Ref No:

SRI KRISHNA INSTITUTE OF TECHNOLOGY

#29, Hesaraghatta Main Road, Chimney Hills,
Chikkabanavara Post, Bangalore- 560090

COURSE PLAN

Academic Year 2019-20

Program:	B E – Mechanical Engineering
Semester :	6
Course Code:	17ME63
Course Title:	Heat Transfer
Credit / L-T-P:	4 / 3-2-0
Total Contact Hours:	50
Course Plan Author:	B.M.Krishne Gowda

Academic Evaluation and Monitoring Cell

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Note : Remove "Table of Content" before including in CP Book
Each Course Plan shall be printed and made into a book with cover page
Blooms Level in all sections match with A.2, only if you plan to teach / learn at higher levels

A. COURSE INFORMATION

1. Course Overview

Degree:	BE	Program:	ME
Semester:	6	Academic Year:	2020
Course Title:	HEAT TRANSFER	Course Code:	17ME63
Credit / L-T-P:	4 / 3-2-0	SEE Duration:	180 Minutes
Total Contact Hours:	50Hours	SEE Marks:	60 Marks
CIA Marks:	40 Marks	Assignment	1 / Module
Course Plan Author:	B.M.Krishne Gowda	Sign ..	Dt:
Checked By:	Naveen Kumara	Sign ..	Dt:
CO Targets	CIA Target : ……. %	SEE Target:	……. %

Note: Define CIA and SEE % targets based on previous performance.

2. Course Content

Content / Syllabus of the course as prescribed by University or designed by institute. Identify 2 concepts per module as in G.

Module	Content	Teaching Hours	Identified Module Concepts	Blooms Learning Levels
1	Introductory concepts and definitions: Modes of heat transfer: Basic laws governing conduction, convection, and radiation heat transfer; Thermal conductivity; convective heat transfer coefficient; radiation heat transfer combined heat transfer mechanism, Types of boundary conditions. General Heat Conduction Equation: Derivation of the equation in (i) Cartesian, (ii) Polar and (iii) Spherical Co-ordinate Systems. Steady-state one-dimensional heat conduction problems in Cartesian System: Steady-state one-dimensional heat conduction problems (i) with and without heat generation and (ii) with and without varying thermal conductivity - in Cartesian system with various possible boundary conditions, Thermal Resistances in Series and in Parallel.Critical Thickness of Insulation: Concept, Derivation, Extended Surfaces	10	Heat interactions and Conduction	L2,L3
2	Fins: Classification, Straight Rectangular and Circular Fins, Temperature Distribution and Heat Transfer Calculations, Fin Efficiency and Effectiveness, Applications Transient [Unsteady-state] heat conduction: Definition, Different	10	Energy dissipation and Temperature variation	L2,L3

	cases - Negligible internal thermal resistance, negligible surface resistance, comparable internal thermal and surface resistance, Lumped body, Infinite Body and Semi-infinite Body, Numerical Problems, Heisler and Grober charts.			
3	Numerical Analysis of Heat Conduction: Introduction, one-dimensional steady conduction, one dimensional unsteady conduction, two-dimensional steady and unsteady conduction, the difference equation, boundary conditions, solution methods, cylindrical coordinates and irregular boundaries. Thermal Radiation: Fundamental principles - Gray, White, Opaque, Transparent and Black bodies, Spectral emissive power, Wien's, Rayleigh-Jeans' and Planck's laws, Hemispherical Emissive Power, Stefan-Boltzmann law for the total emissive power of a black body, Emissivity and Kirchhoff's Laws,View factor, Net radiation exchange in a two-body enclosure, Typical examples for these enclosures, Radiation Shield	10	Heat interactions and Energy emission	L2,L3
4	Forced Convection: Boundary Layer Theory, Velocity and Thermal Boundary Layers, Prandtl number, Governing Equations – Continuity, Navier-Stokes and Energy equations, Boundary layer assumptions, Integral and Analytical solutions to above equations, Turbulent flow, Various empirical solutions, Forced convection flow over cylinders and spheres, Internal flows –laminar and turbulent flow solutions, Forced Convection Cooling of Electronic Devices. Free convection: Laminar and Turbulent flows, Vertical Plates, Vertical Tubes and Horizontal Tubes, Empirical solutions.	10	Boundary Layer and Energy Transfer	L2,L3
5	Heat Exchangers: Definition, Classification, applications, LMTD method, Effectiveness - NTU method, Analytical Methods, Fouling Factors, Chart Solution Procedures for solving Heat Exchanger problems: Correction Factor Charts and Effectiveness-NTU Charts, compact heat exchangers. Heat Transfer with Phase Change: Introduction to boiling, pool boiling, Bubble Growth Mechanisms, Nucleate Pool Boiling, Critical Heat Flux in Nucleate Pool Boiling, Pool Film Boiling, Critical Heat Flux, Heat Transfer beyond the Critical Point, filmwise and dropwise Condensation, heat pipes,entrainment, wicking and boiling limitations.	10	Exchange of heat and Phase change	L2,L3
-	**Total**	**50**	-	-

3. Course Material

Books & other material as recommended by university (A, B) and additional resources used by course teacher (C).

1. Understanding: Concept simulation / video ; one per concept ; to understand the concepts ; 15 – 30 minutes
2. Design: Simulation and design tools used – software tools used ; Free / open source
3. Research: Recent developments on the concepts – publications in journals; conferences etc.

Modules	Details	Chapters in book	Availability
A	**Text books (Title, Authors, Edition, Publisher, Year.)**	-	-

1-5	Principals of heat transfer, Frank Kreith, Raj M. Manglik, Mark S. Bohn, Seventh Edition, Cengage learning, 2011 .		
1-5	Heat Transfer, M. Necati Ozisik, A Basic Approach, McGraw Hill, New York, 2005.		In Lib
1-5	Heat Transfer, Holman, J. P., 9th Edition, Tata McGraw Hill, New York, 2008		
B	**Reference books (Title, Authors, Edition, Publisher, Year.)**	**-**	**-**
1-5	Yunus A. Cengel - Heat transfer, a practical approach, Fifth edition,Tata Mc Graw Hill.	-	In dept
1-5	Heat transfer by R.K.Rajputh	-	
C	**Concept Videos or Simulation for Understanding**	**-**	**-**
C1	Heat Transfer, Convection and Radiation by Prof K Rama Krishna YouTube,NPTEL		
C2	Heat Transfer, Conduction and Heat exchangers by Prof K Rama Krishna YouTube,NPTEL		

4. Course Prerequisites

Refer to GL01. If prerequisites are not taught earlier, GAP in curriculum needs to be addressed. Include in Remarks and implement in B.5.

Students must have learnt the following Courses / Topics with described Content . . .

Modules	Course Code	Course Name	Topic / Description	Sem	Remarks	Blooms Level
1	15MAT21	Engineering Mathematics	Engineering calculus	II		L2
3	15ME33	Basic thermodynamics	Basic thermodynamics	III		L2
3	15ME44	Fluid Mechanics	Basics of Fluid Mechanics	III		L2

5. Content for Placement, Profession, HE and GATE

The content is not included in this course, but required to meet industry & profession requirements and help students for Placement, GATE, Higher Education, Entrepreneurship, etc. Identifying Area / Content requires experts consultation in the area.

Topics included are like, a. Advanced Topics, b. Recent Developments, c. Certificate Courses, d. Course Projects, e. New Software Tools, f. GATE Topics, g. NPTEL Videos, h. Swayam videos etc.

Modules	Topic / Description	Area	Remarks	Blooms Level
2	Heat conduction with internal heat generation.	Industry and GATE	Seminar on internal heat generation in a boundary layer	L3
3	Specular body and diffused body	GATE	Seminar on diffused and specular body	L2
3	Hottels cross string method,	GATE	NPTEL Videos	L3
4	Forced convection internal flow	Industry and GATE	NPTEL Videos	L2
-				

B. OBE PARAMETERS

1. Course Outcomes

Expected learning outcomes of the course, which will be mapped to POs. Identify a max of 2 Concepts per Module. Write 1 CO per Concept.

Modules	Course Code.#	Course Outcome **At the end of the course, student should be able to . . .**	Teach. Hours	Concept	Instr Method	Assessment Method	Blooms' Level
1	15ME63.1	Understand the modes of heat transfer and apply the basic laws to formulate engine	10	Conduction	Lecture	Chalk and board	L3 Understand
2	15ME63.2	Understand and apply the basic laws of heat transfer to extended surface, composite material and unsteady state heat transfer problems.	10	Temperature variation	Lecture/ Tutorial	Chalk and board	L3 Apply
3	15ME63.3	Analyze heat conduction through numerical methods and apply the fundamental principle to solv radiation heat transfer problems	10	Energy dissipation	Lecture	Chalk and board	L3 Understand
4	15ME63.4	Analyze heat transfer due to free and forced convective heat transfer	10	Heat interaction	Lecture	Chalk and board	L3 Apply
5	15ME63.5	Understand the design and performance analysis of heat exchangers and their practical applications, Condensation and Boiling phenomena.	10	s Energy Transfer	Lecture	Chalk and board	L3 Apply
-	**-**	**Total**	**50**	**-**	**-**	**-**	**L2-L3**

2. Course Applications

Write 1 or 2 applications per CO.
Students should be able to employ / apply the course learnings to . . .

Modules	Application Area Compiled from Module Applications.	CO	Level
1	Air conditioning, Fins in all system, Fans,refrigerator, Engine Radiators, cooling heat pipes in electronic Appliances,	CO1	L2
1	To compute the heat flux at any location, compute the thermal stress, design of insulation thickness, chip temperature calculation, heat treatment of metals.	CO2	L3
2	Buildings, Mechanical systems, Refrigeration, Spacecraft, Automotive	CO3	L2
2	Metallurgy, heat treating process applications.	CO4	L3
3	2-D stduy state heat conduction equation is applyed in CFD analysis(Finite difference and finite element method)	CO5	L3
3	Solar flat plate collecor, water heating process (solar pond), photo voltaic cell.	CO6	L2
4	Forced convection systems applicable for extremely high temperatures for functions	CO7	L2
4	Establishing temperature distribution within building, determining heat loss calculations, ventilating and air-conditioning system.	CO8	L2
5	Boiling and condensation knowledge is applicable to calculate critical heat flux, and condensation rate in heat transfer problems.	CO9	L2

5	LMTD and NTU methods for analysis of heat exchangers.	CO10	L3

3. Mapping And Justification

CO – PO Mapping with mapping Level along with justification for each CO-PO pair.
To attain competency required (as defined in POs) in a specified area and the knowledge & ability required to accomplish it.

Modules	Mapping		Mapping Level	Justification for each CO-PO pair	Level
-	**CO**	**PO**	-	**'Area': 'Competency' and 'Knowledge' for specified 'Accomplishment'**	-
1	CO1	PO1	L2	'Engineering Knowledge:'Acquisition of Engineering_Knowledge is required to understand the different forms of heat transfer_to accomplish solutions to complex engineering_problems in Mechanical Engineering.	L2
1	CO1	PO2	L3	'Problem Analysis': Analyzing problems require knowledge / understanding steady -state conduction equation required the knowledge of modes of heat transfer to accomplish solutions to complex engineering problems in Mechanical engineering.	L3
2	CO2	PO1	L3	'Engineering Knowledge:'Acquisition of Engineering_Knowledge is required to understand the steady -state one and two dimension heat conduction equations to accomplish solutions to complex engineering_problems in Mechanical Engineering.	L3
2	CO2	PO2	L3	'Problem Analysis': ': Analyzing problems require knowledge / understanding problems in the unsteady-state heat conduction,to accomplish solutions to complex engineering problems in Mechanical engineering.	L3
3	CO3	PO1	L2	'Engineering Knowledge:'Acquisition of Engineering_Knowledge is required to understand the increase in heat dissipation .to accomplish solutions to complex engineering_problems in Mechanical Engineering.	L2
3	CO3	PO2	L2	'Engineering Knowledge:'Acquisition of Engineering_Knowledge is required to understand the steady-state one and two dimension heat conduction to radiation in heat transfer.accomplish solutions to complex engineering problems in Mechanical Engineering.	L2
4	CO4	PO1	L3	'Engineering Knowledge: Acquisition of Engineering_Knowledge is required to understand the forced convection heat transfer,to complex engineering problems in Mechanical Engineering	L3
4	CO4	PO2	L3	'Problem Analysis 'Acquisition of Engineering_Knowledge is required to understand the free convection heat transfer,to complex engineering problems in Mechanical Engineering	L3
5	CO5	PO1	L3	'Engineering Knowledge:'Analyzing problems require knowledge / understanding problems in the different types in heat exchangers,to complex engineering problems in Mechanical engineering	L3
5	CO5	PO2	L3	'Problem Analysis': Analyzing problems require knowledge / understanding problems in the different types of Boiling to complex engineering problems in Mechanical engineering	L3

4. Articulation Matrix

CO – PO Mapping with mapping level for each CO-PO pair, with course average attainment.

-	-	Course Outcomes	Program Outcomes															-
Modules	CO.#	**At the end of the course student should be able to . . .**	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	Level
1	15ME63.1	Understand the modes of heat transfer and apply the basic	√	√	-	-	-	-	-	-	-	-	-	-	-	-	-	L2

		laws to formulate engine																
2	15ME63.2	Understand and apply the basic laws of heat transfer to extended surface, composite material and unsteady state heat transfer problems.	√	√	-	-	-	-	-	-	-	-	-	-	-	-	-	L3
3	15ME63.3	Analyze heat conduction through numerical methods and apply the fundamental principle to solv radiation heat transfer problems	√	√	-	-	-	-	-	-	-	-	-	-	-	-	-	L3
4	15ME63.4	Analyze heat transfer due to free and forced convective heat transfer	√	√	-	-	-	-	-	-	-	-	-	-	-	-	-	L3
5	15ME63.5	Understand the design and performance analysis of heat exchangers and their practical applications, Condensation and Boiling phenomena.	√	√	-	-	-	-	-	-	-	-	-	-	-	-	-	L3

5. Curricular Gap and Content

Topics & contents not covered (from A.4), but essential for the course to address POs and PSOs.

Modules	Gap Topic	Actions Planned	Schedule Planned	Resources Person	PO Mapping
2	Heat conduction with internal heat generation	NPTEL Videos	-	-	PO2
2	Response time of temperature measuring system	NPTEL Videos	-	-	PO1
3	Shape factors and salient features of shape factors	NPTEL Videos	-	-	PO2
3	Spectacular body and diffused body	NPTEL Videos	-	-	PO2

6. Content Beyond Syllabus

Topics & contents required (from A.5) not addressed, but help students for Placement, GATE, Higher Education, Entrepreneurship, etc.

Modules	Gap Topic	Area	Actions Planned	Schedule Planned	Resources Person	PO Mapping
2	Heat conduction with internal heat generation	Placement, GATE, Higher Study, .	Presentation by students	12/04/2019	Self	PO2
2	Response time of temperature measuring system	Placement, GATE, Higher Study	Presentation	12/04/2019	Self	PO1
3	Shape factors and	Placement,	NPTEL Videos	2/5/2019	Prof K Rama	PO2

	salient features of shape factors	GATE, Higher Study			Krishna	
3	Spectacular body and diffused body	Placement, GATE, Higher Study	NPTEL Videos	3/5/2019	Prof K Rama Krishna	PO2

C. COURSE ASSESSMENT

1. Course Coverage

Assessment of learning outcomes for Internal and end semester evaluation. Distinct assignment for each student. 1 Assignment per chapter per student. 1 seminar per test per student.

Modules	Title	Teach. Hours	No. of question in Exam						CO	Levels
			CIA-1	CIA-2	CIA-3	Asg	Extra Asg	SEE		
1	Introductory concepts and definitions	12	2	-	-	1	1	2	CO1, CO2	L2, L3
2	Critical Thickness of Insulation and Transient [Unsteady-state] heat conduction	9	2	-	-	1	1	2	CO3, CO4	L2, L3
3	Numerical Analysis of Heat Conduction and Thermal Radiation	9	-	2	-	1	1	2	CO5, CO6,	L2,L3
4	Forced Convection and Free convection	8	-	2	-	1	1	2	C07,CO8	L2, L2
5	Heat Exchangers and Heat Transfer with Phase Change	12	-	-	4	1	1	2	CO9,CO10	L2,L3
-	**Total**	50	**4**	**4**	**4**	**5**	**5**	**10**	-	-

2. Continuous Internal Assessment (CIA)

Assessment of learning outcomes for Internal exams. Blooms Level in last column shall match with A.2.

Modules	Evaluation	Weightage in Marks	CO	Levels
1, 2	CIA Exam – 1	15	CO1, CO2, CO3, CO4	L2, L3, L2,L3
3, 4	CIA Exam – 2	15	CO5, CO6, CO7, CO8,	L3,L2,L2
5	CIA Exam – 3	15	CO9,CO10	L2, L3
1, 2	Assignment - 1	05	CO1, CO2, CO3, CO4	L2, L3, L2,L3
3, 4	Assignment - 2	05	CO5, CO6, CO7, CO8,	L3,L2,L2
5	Assignment - 3	05	CO9,CO10	L2, L3
1, 2	Seminar - 1	-	-	-

3, 4	Seminar - 2	-	-	-
5	Seminar - 3	-	-	-
	-	-	-	-
	Final CIA Marks	**20**	**-**	**-**

D1. TEACHING PLAN - 1

Module - 1

Title:	Introductory concepts and definitions	Appr Time:	12 Hrs
a	***Course Outcomes***	-	**Blooms**
-	The student should be able to:	-	**Level**
1		CO1	L2
2		CO2	L3
b	***Course Schedule***	-	-
Class No	**Module Content Covered**	**CO**	**Level**
1	Introductory concepts and definitions: Modes of heat transfer: Basic laws governing conduction, convection, and radiation heat transfer;	C01	L2
2	Thermal conductivity; convective heat transfer coefficient; radiation heat transfer combined heat transfer mechanism	C01	L2
3	Types of boundary conditions. General Heat Conduction Equation	C01	L2
4	Derivation of the equation in (i) Cartesian, (ii) Polar and (iii) Spherical Co-ordinate Systems.	C01	L2
5	Steady-state one-dimensional heat conduction problems in Cartesian System	CO2	L3
6	Steady-state one-dimensional heat conduction problems (i) with and without heat generation and	CO2	L3
7	(ii) with and without varying thermal conductivity - in Cartesian system with various possible boundary conditions	CO2	L3
8	Thermal Resistances in Series and in Parallel.	CO2	L3
c	**Application Areas**	**-**	**-**
-	Students should be able employ / apply the Module learnings to . . .	-	-
1	Air conditioning, Fins in all system, Fans,refrigerator, Engine Radiators, cooling heat pipes in electronic Appliances,	CO1	L2
2	To compute the heat flux at any location, compute the thermal stress, design of insulation thickness, chip temperature calculation, heat treatment of metals.	CO2	L3
d	**Review Questions**	-	-
-	The attainment of the module learning assessed through following questions	-	-
1	The inside temperature of a furnace wall with k = 1.35 N/m.K, 200 mm thick is 1400°C. The heat transfer coefficient at the outside surface is a function of temperature difference and is given by (h = 7.85 + 0.08AT) W/m2.K. where AT is the temperature difference between outside wall surface and surroundings. Determine the rate of heat transfer per unit area, if the surrounding temperature is	CO1	L3

	40°C.		
2	The temperature distribution across a wall, 1 m thick at a certain instant of time is given as T(x) = 900 — 300x —50x2 , where T is in degree Celsius and x in metre. The uniform heat generation of 1000 W/m3 is present in wall of area 10 m2 having the properties p = 1600 kg/m3, k = 40 W/m.K and C = 4 kJ/kg.K. Determine (i) The rate of heat transfer entering the wall at x = 0 and leaving the wall at x = 1 m. (ii) The rate of change of internal energy of the wall (iii) The time rate of temperature change at x = 0, 0.5 m.	CO1	L3
3	Explain the three types of boundary conditions used in conduction heat transfer.	CO1	L2
4	Derive general three dimensional conduction equation in Cartesian co-ordinate.	CO1	L2
5	A furnace wall is made up of three layers of thickness 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65 K and 9.2 W/m° C respectively. The inside is exposed to gases at 1250° C with a convection co-efficient of 25 W/m2°C and the inside surface is at 1100°C, the outside surface is exposed to air at 25° C with convection co-efficient of 12 W/m2°C. Determine (i)The unknown thermal conductivity K (ii)The overall heat transfer co-efficient.	CO2	L3
6	Explain briefly the mechanism of conduction, convection and radiation heat transfer.	CO1	L2
7	The wall of a house in a cold region consists of three layers, an outer brick work 20cm thick, an inner wooden panel 1.4cm thick and an intermediate layer made of an insulating material 10cm thick. The inside and outside temperatures of the composite wall are 28°C and -12°C respectively. The Explain the three types of boundary conditions used in conduction heat transfer. thermal conductivity of brick and wood are 0.7W/m/K and 0.18 W/mK respectively. If the layer of insulation has a thermal conductivity of 0.023W/mK, find i) The heat loss per unit area of the wall ii) Overall heat transfer coefficient.	CO2	L3
8	A pipe with outside diameter 20 mm is covered with two insulating materials. The thickness of each insulating layer is 10 mm The conductivity of Is' insulating layer is 6 times that of the 2"d insulating layer. Initially insulating layer is placed in the order of 1^{st} and 2"d layer.Then it is placed in the order of 2"d layer and 1st layer. Calculate percentage change in heat transfer and increase or decrease. Assume a length of 1 m. In both the arrangement, there is no change in temperature.	CO2	L2
9	State the law governing three modes of heat trannsfer.	CO1	L2
10	furnace has a composite wall constructed of a refractory material for the inside layer and an insulating material on the outside. The total wall thickness is limited to 60 cms. The mean temperature of the gases within the furnace is 850°C, the external air temperature is 30°C and the temperature of the interface of the two materials of the furnace wall is 500°C. The thermal conductivities of refractory and insulating materials are 2 and 0.2 W/m—K respectively. The coefficients of heat transfer between the gases and refractory surface is 200 W/m2 -k and between outside surface and atmosphere is 40 W/m2-k. Find : i) The required thickness of each material ii) The rate of heat loss.	CO2	L3
11	small electric heating application uses 1.82 mm diameter wire with 0.71 mm think insulation. K (insulation) = 0.118 W/m-K, and ho = 34.1 W/m2-k. Determine the	CO2	L3

	critical thickness of insulation for this case and change in heat transfer rate if critical thickness was used. Assume the temperature difference between surface of wire and surrounding air remain unchanged. Explain the three types of boundary conditions used in conduction heat transfer.		
12	What is thermal diffusivity? Explain its importance in heat conduction problems.	CO2	L2
13	Consider a one dimensional steady state heat conduction in a plate with constant thermal conductivity in a region 0 x 5_ L. A plate is exposed to uniform heat flux q W/M2 at x = 0 and dissipates heat by convection at x = L with heat transfer coefficient h in the surrounding air at Tr . Write the mat Explain the three types of boundary conditions used in conduction heat transformation formulation of this problem for the determination of one dimensional steady state temperature distribution within the wall.	CO2	L3
14	An industrial freezer is designed to operate with an internal air temperature of -20°C when the external air temperature is 25°C and the internal and external heat Explain the three types of boundary conditions used in conduction heat transfer transfer coefficients are 12 W/m2°C and 8 W/m2 °C, respectively. The wall of the freezer are composite construction, comprising of an inner layer of plastic 3 mm thick with thermal conductivity of 1 W/m°C. An outer layer of stainless steel of thickness 1 mm and thermal conductivity of 16W/m°C. Sandwiched between these layers is a layer of insulation material with thermal conductivity of 0.07 W/tn°C. Find the width of the insulation required to reduce the convective heat loss to 15 W/m2.	CO2	L3
15	A plate of thickness 'I.,' whose one side is insulated and the other side is maintained at a temperature T1 is exchanging heat by convection to the surrounding area at a temperature T2, with atmospheric air being the outside medium. Write mathematical formulation for one dimensional, steady state heat transfer, without heat generation.	CO2	L3
16	Explain briefly: i) Thermal conductivity Explain the three types of boundary conditions used in conduction heat transfer. ii) Thermal diffusivity Explain the three types of boundary conditions used in conduction heat transfer. iii) Overall heat transfer co-efficient	CO2	L2
17	A square plate heater of size 20 ems x 20 ems is inserted between two slabs. Slab 'A' is 3 ems thick (K = 50 W/mK) and slab 13' is 1.5 ems (K = 0.2 W/mK). The outside heat transfer co-efficients on both sides of A and B are 200 and 50 W/m2K respectively. Temperature of surrounding air is 25°C. If the rating of the heater is 1 kW, find i) Maximum temperature in the system. ii) Outer surface temperature of two slabs. Draw the equivalent circuit for the system	CO2	L3
18	Write the mathematical formulation of one-dimensional, steady-state heat conduction for a hollow sphere with constant thermal conductivity in the region a 5 r b, when heat is supplied to the sphere at a rate of 'go' W/m 2 from the boundary surface at r = a and dissipated by convection from the boundary surface at r = b into a medium at zero temperature with a heat transfer coefficient 'h'.	CO2	L3
19	A stream pipe with internal and external diameters 18 cm and 21 cm is covered with two layers of insulation each 30 mm thick with thermal conductivities 0.18 W/m.K and 0.09 W/m.K. The difference in temperature between inside and outside surfaces is 250°C. Calculate the quantity of heat lost per meter length of the pipe if its thermal conductivity is 60 W/m.K. What is the percentage error if the calculation is carried out considering the pipe as a plane wall?	CO2	L3

20	The walls of a house in cold region consist of three layers, an outer brick work 15 cm thick, an inner wooden panel 1.2 cm thick, the intermediate layer is made of an insulating material 7 cm thick. The thermal conductivity of brick and wood are 0.7 W/mk and 0.18 W/mk respectively. The inside and outside temperatures of the composite wall are 21°C and -15°C respectively. If the layer of insulation offers twice the thermal resistance of the brick wall, calculate, i) Heat loss per unit area of the wall. ii) Thermal conductivity of insulating material.	CO2	L3

Module – 2

Title:	Fins and Transient [Unsteady-state] heat conduction	Appr Time:	10 Hrs
a	***Course Outcomes***	**CO**	**Blooms**
-	At the end of the topic the student should be able to . . .	-	**Level**
1		CO3	L2
2		CO4	L3
b	***Course Schedule***	-	-
Class No	**Portion covered per hour**	**-**	**-**
09	Critical Thickness of Insulation: Concept, Derivation		
10	Extended Surfaces or Fins:Classification, Straight Rectangular and Circular Fins	CO3	L2
11	Temperature Distribution and Heat Transfer Calculations,	CO3	L2
12	Fin Efficiency and Effectiveness, Applications	CO3	L2
13	Transient [Unsteady-state] heat conduction: Definition, Different cases - Negligible internal thermal resistance,	CO3	L2
14	negligible surface resistance,	CO4	L3
15	Comparable internal thermal	CO4	L3
16	surface resistance, Lumped body,Infinite Body and Semi-infinite Body,	CO4	L2
17	Numerical Problems, Heisler and Grober charts.		
c	**Application Areas**	**-**	**-**
-	Students should be able employ / apply the Module learnings to . . .	-	-
1	Buildings, Mechanical systems, Refrigeration, Spacecraft, Automotive	CO3	L2
2	Metallurgy, heat treating process applications.	CO4	L3
d	**Review Questions**	-	-
-	The attainment of the module learning assessed through following questions	-	-
1	Define fin effectiveness. When the use of fins is not justified?	CO3	L2
2	A plane wall k = 45 W/m.K 10 cm thick, generated at a uniform rate of 8 x106 W/m3. The two sides of the wall are maintained at 180°C and i 20°C. Neglect end effects, calculate (I) Temperature distribution across the plate (ii) Position and magnitude of maximum temperature. (iii) The heat flow rate from each surface of the plate.	CO3	L3
3	A very long rod, 25 mm in diameter, has one end maintained at 100°C. The surface of the rod is exposed to ambient air at 25°C with convection coefficient of 10 W/m2.K. What are the heat losses from the rods, constructed of pure copper with K = 398 W/mK and stainless steel with K =14 W/m.K ? Also, estimate how long the rods must be to be considered infinite.	CO3	L3
4	Define critical thickness of insulation and explain its significance.	CO4	L2

5	Obtain an expression for temperature distribution and heat flow through a rectangular fin, when end of the fin is insulated.	CO4	L2
6	A steel rod (K = 30 W/mK) 1 ems diameter and 5 ems long with insulation end is to be used as a spine. It is exposed to the surrounding temperature of 65 °C and heat transfer co-efficient of 50 W/m2 K. The temperature of the base is 98° C. Determine (i) Fin efficiency (ii) Temperature at the end of spine (iii) Heat dissipation from spine.	CO3	L3
7	Obtain an expression for temperature distribution and heat flow through a fin of uniform cross section with the end insulated.	CO3	L2
8	The aluminum square fi ns (0.6mm x 0.6mm), 12mm long are provided on the surface of a semi conductor electronic device to carry 2W of energy generated. The temperature at the surface of the device should not exceed 85 °C, when the surrounding is at 35°C. Given K = 200 W/ m K, h = 15W/m2 K. Determine the number of fins required to carry out the above duty. Neglect the heat loss from the end of the fin.	CO3	L3
9	What is physical significance of critical thickness of insulation? Derive an expression for critical thickness of insulation for a cylinder.	CO4	L2
10	Derive an expression for the temperature distribution for a pin fin, when the tip of the fin is insulated.	CO4	L3
11	Find the amount of heat transferred through an iron fin of thickness of 5 mm, height 50 mm and width 100 cm. Also determine the temperature difference at the tip of the fin assuming atmospheric temperature of 28°C and base temperature of fin = 108°C. Assume the following K = 50 W/mK, h = 10 W/m2K.	CO4	L3
12	Derive an expression for critical thickness of insulation for a sphere.	CO3	L3
13	Derive an expression for the temperature distribution for a short fin of uniform cross section without insulated tip starting from fundamental energy balance equation.	CO3	L3
14	Determine the amount of heat transferred through an iron fin of thickness 5mm, height 50 mm and width 100 cms. Also determine the temperature of the centre of the fin end of the tip of fm. Assuming atmospheric temperature of 28°C. Take K = 50 W/m — K, h = 10 W/m2 — K, Base fin temperature = 108°C.	CO4	L3
15	Define critical thickness of insulation and explain its significance.	CO4	L2
16	Obtain an expression for temperature distribution and heat flow through a rectangular fin, when the end of the fin is insulated.	CO4	L3
17	Derive an expression for critical thickness of insulation for a cylinder. Discuss the design aspects for providing insulation scheme for cable wires and steam pipes.	CO3	L3
18	Find the amount of heat transferred through an iron fin of thickness of 5 mm, height 50 mm and width 100 cm. Also, determine the temperature difference '0' at the tip of fin assuming atmospheric temperature of 28°C and base temperature of fin to be 108°C. Take Kfin = 50 W/m — K, h = 10 W/m2-K.	CO3	L3
19	set of aluminum fins (K = 180 W/mK) that are to be fitted to a small air compressor. The device dissipates I KW by convecting to the surrounding air which is at 20°C. Each fin is 100 mm long, 30 mm high and 5 mm thick. The tip of each fin may be assumed to be adiabatic and a heat transfer coefficient of 15 W/ m- K acts over the remaining surfaces. Estimate the number of fins required to ensure the base temperature does not exceed 120°C.	CO4	L3
20	What is critical thickness of insulation on a small diameter wire or pipe? Explain its physical significance and derive an expression for the same.	CO4	L2
21	Explain the three types of boundary conditions used in conduction heat transfer.	CO4	L2
22	Differentiate between effectiveness and efficiency of the fins.	CO3	L2

23	Derive an expression for temperature distribution for a fin film with the tip insulated.	CO3	L3
24	A carbon steel (k = 54 W/ m7C) rod with a cross section of an equilateral triangle (each side 5 mm) is 80 mm long. It is attached to a plane wall which is maintained at a temperature of 400 °C. °The surrounding environment is at a 50 °C and unit surface conductance is 90 W/ m C. Compute the heat dissipated by the rod (assuming tip is insulated).	CO4	L3
25	A rod (K = 200 W/mK) 10 mm in diameter and 5 ems long has its one end maintained at 100°C. The surface of the rod is exposed to ambient air at 30°C with convective heat transfer co-efficient of 100 W/m2K. Assuming other end insulated, determine i) The temperature of the rod at 25 mm distance from the end at 100°C. ii) Heat dissipation rate from the surface of the rod and iii) Effectiveness.	CO4	L3
26	Derive an expression for the temperature distribution for a long pin of uniform cross section without insulated tip.	CO4	L3
27	Clearly define i) Fin efficiency and ii) Fin effectiveness	CO3	L2
28	Derive an expression for rate of heat transfer and temperature distribution for a plane wall with variable thermal conductivity	CO3	L3
29	Thin fins of brass whose K = 75 W/m.K are welded longitudinally on a 5 cm diameter brass cylinder which stands vertically and is surrounded by air at 20°C. The heat transfer coefficient from metal surface to the air is 17 W/m 2.K. If 16 uniformly spaced fins are used each 0.8 mm thick and extending 1.25 cm from the cylinder, what is the rate of heat transfer from the cylinder per meter length to the air when the cylinder surface is maintained at 150°C?	CO4	L3
30	Define fin efficiency and fin effectiveness with respect to a fin with insulated tip.	CO4	L2
31	What is the physical significance of critical thickness of insulation? Derive an expression for critical thickness of insulation for a sphere.	CO4	L2
32	The inside temperature of a furnace wall with k = 1.35 N/m.K, 200 mm thick is 1400°C. The heat transfer coefficient at the outside surface is a function of temperature difference and is given by (h = 7.85 + 0.08AT) W/m2.K. where AT is the temperature difference between outside wall surface and surroundings. Determine the rate of heat transfer per unit area, if the surrounding temperature is 40°C.	CO3	L3
33	The temperature distribution across a wall, 1 m thick at a certain instant of time is given as T(x) = 900 — 300x —50x2 , where T is in degree Celsius and x in metre. The uniform heat generation of 1000 W/m3 is present in wall of area 10 m2 having the properties p = 1600 kg/m3, k = 40 W/m.K and C = 4 kJ/kg.K. Determine (i) The rate of heat transfer entering the wall at x = 0 and leaving the wall at x = 1 m. (ii) The rate of change of internal energy of the wall (iii) The time rate of temperature change at x = 0, 0.5 m.	CO3	L3
34	Explain the three types of boundary conditions used in conduction heat transfer.	CO4	L2
35	Derive general three dimensional conduction equation in Cartesian co-ordinate.	CO4	L3
36	A furnace wall is made up of three layers of thickness 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65 K and 9.2 W/m° C respectively. The inside is exposed to gases at 1250° C with a convection co-efficient of 25 W/m2°C and the inside surface is at 1100°C, the outside surface is exposed to air at 25° C with convection co-	CO4	L3

	efficient of 12 W/m2°C. Determine (i)The unknown thermal conductivity K (ii)The overall heat transfer co-efficient.		
37	Explain briefly the mechanism of conduction, convection and radiation heat transfer.	CO3	L2
38	The wall of a house in a cold region consists of three layers, an outer brick work 20cm thick, an inner wooden panel 1.4cm thick and an intermediate layer made of an insulating material 10cm thick. The inside and outside temperatures of the composite wall are 28°C and -12°C respectively thermal conductivity of brick and wood are 0.7W/m/K and 0.18 W/mK respectively. If the layer of insulation has a thermal conductivity of 0.023W/mK, find i) The heat loss per unit area of the wall ii) Overall heat transfer coefficient.	CO3	L3
39	A pipe with outside diameter 20 mm is covered with two insulating materials. The thickness of each insulating layer is 10 mm The conductivity of Is' insulating layer is 6 times that of the 2"d insulating layer. Initially insulating layer is placed in the order of 1^{st} and 2"d layer.Then it is placed in the order of 2"d layer and 1st layer. Calculate percentage change in heat transfer and increase or decrease. Assume a length of 1 m. In both the arrangement, there is no change in temperature.	CO4	L3
40	State the law governing three modes of heat transfer.	CO4	L2
41	Furnace has a composite wall constructed of a refractory material for the inside layer and an insulating material on the outside. The total wall thickness is limited to 60 cms. The mean temperature of the gases within the furnace is 850°C, the external air temperature is 30°C and the temperature of the interface of the two materials of the furnace wall is 500°C. The thermal conductivities of refractory and insulating materials are 2 and 0.2 W/m—K respectively. The coefficients of heat transfer between the gases and refractory surface is 200 W/m2 -k and between outside surface and atmosphere is 40 W/m2-k. Find : i) The required thickness of each material ii) The rate of heat loss.	CO4	L3
42	small electric heating application uses 1.82 mm diameter wire with 0.71 mm think insulation. K (insulation) = 0.118 W/m-K, and ho = 34.1 W/m2-k. Determine the critical thickness of insulation for this case and change in heat transfer rate if critical thickness was used. Assume the temperature difference between surface of wire and surrounding air remain unchanged. Explain the three types of boundary conditions used in conduction heat transfer.	CO3	L3
43	What is thermal diffusivity? Explain its importance in heat conduction problems.	CO3	L3
44	Consider a one dimensional steady state heat conduction in a plate with constant thermal conductivity in a region 0 x 5_ L. A plate is exposed to uniform heat flux q W/M2 at x = 0 and dissipates heat by convection at x = L with heat transfer coefficient h in the surrounding air at Tr .Write the mathematical formulation of this problem for the determination of one dimensional steady state temperature distribution within the wall.	CO4	L3
46	An industrial freezer is designed to operate with an internal air temperature of -20°C when the external air temperature is 25°C and the internal and external heat Explain the three types of boundary conditions used in conduction heat transfer transfer coefficients are 12 W/m2°C and 8 W/m2 °C, respectively. The wall of the freezer are composite construction, comprising of an inner layer of plastic 3 mm thick with thermal conductivity of 1 W/m°C. An outer layer of stainless steel of thickness 1 mm and thermal conductivity of 16W/m°C. Sandwiched between these layers is a layer of insulation material with thermal conductivity of 0.07	CO4	L3

	W/tn°C. Find the width of the insulation required to reduce the convective heat loss to 15 W/m2.		
47	A plate of thickness 'I.,' whose one side is insulated and the other side is maintained at a temperature T1 is exchanging heat by convection to the surrounding area at a temperature T2, with atmospheric air being the outside medium. Write mathematical formulation for one dimensional, steady state heat transfer, without heat generation.	CO4	L3
48	Explain briefly: i) Thermal conductivity ii) Thermal diffusivity iii) Overall heat transfer co-efficient	CO3	L2
49	A square plate heater of size 20 ems x 20 ems is inserted between two slabs. Slab 'A' is 3 ems thick (K = 50 W/mK) and slab 13' is 1.5 ems (K = 0.2 W/mK). The outside heat transfer co-efficients on both sides of A and B are 200 and 50 W/m2K respectively. Temperature of surrounding air is 25°C. If the rating of the heater is 1 kW, find i) Maximum temperature in the system. ii) Outer surface temperature of two slabs. Draw the equivalent circuit for the system	CO3	L3
50	Write the mathematical formulation of one-dimensional, steady-state heat conduction for a hollow sphere with constant thermal conductivity in the region a 5 r b, when heat is supplied to the sphere at a rate of 'go' W/m 2 from the boundary surface at r = a and dissipated by convection from the boundary surface at r = b into a medium at zero temperature with a heat transfer coefficient 'h'.	CO4	L3
51	A stream pipe with internal and external diameters 18 cm and 21 cm is covered with two layers of insulation each 30 mm thick with thermal conductivities 0.18 W/m.K and 0.09 W/m.K. The difference in temperature between inside and outside surfaces is 250°C. Calculate the quantity of heat lost per meter length of the pipe if its thermal conductivity is 60 W/m.K. What is the percentage error if the calculation is carried out considering the pipe as a plane wall?	CO4	L3
52	The walls of a house in cold region consist of three layers, an outer brick work 15 cm thick, an inner wooden panel 1.2 cm thick, the intermediate layer is made of an insulating material 7 cm thick. The thermal conductivity of brick and wood are 0.7 W/mk and 0.18 W/mk respectively. The inside and outside temperatures of the composite wall are 21°C and -15°C respectively. If the layer of insulation offers twice the thermal resistance of the brick wall, calculate,i) Heat loss per unit area of the wall.ii) Thermal conductivity of insulating material.	CO4	L3
5			

E1. CIA EXAM – 1

a. Model Question Paper - 1

Crs Code:	17ME63	Sem:	VI	Marks:	40	Time:	75 minutes
Course:	HEAT TRANSFER						

-	-	Note: Answer all questions, each carry equal marks. Module : 1, 2	Marks	CO	Level
1	a	Define Heat Transfer?Explain Modes of Heat Heat Transfer With examples	8	CO1	L2
	b	The inside temperature of a furnace wall with k = 1.35 N/m.K, 200 mm thick is 1400°C. The heat transfer coefficient at the outside surface is a function of temperature difference and is given by(h = 7.85 + 0.08AT) W/m2.K. where	7	CO1	L3

		AT is the temperature difference between outside wall surface and surroundings. Determine the rate of heat transfer per unit area, if the surrounding temperature 40°C.			
		OR			
2	a	Explain the three types of boundary conditions used in conduction heat transfer.	7	CO2	L2
	b	A furnace wall is made up of three layers of thickness 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65 K and 9.2 W/m° C respectively. The inside is exposed to gases at 1250° C with a convection co-efficient of 25 W/m2°C and the inside surface is at 1100°C, the outside surface is exposed to air at 25° C with convection co-efficient of 12 W/m2°C. Determine (i)The unknown thermal conductivity K (ii)The overall heat transfer co-efficient.	8	CO2	L3
		OR			
3	a	Derive the expression for instantaneous and total heat transfer in lumped system analysis.	7	CO3	L2
	b	A steel pipe of 220mm OD is carrying steam at 280°C. It is insulated with a material with K=0.06[1 + 0.0018T] where `K.' is in W/m °K. Thickness of insulation is 50mm and the outer surface temperature is 50°C. Determine the heat flow per `m' length of the pipe and the temperature at the mid thickness of the pipe.	8	CO3	L3
		OR			
4	a	What is the physical significance of critical thickness of insulation? Derive an expression for critical thickness of insulation for a sphere.	7	CO4	L2
	b	The handle of a ladle used for pouring molten metal at 327°C is 30 cm long and is made of 2.5 cm x 1.5 cm mild steel bar stock (K = 43 W/mK). In order to reduce the grip temperature it is proposed to make a hollow handle of mild steel plate of 0.15 cm thick to the same rectangular shape. if the surface heat transfer coefficient is 14.5 W/m 2K and the ambient temperature is at 27°C, estimate the reduction in the temperature of grip. Neglect the heat transfer from the inner surface of the hollow shape.	8	CO4	L3

b. Assignment -1

Note: A distinct assignment to be assigned to each student.

Model Assignment Questions							
Crs Code:	17ME63	Sem:	VI	Marks:	VI	Time:	90 – 120 minutes
Course:	HEAT TRANSFER			Module : 1, 2			
Note: Each student to answer 2-3 assignments. Each assignment carries equal mark.							

SNo	USN	Assignment Description	Marks	CO	Level
1	1KT16ME033	The inside temperature of a furnace wall with k = 1.35 N/m.K, 200 mm thick is 1400°C. The heat transfer coefficient at the outside surface is a function of temperature difference and is given by (h = 7.85 + 0.08AT) W/m2.K. where AT is the temperature difference between outside wall surface and surroundings. Determine the rate of heat transfer per unit area, if the surrounding temperature is 40°C.	5	CO1	L2
2	1KT16ME036	The temperature distribution across a wall, 1 m thick at a certain	5	CO2	L3

		instant of time is given as T(x) = 900 — 300x —50x2 , where T is in degree Celsius and x in metre. The uniform heat generation of 1000 W/m3 is present in wall of area 10 m2 having the properties p = 1600 kg/m3, k = 40 W/m.K and C = 4 kJ/kg.K. Determine (i) The rate of heat transfer entering the wall at x = 0 and leaving the wall at x = 1 m. (ii) The rate of change of internal energy of the wall (iii) The time rate of temperature change at x = 0, 0.5 m.			
3	1KT16ME037	Explain the three types of boundary conditions used in conduction heat transfer.		CO2	L3
4	1KT16ME039	Derive general three dimensional conduction equation in Cartesian co-ordinate.	5	CO1	L3
5	1KT16ME040	A furnace wall is made up of three layers of thickness 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65 K and 9.2 W/m° C respectively. The inside is exposed to gases at 1250° C with a convection co-efficient of 25 W/m2°C and the inside surface is at 1100°C, the outside surface is exposed to air at 25° C with convection co-efficient of 12 W/m2°C.Determine (i)The unknown thermal conductivity K (ii)The overall heat transfer co-efficient.	5	CO1	L2
6	1KT16ME041	Explain briefly the mechanism of conduction, convection and radiation heat transfer.	5	CO2	L3
7	1KT16ME042	The wall of a house in a cold region consists of three layers, Define Heat Transfer?Explain Modes of Heat Heat Transfer With examplesan outer brick work 20cm thick, an inner wooden panel 1.4cm thick and an intermediate layer made of an insulating material 10cm thick. The inside and outside temperatures of the composite wall are 28°C and -12°C respectively. thermal conductivity of brick and wood are 0.7W/m/K and 0.18 W/mK respectively. If the layer of insulation has a thermal conductivity of 0.023W/mK, find i) The heat loss per unit area of the wall ii) Overall heat transfer coefficient.	5	CO2	L3
8	1KT16ME043	A pipe with outside diameter 20 mm is covered with two insulating materials. The thickness of each insulating layer is 10 mm The conductivity of Is' insulating layer is 6 times that of the 2"d insulating layer. Initially insulating layer is placed in the order of 1^{st} and 2"d layer. Then it is placed in the order of 2"d layer and 1st layer. Calculate percentage change in heat transfer and increase or decrease. Assume a length of 1 m. In both the arrangement, there is no change in temperature.	5	CO2	L3
9	1KT16ME044	State the law governing three modes of heat transfer.	5	CO2	L2
10	1KT16ME045	furnace has a composite wall constructed of a refractory material for the inside layer and an insulating material on the outside. The total wall thickness is limited to 60 cms. The mean temperature of the gases within the furnace is 850°C, the external air temperature is 30°C and the temperature of the interface of the two materials of the furnace wall is 500°C. The thermal conductivities of refractory and insulating materials are 2 and 0.2 W/m—K respectively. The coefficients of heat transfer between the gases and refractory surface is 200 W/m2 -k and between outside surface and atmosphere is 40 W/m2-k. Find :	5	CO2	L3

		i) The required thickness of each material ii) The rate of heat loss.			
11	1KT16ME046	small electric heating application uses 1.82 mm diameter wire with 0.71 mm think insulation. K (insulation) = 0.118 W/m-K, and ho = 34.1 W/m2-k. Determine the critical thickness of insulation for this case and change in heat transfer rate if critical thickness was used. Assume the temperature difference between surface of wire and surrounding air remain unchanged..	5	CO2	L3
12	1KT16ME047	What is thermal diffusivity? Explain its importance in heat conduction problems.		CO1	L3
13	1KT16ME048	Consider a one dimensional steady state heat conduction in a plate with constant thermal conductivity in a region 0 x 5_ L. A plate is exposed to uniform heat flux q W/M2 at x = 0 and dissipates heat by convection at x = L with heat transfer coefficient h in the surrounding air at Tr . Write the mathematical formulation of this problem for the determination of one dimensional steady state temperature distribution within the wall.	5	CO1	L2
14	1KT16ME049	An industrial freezer is designed to operate with an internal air temperature of -20°C when the external air temperature is 25°C and the internal and external heat Explain the three types of boundary conditions used in conduction heat transfer coefficients are 12 W/m2°C and 8 W/m2 °C, respectively. The wall of the freezer are composite construction, comprising of an inner layer of plastic 3 mm thick with thermal conductivity of 1 W/m°C. An outer layer of stainless steel of thickness 1 mm and thermal conductivity of 16W/m°C. Sandwiched between these layers is a layer of insulation material with thermal conductivity of 0.07 W/tn°C. Find the width of the insulation required to reduce the convective heat loss to 15 W/m2.	5	CO2	L3
15	1KT16ME051	A plate of thickness 'I.,' whose one side is insulated and the other side is maintained at a temperature T1 is exchanging heat by convection to the surrounding area at a temperature T2, with atmospheric air being the outside medium. Write mathematical formulation for one dimensional, steady state heat transfer, without heat generation.	5	CO2	L3
16	1KT16ME052	Explain briefly: i) Thermal conductivity Explain the three types of boundary conditions used in conduction heat transfer. ii) Thermal diffusivity Explain the three types of boundary conditions used in conduction heat transfer. iii) Overall heat transfer co-efficient	5	CO2	L3
17	1KT16ME053	A square plate heater of size 20 ems x 20 ems is inserted between two slabs. Slab 'A' is 3 ems thick (K = 50 W/mK) and slab 13' is 1.5 ems (K = 0.2 W/mK). The outside heat transfer co-efficients on both sides of A and B are 200 and 50 W/m2K respectively. Temperature of surrounding air is 25°C. If the rating of the heater is 1 kW, findi) Maximum temperature in the system. ii) Outer surface temperature of two slabs. Draw the equivalent circuit for the system	5	CO2	L2
18	1KT16ME056	Write the mathematical formulation of one-dimensional, steady-state heat conduction for a hollow sphere with constant thermal conductivity in the region a 5 r b, when heat is supplied to the	5	CO3	L3

		sphere at a rate of 'go' W/m 2 from the boundary surface at r = a and dissipated by convection from the boundary surface at r = b into a medium at zero temperature with a heat transfer coefficient 'h'.			
19	1KT16ME058	A stream pipe with internal and external diameters 18 cm and 21 cm is covered with two layers of insulation each 30 mm thick with thermal conductivities 0.18 W/m.K and 0.09 W/m.K. The difference in temperature between inside and outside surfaces is 250°C. Calculate the quantity of heat lost per meter length of the pipe if its thermal conductivity is 60 W/m.K. What is the percentage error if the calculation is carried out considering the pipe as a plane wall?	5	CO3	L3
20	1KT16ME060	A house in cold region consist of three layers, an outer brick work 15 cm thick, an inner wooden panel 1.2 cm thick, the intermediate layer is made of an insulating material 7 cm thick. The thermal conductivity of brick and wood are 0.7 W/mk and 0.18 W/mkrespectively. The inside and outside temperatures of the composite wall are 21°C and -15°C respectively. If the layer of insulation offers twice the thermal resistance of the brick wall,calculate,i) Heat loss per unit area of the wall. ii) Thermal conductivity of insulating material.	5	CO3	L3
21	1KT16ME061	Explain the three types of boundary conditions used in conduction heat transfer	5	CO4	L2
22	1KT16ME062	Define Heat Transfer?Explain Modes of Heat Heat Transfer With examples	5	CO4	L3
23	1KT16ME064	Define fin effectiveness. When the use of fins is not justified?	5	CO4	L3
24	1KT16ME065	A plane wall k = 45 W/m.K 10 cm thick, generated at a uniform rate of 8 x106 W/m3. The two sides of the wall are maintained at 180°C and i 20°C. Neglect end effects, calculate (I) Temperature distribution across the plate (ii) Position and magnitude of maximum temperature. (iii)The heat flow rate from each surface of the plate.	5	CO4	L3
25	1KT16ME066	A very long rod, 25 mm in diameter, has one end maintained at 100°C. The surface of the rod is exposed to ambient air at 25°C with convection coefficient of 10 W/m2.K. What are the heat losses from the rods, constructed of pure copper with K = 398 W/mK and stainless steel with K =14 W/m.K ? Also, estimate how long the rods must be to be consideredinfinite.	5	CO4	L2
26	1KT16ME068	Define critical thickness of insulation and explain its significance.	5	CO4	L3
27	1KT16ME071	Obtain an expression for temperature distribution and heat flow through a rectangular fin, when end of the fin is insulated.	5	CO4	L3
28	1KT16ME072	A steel rod (K = 30 W/mK) 1 ems diameter and 5 ems long with insulation end is to be used as a spine. It is exposed to the surrounding temperature of 65 °C and heat transfer co-efficientof 50 W/m2 K. The temperature of the base is 98° C. Determine (i) Fin efficiency (ii) Temperature at the end of spine (iii) Heat dissipation from spine.	5	CO4	L3
29	1KT16ME075	Obtain an expression for temperature distribution and heat flow through a fin of uniform cross section with the end insulated.	5	CO4	L3
30	1KT16ME446	The aluminum square fins (0.6mm x 0.6mm), 12mm long are	5	CO4	L3

		provided on the surface of a semi conductor electronic device to carry 2W of energy generated. The temperature at the surface of the device should not exceed 85 °C, when the surrounding is at 35°C. Given K = 200 W/ m K, h = 15W/m2 K. Determine the number of fins required to carry out the above duty. Neglect the heat loss from the end of the fin.			
31	1KT17ME402	What is physical significance of critical thickness of insulation? Derive an expression for critical thickness of insulation for a cylinder.	5	CO4	L2
32	1KT17ME405	Derive an expression for the temperature distribution for a pinfin, when the tip of the fin is insulated.	5	CO4	L3
33	1KT17ME407	Find the amount of heat transferred through an iron fin of thickness of 5 mm, height 50 mm and width 100 cm. Also determine the temperature difference at the tip of the fin assuming atmospheric temperature of 28°C and base temperature of fin = 108°C. Assume the following K = 50 W/mK, h = 10 W/m2K.	5	CO4	L3
34	1KT17ME410	Derive an expression for critical thickness of insulation for a sphere.	5	CO4	L3
35	1KT17ME419	Derive an expression for the temperature distribution for a short fin of uniform cross section without insulated tip starting from fundamental energy balance equation.	5	CO4	L3
36	1KT17ME422	Determine the amount of heat transferred through an iron fin of thickness 5mm, height 50 mm and width 100 cms. Also determine the temperature of the center of the fin end of the tip of fin. Assuming atmospheric temperature of 28°C. Take K = 50 W/m — K, h = 10 W/m2 — K, Base fin temperature = 108°C.	5	CO4	L3
37	1KT17ME424	Define critical thickness of insulation and explain its significance.	5	CO4	L3
38	1KT17ME427	Obtain an expression for temperature distribution and heat flow through a rectangular fin, when the end of the fin is insulated.	5	CO4	L3
39	1KT17ME430	Derive an expression for critical thickness of insulation for a cylinder. Discuss the design aspects for providing insulation scheme for cable wires and steam pipes.	5	CO3	L2
40		Find the amount of heat transferred through an iron fin of thickness of 5 mm, height 50 mm and width 100 cm. Also, determine the temperature difference '0' at the tip of fin assuming atmospheric temperature of 28°C and base temperature of fin to be 108°C. Take Kfin = 50 W/m-K, h = 10 W/m2-K.	5	CO3	L2
41		set of aluminum fins (K = 180 W/mK) that are to be fitted to a small air compressor. The device dissipates I KW by convecting to the surrounding air which is at 20°C. Each fin is 100 mm long, 30 mm high and 5 mm thick. The tip of each fin may be assumed to be adiabatic and a heat transfer coefficient of 15 W/m- K acts over the remaining surfaces. Estimate the number of fins required to ensure the base temperature does not exceed 120°C.	5	CO3	L2
42		What is critical thickness of insulation on a small diameter wire or pipe? Explain its physical significance and derive an expression for the same.	5	CO3	L2
43		Differentiate between effectiveness and efficiency of the fins.	5	CO4	L3
44		Derive an expression for temperature distribution for a fin film	5	CO4	L2

		with the tip insulated.			
45		A carbon steel (k = 54 W/ m2C) rod with a cross section of an equilateral triangle (each side 5 mm) is 80 mm long. It is attached to a plane wall which is maintained at a temperature of 400 °C. °The surrounding environment is at a 50 °C and unit surface conductance is 90 W/ m C. Compute the heat dissipated by the rod (assuming tip is insulated).	5	CO4	L3
46		A rod (K = 200 W/mK) 10 mm in diameter and 5 ems long has its one end maintained at 100°C. The surface of the rod is exposed to ambient air at 30°C with convective heat transfer co-efficient of 100 W/m2K. Assuming other end insulated, determine i) The temperature of the rod at 25 mm distance from the end at 100°C. ii) Heat dissipation rate from the surface of the rod and iii) Effectiveness.	5	CO4	L3
47		Derive an expression for the temperature distribution for a long pin of uniform cross section without insulated tip.	5	CO4	L3
48		Clearly define i) Fin efficiency and ii) Fin effectiveness	5	CO4	L2
49		Derive an expression for rate of heat transfer and temperature distribution for a plane wall with variable thermal conductivity	5	CO4	L2
50		Thin fins of brass whose K = 75 W/m.K are welded longitudinally on a 5 cm diameter brass cylinder which stands vertically and is surrounded by air at 20°C. The heat transfer coefficient from metal surface to the air is 17 W/m 2.K. If 16 uniformly spaced fins are used each 0.8 mm thick and extending 1.25 cm from the cylinder, what is the rate of heat transfer from the cylinder per meter length to the air when the cylinder surface is maintained at 150°C?	5	CO4	L2
51		Define fin efficiency and fin effectiveness with respect to a fin with insulated tip.	5	CO4	L2
52		What is the physical significance of critical thickness of insulation? Derive an expression for critical thickness of insulation for a sphere.	5	CO4	L2

D2. TEACHING PLAN - 2

Module – 3

Title:	Numerical Analysis of Heat Conduction and Thermal Radiation	Appr Time:	9 Hrs
a	***Course Outcomes***	**CO**	**Blooms**
-	At the end of the topic the student should be able to . . .	-	**Level**
1	Understand steady-state one and two dimension heat conduction	CO5	L2
2	Explain the principles of radiation heat transfer and understand the numerical formula for heat conduction problems.	CO6	L3
b	***Course Schedule***		
Class No	**Portion covered per hour**	**-**	**-**
1	Numerical Analysis of Heat Conduction: Introduction, one-dimensional steady conduction.	CO5	L2

2	two-dimensional steady and unsteady conduction, the difference equation, boundary conditions, solution methods,	CO5	L3
3	cylindrical coordinates and irregular boundaries.	CO5	L2
4	Thermal Radiation: Fundamental principles - Gray, White, Opaque, Transparent and Black bodies,	CO	L2
5	Spectral emissive power, Wien’s, Rayleigh-Jeans’	CO5	L2
6	Planck’s laws, Hemispherical Emissive Power, Stefan-Boltzmann law for the total emissive power of a black body	CO6	L2
7	Emissivity and Kirchhoff’s Laws,View factor	CO6	L2
8	Net radiation exchange in a two-body enclosure,	CO6	L2
9	Typical examples for these enclosures, Radiation Shield	CO6	L2
c	**Application Areas**	**-**	**-**
-	Students should be able employ / apply the Module learnings to . . .	-	-
1	2-D stduy state heat conduction equation is applyed in CFD analysis(Finite difference and finite element method)	CO5	L3
2	Solar flat plate collecor, water heating process (solar pond), photo voltaic cell.	CO6	L2
d	**Review Questions**	-	-
-	The attainment of the module learning assessed through following questions	-	-
1	State and prove the Kirchoff s law of radiation.	CO6	L3
2	Explain the following terms: 1.Black body and greay body. 2. Radiosity and irradiation	CO6	L2
3	The concentric spheres 20 cms and 30 cms in diameter are used to store liquid 02 (-153°C) in a room at 300 K. The space between the spheres is evacuated. The surfaces of the spheres are highly polished as E= 0.04 . Find the rate of evaporation of liquid air per hour.	CO5	L3
4	Explain i)Stefan Boatzman law ii) weins displacement law iii) Radiation shild iv) Radiosity v) Black body.	CO6	L2
5	Two large parallel plates having emissivity's of 0.3 and 0.6 are maintained at a temperature of 900°C and 250°C. A radiation shield having an emissivity of 0.05 on both sides is placed between the two plates. Calculate i) Heat transfer without shield. ii) Heat transfer with shield. iii) Percentage reduction in the heat transfer due to shield. iv) Temperature of the shield.	CO5	L3
6	For a Black body enclosed in a hemispherical space, show that e missive power of Black body is it times the Intensity of Radiation.	CO5	L2
7	Explain briefly the concept of a Blackbody.	CO5	L2
8	Explain briefly concept of black body with an example.	CO5	L2
9	Two parallel plates, each of 4 m2 area, are large compared to a gap of 5 mm separating them. One plate has a temperature of 800 K and surface emissivity of 0.6, while the other has a temperature of 300 K and a surface emissivity of 0.9. Find the net energy exchange by radiation between them. If a polished metal sheet of surface emissivity 0.1 on both sides is now located centrally between the two plates, what will be its steady state temperature? How the heat transfer would be altered? Neglect the convection and edge effects if any. Comment upon the significance of this exercise.	CO5	L3
10	Calculate the net radiant heat exchange per m2 area for two large parallel planes at temperatures of 427°C and 27°C respectively. Take E for hot and cold planes to be 0.9 and 0.6 respectively. If a polished aluminum shield is placed between them, find the percentage reduction in the heat transfer, given E for shield = 0.04.	CO5	L3

11	Sate and prove Wiens displacement law of radiation	CO5	L2
12	he temperature of a black surface 0.2m2 in area is 540°C. Calculate: i)The total rate of energy emission. ii) The intensity of normal radiation. iii) The wavelength of maximum monochromatic emissive power.	CO5	L3
13	Derive an expression for a radiation shape factor and show that it is a function of geometry only.	CO6	L3
14	Prove that emissive power of a black body in a hemispherical enclosure is it times the intensity of radiation.	CO6	L3
15	Calculate net heat radiated (exchange) per m2 for two large parallel plates maintained at 800°C and 300°C. The emissivities of two plates are 0.3 and 0.6 respectively.	CO6	L3
16	Derive the expression for instantaneous and total heat transfer in lumped system analysis.	CO5	L3

Module – 4

Title:	Forced Convection and Free convection	Appr Time:	9 Hrs
a	***Course Outcomes***	**CO**	**Blooms**
-	At the end of the topic the student should be able to . . .	-	**Level**
CO7	Interpret and compute forced heat transfer.		L2
CO8	Interpret and compute free convective heat transfer.		L3
b	***Course Schedule***		
Class No	**Portion covered per hour**	**-**	**-**
1	Boundary Layer Theory, Velocity and Thermal Boundary Layers	CO7	L2
2	Prandtl number, Governing Equations – Continuity	CO7	L3
3	Navier-Stokes and Energy equations, Boundary layer assumptions	CO7	L2
4	Integral and Analytical solutions to above equations	CO7	L3
5	Turbulent flow, Various empirical solutions,Forced convection flow over cylinders and spheres	CO8	L3
6	Internal flows –laminar and turbulent flow solutions, Forced Convection Cooling of Electronic Devices.	CO8	L2
7	Laminar and Turbulent flows, Vertical Plates	CO8	L2
8	Vertical Tubes and Horizontal Tubes	CO8	L3
9	Empirical solutions.	CO8	L3
c	**Application Areas**	**-**	**-**
-	Students should be able employ / apply the Module learnings to . . .	-	-
1	Forced convection systems applicable for extremely high temperatures for functions	CO7	L2
2	Establishing temperature distribution within building, determining heat loss calculations, ventilating and air-conditioning system.	CO8	L2

d	**Review Questions**	-	-
-	The attainment of the module learning assessed through following questions	-	-
1	What do you mean by hydrodynamic and thermal boundary layer? Explain with a neat sketch.	CO7	L2
2	Air at 40 0 C flows over a thin plate with a velocity of 3m/sec. the plate is 2m long and 1m wide. Estimate the boundary layer thickness at the trailing edge of the plate and the total drag force experienced by the plate	CO7	L3
3	A 6m long section of an 8cm diameter horizontal hot water pipe passes through a large room whose temperature is maintained is 20°C. If the outer surface temperature of the pipe is 70°C,determine the rate of heat loss from the pipe by natural convection. If the emissivity of the pipe is 1.0, determine the rate of heat loss by radiation. Also determine total heat loss and percentage of heat loss by natural convection. Properties of air at film temperature are: v =-617.50x10 m2/s, k = 0.02699W/m-K, Pr = 0.7241m, β = 1/318.	CO7	L2
4	Define velocity and thermal boundary layer. Explain its physical significance.	CO7	L2
5	In an effort to increase the removal of heat from a hot surface at 120°C, a cylindrical pin fin (k f = 237 W/m-K) with diameter of 5 mm is attached to the hot surface. Air at 20°C and 1 atmospheric pressure is flowing across the pin fin with a velocity of 10 m/s. Determine the maximum possible rate of heat transfer from the pin fin. Evaluate the properties at 70°C.	CO8	L3
6	Consider a 0.6 m x 0.6 m thin square plate in a room at 30°C. One side of the plates maintained at a temperature of 90°C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection. If the emissivity of the surface is 1.0, calculate the heat loss by radiation. Also calculate the percentage of heat loss by convection.	CO8	L3
8	Explain the physical significance of the following of dimensionless numbers: i) Reynolds number ii) Prandtl number iii) Nusselt number iv) Stanton number	CO8	L2
9	Explain the following : i)Velocity boundary layer ii) Thermal boundary layer.	CO8	L2
10	Using dimensional analysis derive an expression relating Nusselt number, Prandtl and Grashoff numbers for natural convection.	CO8	L2

E2. CIA EXAM – 2

a. Model Question Paper - 2

Crs Code:	17ME63	Sem:	VI	Marks:	40	Time:	75 minutes
Course:	HEAT TRANSFER						

-	-	**Note: Answer all questions, each carry equal marks. Module : 3, 4**	**Marks**	**CO**	**Level**
1	a	What do you mean by hydrodynamic and thermal boundary layer? Explain with a neat sketch.	7	7	L2
	b	Air at 40 0 C flows over a thin plate with a velocity of 3m/sec. the plate is 2m long and 1m wide. Estimate the boundary layer thickness at the trailing edge of the plate and the total drag force experienced by the plate	8	7	L3

2	a	A 6m long section of an 8cm diameter horizontal hot water pipe passes through a large room whose temperature is maintained is 20°C. If the outer surface temperature of the pipe is 70°C,determine the rate of heat loss from the pipe by natural convection. If the emissivity of the pipe is 1.0, determine the rate of heat loss by radiation. Also determine total heat loss and percentage of heat loss by natural convection. Properties of air at film temperature are: v =-617.50x10 m2/s, k = 0.02699W/m-K, Pr = 0.7241m, β = 1/318.	8	7	L3
	b	Define velocity and thermal boundary layer. Explain its physical significance.	7	7	L2
3	a	Explain the physical significance of the following of dimensionless numbers: i) Reynolds number ii) Prandtl number iii) Nusselt number iv) Stanton number	8	CO8	L2
	b	Consider a 0.6 m x 0.6 m thin square plate in a room at 30°C. One side of the plates maintained at a temperature of 90°C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection. If the emissivity of the surface is 1.0, calculate the heat loss by radiation. Also calculate the percentage of heat loss by convection.	7	CO8	L3
		OR			
4	a	Using dimensional analysis derive an expression relating Nusselt number, Prandtl and Grashoff numbers for natural convection.	7	8	L2
	b	In an effort to increase the removal of heat from a hot surface at 120°C, a cylindrical pin fin (k f = 237 W/m-K) with diameter of 5 mm is attached to the hot surface. Air at 20°C and 1 atmospheric pressure is flowing across the pin fin with a velocity of 10 m/s. Determine the maximum possible rate of heat transfer from the pin fin. Evaluate the properties at 70°C.	8	8	L3

b. Assignment – 2

Note: A distinct assignment to be assigned to each student.

Model Assignment Questions							
Crs Code:	17ME63	Sem:	VI	Marks:	5	Time:	90 – 120 minutes
Course:	HEAT TRANSFER				Module : 3, 4		
Note: Each student to answer 2-3 assignments. Each assignment carries equal mark.							

SNo	USN	Assignment Description	Marks	CO	Level
1	1KT16ME033	What do you mean by hydrodynamic and thermal boundary layer? Explain with a neat sketch.	5	CO7	L2
2	1KT16ME036	Air at 40 0 C flows over a thin plate with a velocity of 3m/sec. the plate is 2m long and 1m wide. Estimate the boundary layer thickness at the trailing edge of the plate and the total drag force experienced by the plate	5	CO7	L3
3	1KT16ME037	A 6m long section of an 8cm diameter horizontal hot water pipe passes through a large room whose temperature is maintained is 20°C. If the outer surface temperature of the pipe is 70°C,determine the rate of heat loss from the pipe by natural convection. If the emissivity of the pipe is 1.0, determine the rate of heat loss by radiation. Also determine total heat loss and percentage of heat loss by natural convection. Properties of air at film temperature are: v =-617.50x10 m2/s, k = 0.02699W/m-K,	5	CO7	L2

		Pr = 0.7241m, β = 1/318.			
4	1KT16ME039	Define velocity and thermal boundary layer. Explain its physical significance.	5	CO7	L2
5	1KT16ME040	In an effort to increase the removal of heat from a hot surface at 120°C, a cylindrical pin fin (k f = 237 W/m-K) with diameter of 5 mm is attached to the hot surface. Air at 20°C and 1 atmospheric pressure is flowing across the pin fin with a velocity of 10 m/s. Determine the maximum possible rate of heat transfer from the pin fin. Evaluate the properties at 70°C.	5	CO8	L3
6	1KT16ME041	Consider a 0.6 m x 0.6 m thin square plate in a room at 30°C. One side of the plates maintained at a temperature of 90°C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection. If the emissivity of the surface is 1.0, calculate the heat loss by radiation. Also calculate the percentage of heat loss by convection.	5	CO8	L3
7	1KT16ME042	Explain the physical significance of the following of dimensionless numbers: i) Reynolds number ii) Prandtl number iii) Nusselt number iv) Stanton number	5	CO8	L2
8	1KT16ME043	Explain the following : i)Velocity boundary layer ii) Thermal boundary layer.	5	CO8	L2
9	1KT16ME044	Using dimensional analysis derive an expression relating Nusselt number,Prandtl and Grashoff numbers for natural convection.	5	CO8	L2
10	1KT16ME045	The decorative plastic film on a copper sphere of 10-mm diameter is cured in an oven at 75°C. Upon removal from the oven, the sphere is subjected to an air stream at 1 atm and 23°C having a velocity of 10 m/s, estimate how long it will take to cool the sphere to 35°C.	5	CO8	L3
11	1KT16ME046	Engine oil at 60°C flows over a 5 m long flat plate whose temperature is 20°C with a velocity of 2 m/s. Determine the total drag force and the rate of heat transfer per unit width of the entire plate.	5	CO8	L3

D3. TEACHING PLAN - 3

Module – 5

Title:	Heat Exchangers and Heat Transfer with Phase Change	Appr Time:	12 Hrs
a	***Course Outcomes***	-	**Blooms**
-	The student should be able to:	-	**Level**
1	Analysing heat exchangers using LMTD and NTU methods.	CO9	L2
2	Understand the boiling and condensation	CO10	L3
b	***Course Schedule***	-	-
Class No	**Portion covered per hour**	-	-
1	Heat Exchangers: Definition, Classification, applications, LMTD method	CO9	L2
2	Effectiveness - NTU method, Analytical Methods	CO9	L3

3	Fouling Factors, Chart Solution Procedures for solving Heat Exchanger problems	CO9	L3
4	Correction Factor Charts and Effectiveness	CO9	L3
5	NTU Charts, compact heat exchangers	CO9	L3
6	Heat Transfer with Phase Change: Introduction to boiling,	CO10	L2
7	Pool boiling, Bubble Growth Mechanisms, Nucleate Pool Boiling	CO10	L2
8	Critical Heat Flux in Nucleate Pool Boiling, Pool Film Boiling,Critical Heat Flux,	CO10	L2
9	Heat Transfer beyond the Critical Point, film wise and drop wise Condensation, heat pipes,entrainment, wicking and boiling limitations.	CO10	L2
c	**Application Areas**	-	-
-	Students should be able employ / apply the Module learnings to . . .	-	-
1	LMTD and NTU methods for analysis of heat exchangers.	CO9	L3
2	Boiling and condensation knowledge is applicable to calculate critical heat flux, and condensation rate in heat transfer problems.	CO10	L2
d	**Review Questions**	-	-
-	The attainment of the module learning assessed through following questions	-	-
1	Derive an expression for LMTD of double pipe, parallel flow heat exchanger.	CO9	L3
2	8000kg/hr of air at 1000C is cooled by passing it through a single pass cross flow heat exchanger. To what temperature is the air cooled, if water entering at 150C flows through the tubes un mixed at the rate of 7500 kg/hr. Take U = 500 KJ/hr m2, A= 20m2, Cp of air – 1 kJ/kg 0C , Cp of water– 4.2 kJ/kg0C	CO9	L3
3	Obtain an expression for the effectiveness of a counter flow heat exchanger in terms of NTU and the capacity ratio	CO9	L3
4	A counter flow double pipe heat exchanger is to heat water from 20°C to 80°C at a rate of1.2kg/s. The heating is to be accomplished by geothermal water available at 170°C at a mass flow rateof2kg/s. The inner tube is thin walled and has a diameter of 1.5cm. If the overall heat transfer coefficient of the heat exchanger is640W/m²K, determine the length of the heat exchanger required to achieve the desired heating. Use εNTU method	CO9	L3
5	Draw the boiling curve of water at 1 atmospheric pressure and discuss the different regimes of boiling.	CO10	L2
6	What is heat pipe? Write the applications of heat pipe. With reference to heat pipe, explain entrainment and wicking.	CO10	L2
7	With the help of typical experimental boiling curve explain the different regimes of pool boiling	CO10	L2
8	Air free saturated steam at a temperature of 650C (p =25.03 kPa) condenses on a vertical outer surface of a 3m long vertical tube maintained at a uniform temperature of 350C. Assuming film condensation, calculate the average heat transfer coefficient over the entire length of the surface and the rate of condensate flow	CO9	L3
9	Obtain an expression for the effectiveness of a counter flow heat exchanger in terms of NTU and the capacity ratio	CO9	L2
10	Obtain an expression for the effectiveness of a parallel flow heat exchanger in terms of NTU and the capacity ratio	CO9	L2

E3. CIA EXAM – 3

a. Model Question Paper - 3

Crs	17ME63	Sem:	VI	Marks:	40	Time:	75 minutes

Code:							
Course:	HEAT TRANSFER						

-	-	Note: Answer any 2 questions, each carry equal marks.	Marks	CO	Level
1	a	Derive an expression for LMTD of double pipe, parallel flow heat exchanger.	7	9	L3
	b	8000kg/hr of air at 1000C is cooled by passing it through a single pass cross flow heat exchanger. To what temperature is the air cooled, if water entering at 150C flows through the tubes un mixed at the rate of 7500 kg/hr. Take U = 500 KJ/hr m2, A= 20m2, Cp of air – 1 kJ/kg 0C , Cp of water– 4.2 kJ/kg0C	8	9	L3
		OR			
2	a	Obtain an expression for the effectiveness of a counter flow heat exchanger in terms of NTU and the capacity ratio	7	9	L2
	b	A counter flow double pipe heat exchanger is to heat water from 20°C to 80°C at a rate of1.2kg/s. The heating is to be accomplished by geothermal water available at 170°C at a mass flow rateof2kg/s. The inner tube is thin walled and has a diameter of 1.5cm. If the overall heat transfer coefficient of the heat exchanger is640W/m²K, determine the length of the heat exchanger required to achieve the desired heating. Use εNTU method	8	9	L3
3	a	Draw the boiling curve of water at 1 atmospheric pressure and discuss the different regimes of boiling.	8	10	L2
	b	What is heat pipe? Write the applications of heat pipe. With reference to heat pipe, explain entrainment and wicking.	7	10	L2
		OR			
4	a	With the help of typical experimental boiling curve explain the different regimes of pool boiling	8	10	L2
	b	Air free saturated steam at a temperature of 650C (p =25.03 kPa) condenses on a vertical outer surface of a 3m long vertical tube maintained at a uniform temperature of 350C. Assuming film condensation, calculate the average heat transfer coefficient over the entire length of the surface and the rate of condensate flow	7	10	L3

b. Assignment – 3

Note: A distinct assignment to be assigned to each student.

Model Assignment Questions							
Crs Code:	17ME63	Sem:	VI	Marks:	5	Time:	90 – 120 minutes
Course:	HEAT TRANSFER				Module : 5		

Note: Each student to answer 2-3 assignments. Each assignment carries equal mark.

SNo	USN	Assignment Description	Marks	CO	Level
1	1KT16ME033	How do numerical solution methods differ from analytical ones? What are the advantages and disadvantages of numerical methods over analytical methods?	5	CO8	L2
2	1KT16ME036	For one dimensional unsteady state conduction equation without heat generation, obtain finite difference expression using FTCS method and discuss the stability criteria.	5	CO8	L2
3	1KT16ME037	Derive an expression for LMTD of double pipe, parallel flow heat exchanger.		CO8	L2
4	1KT16ME039	Draw the boiling curve of water at 1 atmospheric pressure and	5	CO8	L2

		discuss the different regimes of boiling.			
5	1KT16ME040	Obtain an expression for the effectiveness of a counter flow heat exchanger in terms of NTU and the capacity ratio	5	CO8	L2
6	1KT16ME041	What is heat pipe? Write the applications of heat pipe. With reference to heat pipe, explain entrainment and wicking.		CO10	L2
7	1KT16ME042	State and explain the Fick's law of diffusion.	5	CO10	L2
8	1KT16ME043	Distinguish between the nucleate boiling and film boiling.	5	CO10	L2
9	1KT16ME044	Engine oil is to be cooled from 80°C to 50°C by using a single pass counter flow concentric tube heat exchanger with cooling water available at 20°C. Water flows inside a tube with inner diameter of 2.5cm and at a rate of 0.08kg/sec and oil flows through the annulus at the rate of 0.16kg/sec, the heat transfer coefficient for the water side and oil side are respectively h_w=1000 W/m2 °C and h_{oil}=80 W/m^2 °C. the fouling factor is Fw=0.00018 m^2 °C/W on both the sides and the tube wall resistance is negligible. Calculate the tube length required.	5	CO10	L3
10	1KT16ME045	A counter flow heat exchanger is employed to cool 0.55 kg/sec (C_p=2.45 KJ/KgK) of oil from 115°C to 40°C by the use of water. The inlet and outlet temperature of the cooling water are 15°C and 75°C respectively. The overall heat transfer coefficient is expected to be 1450 W/m2 °C. Using NTU method, calculate the following: i) The mass flow rate of water ii) The effectiveness of heat exchanger iii) The surface area required	5	CO10	L3
11	1KT16ME046	The flow rate of hot and cold flux streams running through a parallel flow heat exchanger are 0.2 kg/s and 0.5kg/s respectively. The inlet temperatures on the hot and cold sides are 75°C and 20°C respectively. The exit temperature of hot water is 45°C. If the individual heat transfer coefficients on both sides are 650 W/m2 °C, Calculate the area of heat transfer.	5	CO10	L3
12	1KT16ME047	Water to water heat exchanger of counter flow heat exchanger has heating surface area 2m^2. Mass flow rate of hot and cold fluids are 2000 Kg/hr and 1500 Kg/hr respectively. Temperatures of hot and cold fluids at inlet are 85°C and 25°C respectively. Determine the amount of heat transferred from hot to cold water and their temperatures at the exit if the overall heat transfer coefficient U=1400 W/m^2K.	5	CO10	L3
13	1KT16ME048	A heat exchanger has an effectiveness of 0.5 when the flow is counter and the thermal capacity of one fluid is twice that of the other fluid. Calculate the effectiveness of the heat exchanger if the direction of one of the fluids is reversed with the same mass flow rate as before.	5	CO10	L3
14	1KT16ME049	A cross flow heat exchanger with both fluids unmixed is used to heat the water with engine oil. Water enters at 30°C and leaves at 85°C at a rate of 1.5 Kg/s, while the engine oil with C_p=2.3 KJ/KgK enters at 120°C with a mass flow rate of 3.5 Kg/s. The Heat transfer surface area is 30m^2. Calculate the overall heat transfer coefficient by using LMTD method.	5	CO10	L3
15	1KT16ME051	Oil at 100°C (C_p=3.6 KJ/KgK) flows at a rate of 30,000 Kg/hr and	5	CO10	L3

		enters a parallel flow heat exchanger. Cooling water (C_p=4.2 KJ/KgK) enter heat exchanger at 10°C at the rate of 50,000 Kg/hr. The heat transfer area is 10m^2 and U=1000 W/m^{2}k. Calculate the outlet temperature of oil and water.			
16	1KT16ME052	An oil cooler consists of straight tune of 2 cm outer diameter and 1.5 cm inner diameter with in a pipe and concentric with it. The external pipe is well insulated. The oil flows through the tube at 0.05kg/sec (C_p=2 KJ/Kg °C) and cooling fluid flows in the annulus in opposite direction at the rate of 0.1 Kg/sec (C_p=4 KJ/Kg °C). The oil enters the cooler at 180°C and leavers at 80°C while cooling liquid enters the cooler at 30°C.Calculate the length of the pipe required if the heat transfer coefficient from oil to tube surface is 1720 W/m2 °C and from metal surface to coolant is 3450 W/m^2 °C. Neglect the resistance of the tube wall. Determine i)The mass flow rate of water ii)The effectiveness of heat exchanger iii) The surface area required	5	CO10	L3

F. EXAM PREPARATION

1. University Model Question Paper

Course:	HEAT TRANSFER					Month / Year	May /2018
Crs Code:	17ME63	Sem:	VI	Marks:	80	Time:	180 minutes

Module	Note	Answer all FIVE full questions. All questions carry equal marks.	Marks	CO	Level
1	a	Derive 3dimensional unsteady state heat conduction equation with heat generation, in Cartesian coordinate system for an isotropic material.	8	CO1	L2
	b	A square plate heater 15cm x 15cm is inserted between two slabs. Slab A is 2cm thick (k = 50W/mK) and Slab B is 1cm thick (k = 0.2W/mK). The outside heat transfer coefficients on side A and side B are 200W/m²K and 50W/m²K respectively. The temperature of surrounding air is 25°C. If rating of heater is 1kW, find (a) Maximum temperature in the system, and (b) outer surface temperature of the two slabs.	8	CO1	L3
		OR			
1	a	Derive an expression for temperature distribution for 1dimensional slab with varying thermal conductivity. Assume the variation of thermal conductivity of slab as $k = k_0(1+\beta t)$.	8	CO2	L3
	b	A 3 mm diameter and 5m long electric wire is tightly wrapped with a 2 mm thick plastic cover whose thermal conductivity is k = 0.15 W/mK. Electrical measurements indicate that a current of 10 A passes through the wire and there is a voltage drop of 8 V along the wire. If the insulated wire is exposed to a medium at T_∞ = 30°C with a heat transfer coefficient of h = 12 W/m²K, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also state with reason, whether doubling the thickness of the plastic cover will increase or decrease heat transfer.	8	CO2	L3
2	a	Define critical thickness of insulation. Derive an expression for critical thickness of insulation of a cylinder.	8	C03	L3
	b	A turbine blade made of stainless steel (k = 29 W/m°C) is 60 mm long, 500 mm² cross sectional area and 120 mm perimeter. The temperature of the	8	CO3	L3

		root of the blade is 480°C and it is exposed to products of combustion passing through the turbine at 820°C. If the heat transfer coefficient between the blade and the combustion gases is 320 W/m²C, determine (i) The temperature at the middle of the blade; (ii) the rate of heat flow from the blade. Assume the blade as short fin which is uninsulated.			
		OR			
2	a	In a quench hardening process, steel rods (ρ = 7832kg/m³, Cp= 434 J/kgK, and k = 63.9 W/mK) are heated in a furnace to 850°C and then cooled in a water bath to an average temperature of 95°C. The water bath has a uniform temperature of 40°C and convection heat transfer coefficient of 450 W/m²K. If the steel rods have a diameter of 50 mm and a length of 2 m, determine (a) the time required to cool a steel rod from 850°C to 95°C in the water bath, considering only lateral surface area, and lateral surface area and crosssectional area of the steel rod, and (b) the total amount of heat transferred to water during the quenching of a single rod.	8	CO4	L3
	b	What are Heisler and Grober charts? Explain their significance in solving transient convection problems.	8	CO4	L2
3	a	How do numerical solution methods differ from analytical ones? What are the advantages and disadvantages of numerical methods over analytical methods?	8	CO5	L2
	b	For one dimensional unsteady state conduction equation without heat generation, obtain finite difference expression using FTCS method and discuss the stability criteria.	8	CO5	L3
		OR			
3	a	State and explain: (i) Planck's law, (ii) Kirchoff's law, (iii) Wein's displacement law.	8	CO6	L2
	b	Calculate the net radiant heat exchange per m²area for two large parallel plates at temperature of 427°C and 27°C respectively. Emissivity for hot plate is 0.9 and for cold plate is 0.6. If polished Aluminum shield is placed between them, find the percentage reduction in the heat transfer. Assume emissivity for shield as 0.4.	8	CO6	L3
4	a	Define velocity and thermal boundary layer. Explain its physical significance.	8	CO7	L2
	b	In an effort to increase the removal of heat from ahot surface at 120°C, a cylindrical pin fin (kf= 237 W/mK) with diameter of 5 mm is attached to the hot surface. Air at 20°C and 1 atmospheric pressure is flowing across the pin fin with a velocity of 10 m/s. Determine the maximum possible rate of heat transfer from the pin fin. Evaluate the properties at 70°C.	8	CO7	L3
		OR			
4	a	Hot air at atmospheric pressure and 80°C enters an 8 m long uninsulated square duct of cross section 0.2 m x 0.2 m that passes through the attic of a house at a rate of 0.15m³/s. The duct is observed to be nearly isothermal at 60°C. Determine the exit temperature of the air.	8	CO8	L3
	b	Consider a 0.6 m x 0.6 m thin square plate in a room at 30°C. One side of the plate is maintained at a temperature of 90°C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection. If the emissivity of the surface is 1.0, calculate the heat loss by	8	CO8	L3

		radiation. Also calculate the percentage of heat loss by convection.			
5	a	Derive an expression for LMTD of double pipe, parallel flow heat exchanger.	8	CO9	L3
	b	A counter flow double pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2kg/s. The heating is to be accomplished by geothermal water available at 170°C at a mass flow rate of 2kg/s. The inner tube is thin walled and has a diameter of 1.5cm. If the overall heat transfer coefficient of the heat exchanger is 640W/m²K, determine the length of the heat exchanger required to achieve the desired heating. Use εNTU method.	8	CO9	L3
		OR			
5	a	Draw the boiling curve of water at 1 atmospheric pressure and discuss the different regimes of boiling.	8	CO10	L2
	b	What is heat pipe? Write the applications of heat pipe. With reference to heat pipe, explain entrainment and wicking.	8	CO10	L2

2. SEE Important Questions

Course:	HEAT TRANSFER					Month / Year		May /2018
Crs Code:	17ME63	Sem:	VI	Marks:	80	Time:		180 minutes

	Note	Answer all FIVE full questions. All questions carry equal marks.	-	-	
Module	Qno.	Important Question	**Marks**	**CO**	**Year**
1	1	Derive 3dimensional unsteady state heat conduction equation with heat generation, in Cartesian coordinate system for an isotropic material.	8	CO1	2017
	2	A square plate heater 15cm x 15cm is inserted between two slabs. Slab A is 2cm thick (k = 50W/mK) and Slab B is 1cm thick (k = 0.2W/mK). The outside heat transfer coefficients on side A and side B are 200W/m²K and 50W/m²K respectively. The temperature of surrounding air is 25°C. If rating of heater is 1kW, find (a) Maximum temperature in the system, and (b) outer surface temperature of the two slabs.	8	CO1	2016
	3	Derive an expression for general three dimensional heat conduction equation for general three dimensional heat conduction equation in cylindrical coordinate.	8	CO2	2014
	4	A composite cylindrical wall is composed of two materials of thermal conductivity KAand KB. A thin electric resistance heater for which interfacial contact resistances are negligible separates the two materials. Liquid pumped through the inner tube is at temperature Ti with the inside surface heat transfer coefficient hi. The outer surface of the composite wall is exposed to an ambient at a uniform temperature To with a surface heat transfer coefficient ho. Under steady state conditions a uniform heat flux of qh is dissipated by the heater. I.Sketch the equivalent thermal circuit for the composite wall and express all thermal resistances in terms of the relevant variables. II.Obtain an expression that may be used to determine the temperature of the heater	8	CO2	2013
2	1	Derive an expression for temperature distribution for 1dimensional slab with varying thermal conductivity. Assume the variation of thermal conductivity of slab as $k = k_o(1+\beta t)$.	8	C03	2013

	2	A 3 mm diameter and 5m long electric wire is tightly wrapped with a 2 mm thick plastic cover whose thermal conductivity is k = 0.15 W/mK. Electrical measurements indicate that a current of 10 A passes through the wire and there is a voltage drop of 8 V along the wire. If the insulated wire is exposed to a medium at T_∞ = 30°C with a heat transfer coefficient of h = 12 W/m²K, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also state with reason, whether doubling the thickness of the plastic cover will increase or decrease heat transfer.	8	CO3	2015
	3	Define critical thickness of insulation. Derive an expression for critical thickness of insulation of a cylinder.	8	CO4	2014
	4	A turbine blade made of stainless steel (k = 29 W/m°C) is 60 mm long, 500 mm² cross sectional area and 120 mm perimeter. The temperature of the root of the blade is 480°C and it is exposed to products of combustion passing through the turbine at 820°C. If the heat transfer coefficient between the blade and the combustion gases is 320 W/m²C, determine (i) The temperature at the middle of the blade; (ii) the rate of heat flow from the blade. Assume the blade as short fin which is uninsulated.	8	CO5	2016
	5	Define critical thickness of insulation. A 3mm diameter and 5m long electric wire is tightly wrapped with a 2mm thick plastic cover whose thermal conductivity is k = 0.15W/m-K. Electrical measurements indicate that current of 10A passes through the wire and there is a voltage drop of 8V along the wire. If the insulated wire is exposed to a medium at T_∞ = 30°C with a heat transfer coefficient of h = 12W/m²-K, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also determine whether doubling the thickness of the cover will increase or decrease this	10	CO5	2015
3	1	For one dimensional steady state heat conduction problem obtain the finite difference formulation when one end is subjected to prescribed temperature and the other end is subjected constant heat flux.	8	CO7	2017
	2	Define the following: 1)Black body and opaque body 2)Stefan Boltzman Law 3) Wein's displacement law 4) Plank's Law	8	CO6	2016
	3	Calculate the net radiant heat exchange per unit area for two parallel plates at temperatures of 4270C and 270C respectively. ε(hot plate) is 0.9 and ε(cold plate) is 0.6. A polished aluminum shield is placed between them, find the percentage reduction in heat transfer. ε(Shield) is 0.4	8	CO6	2014
	4	State and explain:(i)Planck's law, (ii)Kirchoff's law, (iii)Wein's displacement law	8	CO7	2014
4	1	Define velocity and thermal boundary layer. Explain its physical significance.	10	CO7	2017
	2	In an effort to increase the removal of heat from ahot surface at 120°C, a cylindrical pin fin (kf= 237 W/mK) with diameter of 5 mm is attached to the hot surface. Air at 20°C and 1 atmospheric pressure is flowing across the pin fin with a velocity of 10 m/s. Determine the maximum possible rate of heat transfer from the pin fin. Evaluate the properties at 70°C.	8	CO8	2013
	3	Hot air at atmospheric pressure and 80°C enters an 8 m long uninsulated square duct of cross section 0.2 m x 0.2 m that passes through the attic of a house at a rate of 0.15m³/s. The duct is observed to be nearly isothermal at 60°C. Determine the exit temperature of the air.	8	C08	2015
5	1	Derive an expression for LMTD of double pipe, parallel flow heat exchanger.	10	CO9	2017

	2	Draw the boiling curve of water at 1 atmospheric pressure and discuss the different regimes of boiling.	8	CO10	2015
	3	Air free saturated steam at a temperature of 650C (p =25.03 kPa) condenses on a vertical outer surface of a 3m long vertical tube m maintained at a uniform temperature of 350C. Assuming film condensation, calculate the average heat transfer coefficient over the entire length of the surface and the rate of condensate flow.	6	CO9	2014
	4	With the help of typical experimental boiling curve explain the different regimes of pool boiling	8	CO10	2016

G. Content to Course Outcomes

1. TLPA Parameters

Table 1: TLPA – Example Course

Module-#	Course Content or Syllabus (Split module content into 2 parts which have similar concepts)	Content Teaching Hours	Blooms' Learning Levels for Content	Final Blooms' Level	Identified Action Verbs for Learning	Instruction Methods for Learning	Assessment Methods to Measure Learning
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1	Introductory concepts and definitions: Modes of heat transfer: Basic laws governing conduction, convection, and radiation heat transfer; Thermal conductivity; convective heat transfer coefficient; radiation heat transfer combined heat transfer mechanism, Types of boundary conditions	4	L1,L2	L2	Understand	Chalk and board	Assignment
1	General Heat Conduction Equation: Derivation of the equation in (i) Cartesian, (ii) Polar and (iii) Spherical Co-ordinate Systems. Steady-state one-dimensional heat conduction problems in Cartesian System: Steady-state one-dimensional heat conduction problems (i) with and without heat generation and (ii) with and without varying thermal conductivity - in Cartesian system with various possible boundary conditions, Thermal Resistances in Series and in Parallel.	8	L1,L2,L3	L3	Analyse	Chalk and board	Assignment
2	Critical Thickness of Insulation: Concept, Derivation, Extended Surfaces or Fins: Classification, Straight Rectangular and Circular Fins, Temperature Distribution and Heat Transfer Calculations, Fin Efficiency and Ef-	4	L1,L2,L3	L3	Analyse	Chalk and board	Assignment and Slip Test

	fectiveness, Applications						
2	Transient [Unsteady-state] heat conduction: Definition, Different cases - Negligible internal thermal resistance, negligible surface resistance, comparable internal thermal and surface resistance, Lumped body, Infinite Body and Semi-infinite Body, Numerical Problems, Heisler and Grober charts.	5	L1,L2,L3	L3	Analyse	Chalk and board	Assignment
3	Numerical Analysis of Heat Conduction: Introduction, one-dimensional steady conduction, one dimensional unsteady conduction, two-dimensional steady and unsteady conduction, the difference equation, boundary conditions, solution methods, cylindrical coordinates and irregular boundaries.	4	L1,L2,L3	L3	Analyse	Chalk and board	Assignment and slip test
3	Thermal Radiation: Fundamental principles - Gray, White, Opaque, Transparent and Black bodies, Spectral emissive power, Wien's, Rayleigh-Jeans' and Planck's laws, Hemispherical Emissive Power, Stefan-Boltzmann law for the total emissive power of a black body, Emissivity and Kirchhoff's Laws,View factor, Net radiation exchange in a two-body enclosure, Typical examples for these enclosures, Radiation Shield	5	L1,L2	L2	Understand	Chalk and board	Assignment
4	Forced Convection: Boundary Layer Theory, Velocity and Thermal Boundary Layers, Prandtl number, Governing Equations – Continuity, Navier-Stokes and Energy equations, Boundary layer assumptions, Integral and Analytical solutions to above equations, Turbulent flow, Various empirical solutions,Forced convection flow over cylinders and spheres, Internal flows –laminar and turbulent flow solutions, Forced Convection Cooling of Electronic Devices.	4	L1,L2,L3	L3	Analyse	Chalk and board	Assignment
4	Free convection: Laminar and Turbulent flows, Vertical Plates, Vertical Tubes and Horizontal Tubes, Empirical solutions.	4	L1,L2,L3	L3	Analyse	Chalk and board	Assignment
5	Heat Exchangers: Definition, Classification, applications, LMTD method, Effectiveness - NTU method, Analytical Methods, Fouling Factors, Chart Solution Procedures for solving Heat Exchanger problems: Correction Factor Charts and Effectiveness-NTU Charts, compact heat exchangers.	6	L1,L2,L3	L3	Analyse	Chalk and board	Assignment
5	Heat Transfer with Phase Change: Introduction to boiling, pool boiling, Bubble Growth Mechanisms, Nucleate Pool Boiling, Critical Heat Flux in Nucleate Pool Boiling, Pool Film Boiling, Critical Heat Flux, Heat Transfer beyond the Criti-	6	L1,L2,L3	L3	Analyse	Chalk and board	Assignment

	cal Point, filmwise and dropwise Condensation, heat pipes, entertainment, wicking and boiling limitations.						

2. Concepts and Outcomes:

Table 2: Concept to Outcome – Example Course

Module-#	Learning or Outcome from study of the Content or Syllabus	Identified Concepts from Content	Final Concept	Concept Justification (What all Learning Happened from the study of Content / Syllabus. A short word for learning or outcome)	CO Components (1.Action Verb, 2.Knowledge, 3.Condition / Methodology, 4.Benchmark)	Course Outcome **Student Should be able to ...**
A	*I*	*J*	*K*	*L*	*M*	*N*
1	- -	- -	Heat interactions	Mechanism of Heat transfer	- Understand - Mechanism of Heat transfer - -	Understand the basic modes of heat transfer.
1	- -	- -	Conduction	Examine the problems for heat conduction equation	- Analyze - Heat conduction - -	Understand Steady-state one-dimensional heat conduction.
2	- -	- -	Energy dissipation	Analysing the energy dissipation for a different types of fins	- Analyze - Critical thickness - Extended Surface of fins	Understand the percentage increase in heat dissipation of critical thickness of insulation.
2	- -	- -	Temperature variation	Understand the transient heat conduction problems	- Understand - Unsteady state -	Compute temperature distribution in unsteady-state heat conduction.
3	- -	- -	Heat interactions	Analysing the heat interactions for different problems.	- Understand - Conduction - -	Understand steady-state one and two dimension heat conduction
3	- -	- -	Energy emission	Analysing the numerical analysis for energy equation	- Apply - Radiation - -	Explain the principles of radiation heat transfer and understand the numerical formula for heat conduction problems.
4	- -	- -	Boundary Layer	Understanding Boundary layer concepts for different flow	- Apply - Forced convection - -	Interpret and compute forced heat transfer.
4	-	-	Energy	Understanding the	- Analyze	Interpret and

	-	-	Transfer	different energy transfer by radiation	-Free convection	compute free convective heat transfer.
5	- -	- -	Exchange of heat	Understanding different exchange of heat with different methods	- Understand - Heat Exchanger	Design heat exchangers using LMTD and NTU methods.
5			Phase change	Understanding the Phase change analysis in Boiling and condensation	- Understand - Boiling and condensation	Understand the boiling and condensation.