length to pole pitch = 1.25. kws = 0.955, synchronous speed = 750 rpm current density = 2 3.5 A/mm , mean length of stator turn = 0.75 m. Specific resistance = 0.021Ω/m & 2 mm .
Calculate
1) Stator bore diameter
2) Length of stator core
3) No. of turns / ph.
4) Full load current & cross sectional area of conductor.
5) Total I^2R loss of stator. **7S17**

59. A 11 KW, 3ϕ, 6 pole, 50 Hz, 220 V, star connected induction motor has 54 stator slots, each containing 9 conductors. Calculate the values of bar and end ring currents. The number of rotor bars is 64. The machine has an efficiency of 0.86 and a power factor of 0.85. The rotor mmf may be assumed as 85% of stator mmf. Also find the bar and the end ring sections if the current density is 5A/mm2. **8S17**

Unit V: Design of Induction Motor (Rotor Design)

60. State factors affecting selection of **air gap** length in case of 3ϕ Induction motor. **6S18,5S17**
61. Discuss **crawling** and **cogging** in case of Induction motor. **5W17,5S18**
62. Explain in detail the effect of **harmonics** on the Induction Motor. **5S17**
63. 15 KW, 400 V, 3 phase, 50 Hz, 6 pole, induction motor has a diameter of 0.3 m and length of core 0.12m, The number of stator slots is 72 with 20 conductors per slot. The stator is delta connected. Calculate value of magnetising current per phase if length of air gap is 0.55mm. The gap contraction factor is 1.2. Assume the mmf required for the iron parts to be 35% of the air gap mmf. coil span = 11 slots. **7S18, 8S17**
64. The following design data are provided for an induction motor. Calculate **8S18**
i) No load maximum flux.
ii) Length of air gap.
iii) Number of turns per phase.
iv) Rotor bar current and area.
v) End ring current and area.
vi) Losses in bars and end rings.
Diameter of stator bore = 15cm, Length of stator core = 9 cm.
Average flux density = 0.45 Tesla, Efficiency = 84%, Power factor = 0.86.
3 phase, 4 pole, 400 V, delta connected 10 KW,

Frequency = 50 Hz, Stator slots = 36, Rotor slots = 30.
Length of rotor bar = 15 cm. Mean diameter of end ring = 12 cm.
Current density of rotor bar = 6 A/mm^2.
Current density of end rings = 7 A/mm^2.

65. Following design data are provided for 3-ϕ 4 pole, Δ-connected 10kW squirrel cage Induction motor:
Stator bore diameter = 15 cm
Axial length of stator = 9cm
No. of stator slots = 36, ϕ m = 4.768 mwb
kws = 0.96, Stator current / phase = 11.53A
current density in bar and end rings is 5 and 6A/mm^2 respectively.
Length of rotor bar = 13 cm, ρ= 2.1x10^{-8}. Design suitable cage rotor giving bar and end ring dimensions. Also determine rotor speed. **13W17**

66. A 90kW, 500V, 50Hz, 3-ϕ, 8-pole induction motor has a star-connected stator winding Accommodated in 63 slots with 6 conductors per slot. If the slip ring voltage on open circuit is to be about 400V, Design a suitable rotor winding, giving
i) No. of slots.
ii) No. of conductors per slot
iii) Slip-ring voltage on open circuit.
iv) Approximate full load current / phase in rotor. Assume η= 90%, cosϕ= 0.86 **8W17**

UNIT VI: Synchronous Machine

67. Explain the short circuit Ratio of synchronous machine. Discuss the effect of SCR on machine performance. **7S18, 5S17, 7W17, 5S18**
68. Write short notes on:
    i) Advantages of hydrogen cooling. **5W17, 5S18**
    ii) Runaway speed of alternator. **5W17**
    iv) Pitch factor and distribution factor. **4S18**
69. Design the suitable values of diameter and length of a 75 MVA, 11 KV, 50 Hz, 3000 rpm, 3 phase, Y-connected alternator. Also determine the value of flux, conductors per slot, number of turns per phase and size of armature conductor.
    Given :
    Average gap density = 0.6 Tesla
    Average ampere conductor per meter = 50,000
    Winding factor = 0.95
    Current density = 6 A/mm2
    Peripheral speed should not exceed 180 m/s. **7S18**
70. A 90kW, 500V, 50Hz, 3-ϕ, 8-pole induction motor has a star-connected stator winding Accommodated in 63 slots with 6 conductors per slot. If the slip ring voltage on open circuit is to be about 400V, Design a suitable rotor winding, giving
    i) No. of slots.
    ii) No. of conductors per slot
    iii) Slip-ring voltage on open circuit.
    iv) Approximate full load current / phase in rotor. Assume η= 90%, cosϕ= 0.86 **8W17**
71. Determine the main dimensions for a 1mVA, 50Hz, 3-ϕ, 375rpm alternator, Bar = 0.55 wb/m2, ac = 28,000 A/m. Use rectangular poles. Maximum permissible peripheral speed is 50 m/sec. The ran away. speed is 1:8 times the synchronous speed suggest suitable pole construction. **7W17**
72. Determine the main dimensions of a 75000 KVA, 13.8 KV, 50 Hz, 62.5 r.p.m. 3ϕ, star connected alternator. Also find the number of stator slots, conductor per slot, conductor area and workout the winding details. The peripheral speed should be about 40 m/s. Assume, average gap density = 0.65wb/m2 . ampere conductors per meter = 40,000 and current density =4A/mm2 . **9S17**
73. Obtain the main dimensions of the rotor of a 50 MVA, 2 pole, 50 Hz, synchronous generator. The peripheral speed is limited to approximately 160 m/sec. Take the electric loading of 65000 A/m and the mean gap density of 0.575wb/m2 . Assume gap length of 25 mm. **8S17**
74. A 50 MVA, turbo alternator has a total loss of 1550 kw. Calculate the volume of air required per second and also the fan power if the temp. rise in the machine is to be limited to 30ºC. The data given is, inlet temp of air = 25º C. Barometric height = 760 mm of mercury, Pressure = 2KN /m2 . fan efficiency = 0.4.