Ref. No.: Ex/ME(M2)/PC/B/T/214/2024(S)

B.E. MECHANICAL ENGINEERING SECOND YEAR FIRST SEMESTER SUPPLEMENTARY EXAM 2024

HEAT TRANSFER

Time: Three hours **Full Marks 100**

	All Groups of the same question must be answered together. Assume any unfurnished data suitably	
	Group I	
	Answer any ten questions	
1 (a)	Write the physical significance of the thermal diffusivity.	
(b)	What is critical thickness of insulation? Explain its significance.	
(c)	Demonstrate the difference between fin effectiveness and fin efficiency.	
(d)	How is the thermal boundary layer thickness defined for flow over a flat plate under a laminar flow?	
(e)	Illustrate the thermal and hydrodynamic boundary layer in a high Prandtl number fluid flow over a flat plate.	
(f)	Why is the Nusselt number essential to know for analyzing convection?	
(g)	Define the bulk mean temperature for convection heat transfer. Explain its significance.	
(h)	What is monochromatic or spectral hemispherical emissivity?	
(i)	Write down the statement of Plank's Law for radiation.	10 x 2 = 20
(j)	What is radiation shield?	
(k)	What is fouling factor in heat exchangers?	
(l)	Define log mean temperature difference (LMTD). Explain its role in heat transfer in heat exchangers.	
	Group II	
	Answer any four questions	
2 (a)	Derive the three-dimensional steady-state heat conduction equation in a rectangular coordinate system for a stationary solid having constant thermo-physical properties with a volumetric heat source.	10

(b)	Consider steady-state one-dimensional heat flow in a plate of 20 mm thickness with a uniform heat generation of 80 MW/m^3. The left and right faces are kept at 160 °C and 120 °C, respectively. The plate has constant thermal conductivity with k= 200 W/mK. Find the location of the maximum temperature within the plate from its left face. Determine the maximum temperature within the plate.	10
3.(a)	What is Biot number? Explain its physical significance.	5
(b)	Determine the temperature response in a slab subject to mixed boundary conditions by adopting a lumped system analysis.	15
4. (a)	A 400mm x 400mm hot plate at 100°C is exposed to air at 20°C. Calculate heat loss from both plate surfaces if the plate is kept vertical. Air properties at mean temperature are ρ = 1.06 kg/m^3, k = 0.028 W/m-k, Cp = 1.008 KJ/kg-k, and $\nu = 18.97 \times 10^{-6}$ m_2/s. Use the following correlations: $Nu = 0.125(Gr.Pr)^{0.33}$ *for the vertical plate.*	15
(b)	Describe the thermally fully developed condition for internal flows.	5
5. (a)	Define spectral black body intensity and spectral emissive power of a black body. Derive the relationship between these two.	10
(b)	Define spectral transmissivity, absorptivity, and reflectivity and state how they relate.	5
(c)	What is the radiation shape factor? What is the summation relation among the shape factors?	5
6.(a)	Define the effectiveness and NTU of a heat exchanger.	5
(b)	In a flow single pipe heat exchanger, water is heated from 25°C to 65°C by oil with a specific heat of 1.45 kJ/(kg K) and a mass flow rate of 0.9 kg/s. The oil is cooled from 230°C to 160°C. Suppose the overall heat transfer coefficient is 420 $W/(m^2\ °C)$. Calculate the following for both parallel and counter flow conditions: a) The rate of heat transfer and b) The surface area of the heat exchanger.	10
(c)	Write down the governing equations for natural convection over a vertical flat plate, showing a schematic diagram and coordinate system.	5
7.(a)	Explain the concept of black body and gray body	5

(b)	Calculate the net radiant heat exchange rate for two parallel plates at 427°C and 27°C, respectively. ε (hot plate) is 0.9, and ε (cold plate) is 0.6. A polished aluminum shield is placed between them to find the percentage reduction in heat transfer. ε (aluminum shield) is 0.4. The area of the above plates can be considered unity. Draw the resistance network and explain the causes for decreasing heat transfer by introducing a shield. What do you suggest to reduce heat transfer more for the above problem?	15