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

B.E. MECHANICAL ENGINEERING SECOND YEAR FIRST SEMESTER EXAMINATION, 2024

HEAT TRANSFER

Time: Three hours **Full Marks 100**

	All parts of the same question must be answered together. Assume any unfurnished data suitably	
	Group I	
	Answer any ten questions	
1. (a)	How does the temperature affect the thermal conductivity?	
(b)	What is meant by the term *one-dimensional* when applied to conduction problems?	
(c)	What do you mean by the film temperature?	
(d)	Define Prandtl number. Why is it important?	
(e)	Explain the mechanism of heat transfer in free and forced convection.	
(f)	Define the Grashoff number. What is its physical significance?	
(g)	Define radiation intensity.	
(h)	What is Kirchhoff's identity for the radiation?	
(i)	When is the LMTD method applicable to heat exchange calculations?	
(j)	What is spectral hemispherical emissivity?	
(k)	What is the radiation view factor? Explain its significance.	
(l)	Define the Biot number and explain its importance in conducting heat transfer analysis.	10 x 2 = 20
	Group II	
	Answer any four questions	
2. (a)	Derive a three-dimensional unsteady heat conduction equation with volumetric heat generation in the cylindrical coordinate system for isotropic materials based on Fourier heat transfer. Hence, write down the steady heat conduction equation with and without internal heat generation.	16
(b)	What is thermal diffusivity? What are the effects of thermal diffusivity on transient heat conduction and steady-state heat conduction?	4

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3.(a)	Explain fin effectiveness and fin efficiency.	4
(b)	A carbon steel ball (ρ = 7833 kg/m3, k = 54 W/m °C, cp = 0.465 kJ/kg °C, and α = 1.474×106 m^2/s) with 8 mm in diameter is annealed by heating them first to 900°C in a furnace and then allowing them to cool slowly to 100°C in ambient air at 35°C. If the average heat transfer coefficient is 75 W/m^2 °C, determine how long the annealing process will take. If 2500 balls are to be annealed per hour, determine the amount of heat transfer per hour from the balls to the ambient air.	16
4. (a)	Derive a relation of heat transfer parameters for a convection operation using the order of magnitude analysis. Why is this analysis used to study convection heat transfer?	10
(b)	The flat floor of a hemispherical furnace is at 800 K and has an emissivity of 0.5. The corresponding values for the hemispherical roof are 1200 K and 0.25. Determine the net heat transfer rate per unit area from the roof to the floor.	10
5. (a)	In a counter-flow double 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 average overall heat transfer coefficient is 420 W/m^2 °C. Calculate the following: i) The rate of heat transfer. ii) The mass flow rate of water. iii) The surface area of the heat exchanger.	10
(b)	Derive a general expression of the radiation view factor between two finite surfaces and explain its algebraic property. Physically interpretate it from the mathematical expression. Interpret it physically from the mathematical expression.	10
6.(a)	Define the effectiveness of a heat exchanger. Show typical temperature variations of the hot and cold fluids along the length of a counterflow heat exchanger when the hot fluid is condensing. Show the inlet and outlet temperature differences.	5
(b)	Show that for a counter flow heat exchanger, effectiveness is given by	15

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	$$\varepsilon = \frac{1-\exp[-NTU(1-C_r)]}{1-C_r\exp[-NTU(1-C_r)]}$$ Where *NTU* is the number of transfer units, and C_r is the heat capacity ratio in a fractional form. When is the effectiveness coupled with the NTU in the heat exchanger's design?	
7 (a)	When is one-dimensional heat flow taking place in a slab?	2
(b)	Under transient response (time variable t) with no internal energy source and a constant thermal conductivity k, a slab transfers heat from a higher temperature T_1 to a lower temperature T_2. The length of the slab in the heat conduction direction is L. A constant temperature of T_0 can be chosen as an initial condition to analyze the problem. Derive the temperature pattern in the slab with the time variable using the separation of variables.	18