SREENIVASA INSTITUTE OF TECHNOLOGY AND MANAGEMENT STUDIES (AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTION BANK

Year / Semester: **III B.Tech VI Semester** **Regulation: R23**

Subject and Code: **HEAT AND MASS TRANSFER & 23MEC363T**

SYLLABUS

UNIT I: Introduction

Basic modes of heat transfer- rate equations- generalized heat conduction equation-various forms - steady state heat conduction solution for plane and composite slabs - cylinders - critical thickness of insulation- heat conduction through fins of uniform cross section- fin effectiveness and efficiency.

Unsteady State Heat Transfer Conduction- Transient heat conduction- lumped system analysis and use of Heisler charts.

UNIT II: Convection

Convection: Basic concepts of convection–heat transfer coefficients-types of convection– forced convection and free convection.

Free Convection: development of hydro dynamic and thermal boundary layer along a vertical plate – use of empirical relations for convective heat transfer on plates and cylinders in horizontal and vertical orientation

Forced convection: In external flow–concepts of hydro dynamic and thermal boundary layer- use of empirical correlations for flow over plates and cylinders. Fluid friction – heat transfer analogy, approximate solution to laminar boundary layer equation for external flow. Internal flow – Use of empirical relations for convective heat transfer in horizontal pipe flow- problems.

UNIT III Boiling and Condensation

Different regimes of boiling-nucleate, transition and film boiling–condensation–filmwise and drop wise condensation-problems.

UNIT IV Heat Exchangers

Types of heat exchangers- parallel flow- counter flow- cross flow heat exchangers- overall heat transfer coefficient- LMTD and NTU methods- fouling in heat exchangers-problems.

UNIT V Radiation and Mass Transfer

Radiation: Radiation heat transfer – thermal radiation – laws of radiation - Black and Gray bodies – shape factor-radiation exchange between surfaces - Radiation shields - Greenhouse effect- simple problems,

Mass Transfer: Conservation laws and constitutive equations - Fick's law of diffusion, isothermal equi-mass - Equimolal diffusion- - diffusion of gases and liquids- mass transfer coefficient.

Text books:

1. P.K.Nag, Heat Transfer, 3/e, Tata McGraw-Hill, 2011.
2. J.P.Holman, Heat Transfer, 9/e, Tata McGraw-Hill, 2008.
3. R.C.Sachdeva, Fundamentals of Engineering Heat & Mass transfer, New Age International Publishers, 2017.

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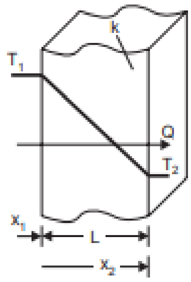
Max Marks: 10

S.No.	CO	Questions	BT
		Unit I: (CONDUCTION)	
1	**1**	Derive the Cartesian co-ordinates of general heat conduction equation.	**L2**
2	**1**	What is the critical thickness of insulation on a small diameter wire or pipe? Explain its physical significance and derive an expression for the same.	**L2**
3	**1**	Determine the heat flow across a plane wall of 10 cm thickness with a constant thermal conductivity of 8.5 W/mK when the surface temperatures are steady at 100°C and 30°C. The wall area is 3m^2. Also find the temperature gradient in the flow direction. 	**L4**
4	**1**	A composite wall is made of a 2.5 cm copper plate (k = 355W / m K), a 3.2 mm layer of asbestos (k = 0.11W / m K) and a 5 cm layer of fiber plate (k = 0.049W / m K). The wall is subjected to an overall temperature difference of 5600 C on the Cu plate side and 0^{0}C on the fiber plate side. Estimate the heat flux through this composite wall and interface temperature between asbestos and fiber plate.	**L4**
5	**1**	A furnace wall is made up of three layers, one is fire brick, one is insulating layer and one is red brick. The inner and outer surfaces temperature are at 870°C and 40°C respectively. The respective conductive heat transfer coefficients of the layers are 1.163, 0.14 and 0.872 W/m°C and the thicknesses are 22 cm, 7.5 cm and 11 cm. Find the rate of heat loss per sq. meter and the interface temperatures.	**L4**
6	**1**	A steel tube of 5.08 cm ID and 7.62 cm OD is cover with 2.5 cm thick of asbestos, k_{steel} = 43.26 W/m°K; $k_{asbestos}$ = 0.208 W/m°C. The inside surface receives heat from hot gases at 316°C with heat transfer coefficient 284 W/m²C whereas outer surface is exposed to air at 38°C with heat transfer coefficient of 17 W/m²C. Determine the heat loss for 3m length of tube.	**L4**

7	**1**	A steel tube of 5 cm ID, 7.6 cm OD and k=15 W/mK is covered with an insulation of thickness 2 cm and thermal conductivity 0.2 W/mK. A hot gas 330^0Cand h = 400 W/m².K flows inside the tube. The outer surface of the insulation is exposed to cold air at 30°C with h = 60 W/m².K. Assuming a tube length of 10 m, find the heat loss from the tube to the air. Also find, across which layer the largest temperature drop occurs.	**L4**
8	**1**	A 40 x 40 cm copper slab 5 mm thick at a uniform temperature of 250°C suddenly has its surface temperature lowered at 30°C. Find the time at which the slab temperature becomes 90°C. ρ = 9000 kg /m^3, c = 0.38 kJ/kgK, k = 370 W/mK and h = 90 W/m^2K.	**L4**
9	**1**	A stainless steel rod of outer diameter 1 cm originally at a temperature of 320°C is suddenly immersed in a liquid at 120°C for which the convective heat transfer coefficient is 100 W/m²K. Determine the time required for the rod to reach temperature of 200°C.	**L4**
10	**1**	An aluminium sphere weighing 5.5 kg and initially at a temperature of 290°C is suddenly immersed in a fluid at 15°C. The convective heat transfer coefficient is 58 W/m²K. Estimate the time required to cool the aluminium to 95°C, using the lumped capacity method of analysis.	**L4**

S.No.	CO	Questions	BT
		Unit II: (*CONVECTION*)	
1	**2**	Define Reynolds, Nusselt, Prandtl and Stanton numbers. Explain their importance in convective heat transfer.	L2
2	**2**	Write the momentum equation for laminar boundary layer on a plate. List the assumptions made in deriving this equation.	L4
3	**2**	An immersion water heater of surface area 0.1 m^2 and rating 1 KW is designed to operate fully submerged in water. Estimate the surface temperature of the heater when the water is at 40^0C and the heat transfer coefficient is 300 W/m^2K. If this heater is by mistake used in air at 40^0C with h= 9 W/m^2K, what will be its surface temperature?	**L4**
4	**2**	A person stands in front of a fire at 65°C in a room where air is at 5°C. Assuming the body temperature to be 37°C and a connection coefficient of 6 W/m^2k, the area exposed to convection as 0.6m^2, determine the net heat flow from the body. The fraction of radiation from the fire of 1m^2 are reaching the person is 0.01.	L4

5	**2**	A horizontal plate 1 m x 0.8 m is kept in a water tank with the top surface at 60^0C providing heat to warm stagnant water at 20^0C. Determine the value of convection coefficient.	L4
6	**2**	Consider a 0.6m ×0.6m thin square plate in a room at 30^0C. One side of the plate is maintained at a temperature of 90^0C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection if the plate is vertical.	L4
7	**2**	Consider a 0.6m ×0.6m thin square plate in a room at 30^0C. One side of the plate is maintained at a temperature of 90^0C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection if the plate is horizontal with (a) hot surface facing up, and (b) horizontal with hot surface facing down.	L4
8	**2**	A flat plate 1.0 m wide and 1.0 m long is placed in a wind tunnel. The temperature and velocity of free stream air are 10°C and 80 m/s respectively. The flow over the whole length of the plate is made turbulent with the help of a turbulizing grid placed upstream of the plate. Determine the thickness of the boundary layer at the trailing edge of the plate. Also calculate the mean value of the heat transfer coefficient from the surface of the plate.	L4
9	**2**	Assuming that a man can be represented by a cylinder 30 cm in diameter and 1.7 m high with a surface temperature of 30°C, calculate the heat he would lose while standing in a 36 km/hr wind at 10°C.	**L4**
10	**2**	Air stream at 27°C is moving at 0.3 m/s across a 100 W electric bulb at 127°C. If the bulb is approximated by a 60 mm diameter sphere, estimate the heat transfer rate and the percentage of power lost due to convection.	**L4**

S.No.	CO	Questions	BT
		Unit III: (*BOILING and CONDENSATION*)	
1	**3**	Define boiling and explain different regimes of boiling with the help of boiling curve.	L2
2	**3**	Water at atmospheric pressure (saturation temperature = 100°C) is boiling on a brass surface heated from below. If the surface is at 108°C, determine the heat flux and compare the same with critical heat flux.	L4

3	**3**	A vertical tube of 50mm outside diameter and 2m long is exposed to steam at atmospheric pressure. The outer surface of the tube is maintained at the temperature of 84ºC by circulating cold water through the tube. Determine the rate of heat transfer.	L4
4	**3**	Define Condensation and explain its types also comparison between filmwise and dropwise condensation.	L4
5	**3**	Saturated steam at 65°C condenses on horizontal cylinder of 0.2 m diameter at 55°C. Determine the value of convection coefficient for (i) single tube and (ii) for a bank of tubes of 10 rows arranged vertically one below the other.	L4
6	**3**	Steam at 65°C condenses on vertical tubes of diameter of 0.3m in 55°C. Determine then location at which the film will become turbulent.	L4
7	**3**	A 10 by 10 array of horizontal tubes of 1.27 cm diameter is exposed to pure steam at atmospheric pressure. If the tube wall temperature is 98°C, Estimate the mass of steam condensed assuming a tube length of 1.5 m.	L4
8	**3**	A shell-and-tube condenser is used to condense steam at a saturation pressure corresponding to a temperature (T_{sat}) of 50^0C. Cooling water enters at 20^0C and leaves at 35^0C. The total heat load (Q) is 1 MW (10^6W). The overall heat transfer coefficient (U) is 2500W/m^2. Calculate the required heat transfer surface area (A).	L4
9	**3**	A steam condenser condenses 2kg/s of dry saturated steam at 0.1 bar (T_{sat}=45.8^{0}C). Cooling water enters the tubes at 20^0C and leaves at 30^0C. The overall heat transfer coefficient (U) is 2000 W/m^{2}K. Calculate the required heat transfer surface area (A). Assume latent heat of vaporization (h_{fg}) at 0.1 bar = 2392kJ/kg.	L4
10	**3**	Saturated steam at 100°C condenses on a vertical plate of height 0.5 m. Plate temperature = 80°C. Properties of water film at mean temperature: k=0.68 W/mK, ρ=958 kg/m^3, μ=0.00028 kg/m-s, h_{fg}=2257×10^3 J/kgh and Width of plate = 1 m. Find: Average heat transfer coefficient and heat transfer rate.	L4

S.No.	CO	Questions	BT
		Unit IV: (*HEAT EXCHANGERS*)	
1	**4**	How the Heat exchangers classified? Explain neatly.	L2

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2	**4**	In an evaporator of a refrigerator, the refrigerant at -20°C, over the tubes. Water flowing inside the tubes enter at 15°C and is cooled capacity is 5kW. Determine the cooling rate if the water flow is increased by 25% keeping the inlet temperature to be the same.	**L4**
3	**4**	Determine the area required in parallel flow heat exchanger to cool oil from 60°C to 30°C using water available at 20°C. The outlet temperature of the water is 26°C. The rate of flow of oil is 10 kg/s. The specific heat of the oil is 2200 J/kg K. The overall heat transfer coefficient U = 300 W/m^2 K.	**L4**
4	**4**	A cross flow heat exchanger with both fluids unmixed is used to heat water flowing at rate of 20kg/s from 25°C to 75°C using gases available at 300°C to be cooled to 180°C. The overall heat transfer coefficient has a value of 95 W/m^2 K. Determine the area required. For gas C_p =1005 J/kg.k.	**L4**
5	**4**	A counter flow double pipe heat exchanger using superheated steam is used to hot water at the rate of 10500 kg/h. The steam enters the heat exchanger at 180°C and leaves at 130°C. The inlet and exit temperature of water are 30°C and 80°C respectively. If overall heat transfer from steam to water is 814W/m°C. Calculate the heat transfer area. What would be the increase in area if the fluid flows were parallel?	L4
6	**4**	Oil (Cp=3.6kJ/Kg°C) at 100°C flows at the rate of 3000Kg/h and enters into a parallel flow heat exchanger. Cooling water (Cp=4.2kJ/Kg°C) enters the heat exchanger at 10°C at the rate of 50000Kg/h. The heat transfer area is 10m^2 and U=1000W/m^{2}°C calculate the following (i) The outlet temperature of oil, and water (ii) The maximum possible outlet temperature of water.	L4
7	**4**	A concentric tube heat exchanger (parallel flow) is used to cool oil (Cp=2200 J/kg.K) from 100^0C to 60^0C using water (Cp=4180 J/kg.K) entering at 20^0C and leaving at 40^0C. The oil flow rate is 2 kg/s. If the overall heat transfer coefficient (U) is 300 W/m^2.K, calculate the surface area required.	L4
8	**4**	The overall temperature rise of the cold fluid in a cross-flow heat exchanger is 20^0C and overall temperature drop of hot-fluid is 30^0C. The effectiveness of heat exchanger is 0.6. The heat exchanger area is 1m^2 and overall heat transfer coefficient is 60W /m^2 C. Find out the rate of heat transfer. Assume both fluids are unmixed.	L4

9	**4**	A vertical cooling tube of 1 m height and 50 mm diameter, maintained at a constant surface temperature of 70^0C, is exposed to saturated steam at 1 atm (T_{sat}=100^0C). Calculate the condensation rate per tube assuming filmwise condensation.	L4
10	**4**	Two fluids, A and B exchange heat in a counter-current heat exchanger. Fluid A enters at 420^0C and has a mass flow rate of 1 kg/s. Fluid B enters at 20°C and has a mass flow rate of 1 kg/s. Effectiveness of heat exchanger is 75%. Determine: (i) The heat transfer rate; (ii) The exit temperature of fluid B. Specific heat of fluid A is 1 kJ/kg K and that of fluid B is 4 kJ/kg K.	L4

S.No.	**CO**	**Questions**	**BT**
		Unit V: (*RADIATION and MASS TRANSFER*)	
1	**5**	Emissivities of two large parallel plates maintained at 800ºC and 300ºC are 0.3 and 0.5 respectively. Find the net radiation heat exchange per square meter for this plate. Find the percentage reduction in heat transfer when a polished aluminum radiation shield (ε=0.05) is placed between them. Also find the temperature of shield.	**L4**
2	**5**	Two large parallel plates of 1mx1m spaced 0.5m apart in a very large room whose walls are at 27°C. The plates are at 900°C and 400°C with emissivities 0.2 and 0.5 respectively. Find the net heat transfer to each plate and to the room.	L4
3	**5**	Derive the radiation exchange between: (i) Large parallel gray surfaces and (ii) Small gray bodies.	L4
4	**5**	A pipe carrying steam having an outside diameter of 20cm runs in a large room, and is exposed to air at a temperature of 30ºC. The pipe surface temperature is 200ºC. Find the heat loss per meter length of the pipe by convection and radiation taking the emissivity of the pipe surface as 0.8.	L4
5	**5**	Dry air at 27ºC and 1 atm. flows over a wet flat plate 50cm long at a velocity of 50m/s. Calculate the mass transfer coefficient of water vapor in air at the end of the plate.	L4
6	**5**	How does mass transfer differ from bulk fluid motion? State Fick's law of diffusion.	L2

7	**5**	Explain the Ficks first and second laws of diffusion and when it is applicable?	L2
8	**5**	A mixture of O_2 and N_2 with their partial pressures in the ratio 0.21 to 0.79 is in a container at 25°C. Calculate the molar concentration, the mass density, and the mole fraction of each species for a total pressure of 1 bar. What would be the average molecular weight of the mixture?	L4
9	**5**	The dry bulb and wet bulb temperature recorded by a thermometer in moist air are 27°C and 17°C respectively. Determine the specific humidity of air assuming the following values: Prandtl Number=0.74, Schmidt Number = 0.6, Specific heat at constant pressure=1.004 kJ/KgK, pressure=1.0132x105 N/m^2.	L4
10	**5**	Differentiate between mass transfer and heat transfer.	L2

Note: L1-Remembering, L2-Understanding, L3-Applying, L4-Analyzing, L5-Evaluating, and L6-Creating

Instruction to Faculty Members:

The Six Levels of Bloom's Taxonomy:

1. **Remembering:** Retrieving, recognizing, and recalling relevant knowledge from long-term memory (e.g., list, define, name, locate).
2. **Understanding:** Constructing meaning, explaining ideas, or concepts (e.g., summarize, interpret, classify, compare).
3. **Applying:** Using information in new situations or implementing procedures to solve problems (e.g., solve, use, demonstrate, implement).
4. **Analyzing:** Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure (e.g., contrast, categorize, distinguish, diagram).
5. **Evaluating:** Making judgments based on criteria and standards through checking and critiquing (e.g., judge, critique, justify, defend, argue).
6. **Creating:** Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure (e.g., design, construct, develop, formulate).

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