ELECTRIC MACHINE DESIGN

ENEE 306

Year/Part: III/I

Teaching Schedule				Examination Scheme						Total
				Theory			Practical			
				Assessment Marks	Final		Assessment Marks	Final		
L	T	P	Total		Duration (Hrs)	Marks		Duration (Hrs)	Marks	
3	0	3	6	40	3	60	50	0	0	150

Depth Codes:

E-Explanation	C-Circuit	D-Definition	DM-Demonstration
DV-Derivation	DW-Drawing	P-Proof	I-Illustration
NUM-Numerical	PRG-Programming	S-State	ACT-Activity-based Learning
MP-Mini Project	EXP-Experiment	REV-Review / Recap	PS-Problem Solving
QA-Question Answer	Q-Quiz	ST-Surprise Test	MT-Mid Term Test

Unit	Topic/ Sub topic	Depth Code	Description of Depth	Actual Plan L	T	P	Week
1	**Materials used in Electrical equipment**			**5**			**1,2**
	1.1 Review of electrical conducting materials 1.1.1 Various characteristics and comparison between conducting materials. 1.1.2 Materials of high conductivity and high resistivity.	D, E, DV	• Define conductor • Explain its two major purposes as passage of electrical current and heating purposes • Explain the characteristics of copper as conducting material. • Explain the characteristics of Aluminum as conducting material. • Comparison between copper and aluminum as conducting material • Derivation for comparison between conducting material copper and aluminum in terms of mass and space • Classify and mention the properties of conducting materials as materials of high conductivity and materials of high resistivity. • Classify the materials of high resistivity as materials used for precision work, rheostat and heating devices and electric furnace with its characteristics	1 1			
	1.2 Magnetic materials 1.2.1 Classification, characteristics and application of magnetic Materials 1.2.2 Materials for steady flux (solid core materials), Materials for Pulsating fluxes (laminated core material sheet) 1.2.3 Special purpose alloys, hot rolled and cold rolled	D, E, I	• Define and explain magnetic circuit and magnetic materials • Define relative permeability and illustrate its importance. • Classify the insulating material in three main parts as diamagnetic materials, Ferromagnetic materials and paramagnetic materials with their characteristics. • Again classify Ferromagnetic material as soft and hard magnetic materials and explain their properties and use. • Again classify the soft magnetic material as solid	0.5 0.5 0.5			

Unit	Topic/ Sub topic	Depth Code	Description of Depth	Actual Plan L	T	P	Week
	steel sheets, sintered powder core 1.2.4 Magnetic materials used in transformers, dc machines and ac machines.		core materials, electrical sheet materials and special purpose alloys. • Explain the properties and application of solid core materials and laminated core materials • Explain Ageing effect, its cause and remedy • Explain the purpose of special purpose alloy, classify it and explain about Mumetal, permalloy, sintered powder core and hot rolled and cold rolled steel sheets properties. • Explain magnetic materials used in transformers, DC machines and AC machines	0.5			
	1.3 Insulating materials 1.3.1 Classification, characteristics, application 1.3.2 Insulating materials for transformers, DC machines and AC machines, ceramics.	D, E, S	• State insulating materials • Classify insulating materials • Explain characteristics of insulating materials • Classify insulating materials on the basis of thermal stability • Mention the application of insulating materials for transformers, DC and AC machines, for wires, for laminations. • Explain how ceramics are prepared. • Main features of ceramics and its applications	0.5 0.5			
2	**Heating and cooling of machines**			**7**			**2,3,4**
	2.1 Review of heat transfer: conduction, convection and radiation	E, D, DV, NUM	• Explain causes of heat loss in machines • Define different methods of heat transfer like conduction, convention and radiation • Derive or explain expression for heat dissipated by above mentioned each method. • Related numerical	0.5			
	2.2 Internal temperature (hot spots and their calculations)	E, D, DV	• Define hot spots and causes of their formation • Derive the expression for the temperature of the hottest spot • Related numerical	0.5			
	2.3 Temperature gradients in iron core	D, E, NUM	• Explain the temperature gradients in iron core for both along and across the laminations. • Related numerical	0.5			
	2.4 Temperature gradients in conductors placed in slots	D, E, Dw, DV, NUM	• Derive the expression for temperature gradients in conductor placed in slots in cases: i) The heat produced in the embedded portion of the conductor is conducted along its length ii) Across the insulation of conductor embedded in slot iii) Related numerical	1			

Unit	Topic/ Sub topic	Depth Code	Description of Depth	Actual Plan L	T	P	Week
	2.5 Ventilation of electrical machine 2.5.1 Types of enclosures, methods of cooling, Schemes of ventilation. 2.5.2 Cooling of totally enclosed machines, cooling circuits, cooling systems	D, E, I, DV	• Explain the need of enclosures • Define and explain different types of enclosure • Define and explain cooling process • Classify the types of cooling as natural, self, separate and define each of them. • Classify, explain different types of ventilating system: Radial, Axial, Combined axial and radial, multiple inlet ventilation system with necessary figures. • Define and explain Totally enclosed machines	1			
	2.6 Temperature rise, heating time constant, final steady temperature rise, Cooling time constant	D, E, I, DV, NUM	• Explain open circuit and closed circuit ventilation • Derive expression of temperature rise and heating time constant for machine under heating and final steady temperature rise.	2			
	2.7 Rating of electric machine based on temperature rise	E	• Derive expression of temperature rise and cooling time constant for machine under cooling and final steady temperature rise. • Related numerical • Explain the theory related to rating of electric machines based on temperature rise in short explanation.	0.5			
	2.8 Calculation of temperature rise in armature, field coils and commutators.	E, DV	• Derive and explain the temperature rise of armature. • Derive and explain the temperature rise of field coil. • Calculation of temperature rise of commutator	1			
3	**Transformer Design**			**14**			**5,6,7,8,9**
	3.1 Types of transformer: Power transformer, distribution transformer, core type and shell type	D, E, Dw, Dm	• Define transformer, draw its equivalent circuit • Draw and explain characteristics of core type and shell type transformer • Demonstrate the photo of both types trans • Comparison between core type and shell type transformer	2			
	3.2 Design approach 3.2.1 Output equations (single and three phase), volt per turn 3.2.2 Choice and sizing of core: square core, stepped and cruciform core 3.2.3 Choice of flux density 3.2.4 Design of winding and choice of current density 3.2.5 Design of insulation 3.2.6 Design of window and window space factor 3.2.7 Design of yoke and limb	D, E, NUM, I, Dw, DV	• Describe the characteristics of power and Distribution transformer • Draw the figure of single phase transformer • Derive the expression for output of single phase transformer • Draw the figure of three phase transformer • Derive the expression for output of three phase transformer • Derive the expression for volt per turn in terms of transformer rating • Related numerical • Define stacking factor • Draw and explain characteristics of Rectangular core, square core, need of square core, Stepped core (Cruciform Core), mathematical analysis of two stepped core and only formula and figure for three stepped core • Calculation of core area • Explain on which factor choice of magnetic flux density depends upon for sizing of core	8			

Unit	Topic/ Sub topic	Depth Code	Description of Depth	Actual Plan L	T	P	Week
	3.3 Calculation of operating characteristics from design data 3.3.1 Resistance of winding, leakage reactance of winding in Core type transformer, iron loss, copper loss, efficiency, Regulation.	S, D, E, Dw, DV	• Explain on which factor choice of current density depends on for design of windings • Explain the different types of windings and their selection like rectangular, circular, cylindrical, helical, crossover, continuous disc, and sandwiched with their characteristics • Explain the need of insulation and insulation calculations guidelines • Define window space factor • Explain the guidelines for design of window • Explain the guidelines for design of yoke, limb and overall dimension • Draw and explain single and three phase transformer • Related numerical • Derive the expression for resistance calculation of windings • Derive the expression for leakage reactance calculation of windings • Define voltage regulation and derive expression for it. • Calculation of no load current for single phase and three phase transformer • Calculation of iron loss, copper loss and efficiency calculation • Related numerical • Explain the temperature rise in plain walled tank and derive expression for it • Explain and derive expression for design of tanks and number of tubes • Related numerical • Long numerical covering overall design	2			
	3.4 Design of cooling system 3.4.1 Temperature rise in plain walled tank, design of tank and Tubes.	E, D, Dw, DV		2			
4	**Three phase induction motor design**			**10**			**9,10,11,12**
	4.1 Three phase induction motor 4.1.1 Construction, core material 4.1.2 Types of three phase stator winding: Mush winding, Lap winding and wave winding	E, D, Dw	• Define three phase induction motor • Draw and explain construction of induction motor • Explain core materials used in core of induction motor • Explain the characteristics of stator winding: Mush winding, Lap winding and wave winding • Define and draw Main dimensions, define total and specific magnetic and electric loading • Derive the expression for output equation(KVA) of induction machine • Explain factors affecting size of the machine • Explain on which factor choice of specific magnetic and electric loading of induction	1.5			

Unit	Topic/ Sub topic	Depth Code	Description of Depth	Actual Plan L	T	P	Week
	4.2 Design approach: 4.2.1 Output equation, choice of magnetic and electric loading 4.2.2 Choice of stator winding, stator slots and insulation, stator Teeth, stator core and stator stamping dimension 4.2.3 Air gap length, rotor design (squirrel cage and slip ring Type) 4.2.4 Leakage inductance, evaluation of equivalent circuit Parameters and operating characteristics from design data.	D, E, S, NUM, DV, Dw	machine depends on • Define machine proportion and explain its value selection during design • Numerical related to main dimension • Design of stator winding and selection of conductor • Explain steps for finding stator winding turns/ phase • Explain steps for determining size of stator conductor • Explain shape of slots as open slot and semi-open slots and compare • Explain the factors on which choice of number of slots of stator depends • Derive the necessary formulas for determining selection of number of slots, area of stator slots and minimum width of teeth • Related long numerical • Explain the steps for determining overall dimension of stator core • Explain on what factors the length of air gap depends • Design of squirrel cage rotor • Selection of number of slots of rotor • Explain and compare shapes closed slots and open slots • Explain the steps for calculations of area and current in end rings with necessary formulae • Explain the steps for electrical design like area and current of rotor bars with mathematical formulas • Related numerical • Explain the steps for design of phase wound rotor • Find number of slots, number of rotor turns • Explain the steps for finding rotor current and size of conductor • Also mention to find minimum width of rotor teeth, dimension of rotor core, losses in rotor • Related numerical	8.5			
5	**DC Machine Design**			**9**			**13,14, 15**
	5.1 Armature winding 5.1.1 Lap and wave Winding	E, D	• Define and Explain lap winding and wave winding • Compare both	0.5			
	5.2 Design approach 5.2.1 Output equation, choice of average gap	E, DV, NUM	• Derive output equation of DC machine in terms of main dimension, specific electric and magnetic loadings • Explain the factors affecting the size of the DC machine • Explain the factors on which choice of average flux density depends upon • Explain the factors on which choice of armature conductor depends upon • Explain the factors on which choice of number of poles depends upon • Explain the factors on which choice of air gap	1.5 0.5 2.5			

Unit	Topic/ Sub topic	Depth Code	Description of Depth	Actual Plan L	T	P	Week
	density, choice of Ampere conductors per meter 5.2.2 Choice of number of poles in DC machine, pole Proportions 5.2.3 Selection of length of air gap 5.2.4 Choice of armature windings, number of armature Conductors number of coils, number of armature slots, Armature conductor selection. 5.2.5 Design of commutator, design of brushes, design of field winding and Compensating winding		length depends upon • Numerical related to finding main dimension • Choice of armature winding: lap and wave • Derive the relation for design of number of conductor and number of coils • Explain the factors on which choice of armature slots depends upon • Explain the steps for size of armature conductor selection • Explain the guidelines for Design of commutator segments and carbon brushes • Design of compensating winding • Related numerical	2 2			

ELECTRIC MACHINE DESIGN
ENEE 306

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QN	Question	Marks	Unit
1.	a. Discuss in brief about insulating material with their classification. What are the fundamentals requirements of a good insulating material, electrical properties of insulating materials? b. Discuss in brief about insulating material with their classification. What are the fundamentals requirements of a good insulating material, electrical properties of insulating materials?	4 4	1 1
2.	a. What are heating time constant and cooling time constant? Explain b. An induction machine has a temperature rise of 25^0c and 40^0c after 1hr and 2 hr, respectively while operating at full load of 7.5 kw. The constant losses are 80% of full load copper loss. Determine how long the motor can be operated at twice the rated output without overheating.	5 4	2 2
3.	a. For a 500 kVA, 50Hz, 6600/400, single phase core type, oil immersed, natural cooled power transformer, the design parameters are: Constant for output voltage per tum (K) = 0.8 Resistivity of copper = 0.021 Ω-mm2/m Maximum flux density in core (Bm) = 1.5 Wb/m2 Current density = 2.75 A/mm^2 Core type = Cruciform window space factor (kw) = 0.27 Stacking factor (K_i) = 0.9 Ratio of height to width of windows (Hw/W_w) = 2.5 Ratio of yoke height to width (Hy/Dy) = 1 Axial depth of LV winding = 402mm Axial depth of HV winding = 377.5mm Inside diameter of LV winding = 310 mm outside diameter of LV winding = 348 mm Inside diameter of HV winding = 360 mm Outside diameter of HV winding = 418 mm Calculate i) Dimension of core, window & yoke. ii) Overall dimension of frame iii) Perunit resistance & leakage reactance. iv) Perunit regulation at 0.8 pf lagging Taking iron loss =1460w, copper loss=3865w at full load, height of tank=1.6m, length of tank =1.05 m, width of tank=0.62m, find the temperature rise. If the mean rise of oil is not to rise 35^0c, find the necessary number of tubes and show its arrangement. b. What are the differences between power transformer and distribution transformer from design aspect point of view?	16 3	3 3
4.	a. Write about the factors to be considered while estimating the length of air gap in induction machines. b. A 15 KW, 440V, 50 HZ, 1480 rpm ,3-phase induction motor is built with an inner diameter of stator 25 cm and length 16cm. The specific loading is 23000 amp-conductors per meter. Estimate the following parameter for a 11KW, 460V,6 pole,50 HZ delta connected induction motor, assuming same specific loadings as the previous motor with 84% efficiency and power factor 85% for each machine. Assume, current density 4A/mm^2, stator slot pitch is 15 to 25mm, ratio of slot depth to width is 3 and flux density in stator core is 1.2 wb/m^2. Calculate i) Main dimension ii) No of stator slot iii) No of stator conductor and area of stator slot iv) Dimension of each stator slot v) Minimum width of stator teeth	6 8	4 4
5.	a. Derive the output equation of DC machine b. A design is required for a 25 KW, 4 pole, 900rpm dc shunt generator, the full load terminal voltage is 220V.Assume the full load armature voltage is 3% of the terminal voltage. Calculate the main dimensions of the machine if maximum gap density B_g= 0.85Wb/m^2; specific electric loading of 20000 AC/m and R_f= 110 Ω; ratio of pole-length to the pole pitch is 0.7.	5 5	5 5

(***Note:*** *Number of questions and distribution of marks are indicative only.*)