BACHELOR OF ENGINEERING(MECHANICAL ENGINEERING) SECOND YEAR FIRST SEMESTER (OLD)– 2019

HEAT TRANSFER

Time: Three hours Full Marks: 100

Answer any *five*questions
All questions carry equal marks

1 (a)	Discuss under what circumstances, you can apply the concept of electrical analogy for thermal resistances.	5
(b)	Consider a 1.2 m high and 0.6 m wide double pane window consisting of two 3 mm thick layers of glass (k = 0.78 $W/m.^0C$) separated by a 12 mm wide stagnant air space (k = 0.026 W/m^0C). Determine the steady rate of heat transfer through the double pane window and the temperature of its inner surface for a day during which the room temperature is maintained at 22 ^0C while the temperature of the outdoors is 35 ^0C. Take the heat transfer coefficients on the inner and the outer surfaces of the window to be 10 $W/m^2.^0C$ and 25 $W/m^2.^0C$, respectively.	15
2 (a)	The fins attached to a surface have an effectiveness of 0.9. Do you think rate of heat transfer from the finned surface has increased or decreased, due to attachment of these fins? What measures do you suggest to improve the effectiveness of the fin?	4
(b)	Consider a straight fin of length L, cross sectional area A and perimeter P with its base maintained at a temperature T_b. The fin loses heat by convection to an ambient at a temperature T_∞ with heat transfer coefficient h. The thermal conductivity of the fin material is k. Derive the differential equation that governs the temperature distribution in the fin. Hence, solve for the temperature distribution in the fin, assuming it to be a fin with insulated tip.	16
3 (a)	What is lumped system analysis in transient heat conduction? Consider heat transfer between two identical solid bodies and the air surrounding them. The first solid is being cooled by a fan and the second is being allowed to cool naturally. For which solid, is the lumped system analysis more likely to be applicable?	5
(b)	Explain the significance of Biot number when lumped capacitance method is used for analyzing transient heat conduction problems.	3

(c)	Consider a hot metal sphere, having a volume V, surface area A, density ρ, specific heat c, that is initially at a uniform temperature T_i and is suddenly immersed in a quenching bath maintained at a constant temperature of T_∞. Heat loss from the sphere to the quenching bath takes place with constant heat transfer coefficient h. Treating the body as a lumped system, derive the governing equation, and solve for the variation of temperature of the sphere with respect to time.	12
4 (a)	Derive an expression of critical radius of insulation of a cylindrical wire of radius r_i. Thermal conductivity of insulating material is k and heat transfer coefficient between the outer surface and ambient is h. Show graphically how the conductive resistance of the insulation, the convective resistance and the total resistance vary with the outer radius of the insulation.	10
(b)	Steam at 320 ^0C flows in a stainless steel pipe (k = 15 $W/m.^0C$) whose inner and outer diameters are 5 cm and 5.5 cm, respectively. The pipe is covered with 3 cm thick glass wool insulation (k = 0.038 $W/m.^0C$). Heat is lost to the surrounding at 5^0C, by convection, with a heat transfer coefficient of 15 $W/m^2.^0C$. Taking the heat transfer coefficient inside the pipe to be 80 $W/m^2.^0C$, determine the rate of heat loss per unit length of the pipe.	10
5	Consider steady, laminar boundary type flow of a low Prandtl number (Pr<<1) fluid over a flat plate. The free stream velocity and temperature are U_∞ and T_∞, respectively. The plate is maintained at a uniform temperature of T_w. Show the following by the method of scale analysis: $$\delta / L \sim Re_L^{-1/2}$$ $$\delta_T / L \sim Re_L^{-1/2}\, \mathrm{Pr}^{-1/2}$$ $$Nu_L \sim Re_L^{1/2}\, \mathrm{Pr}^{1/2}$$	20
6 (a)	Define spectral intensity and directional spectral emissive power of a black body. Derive the relation between them.	8
(b)	Define transmissivity, absorptivity and reflectivity and state how they are related.	6
(c)	Define shape factor. What is reciprocity relation in this connection?	6
7 (a)	Define effectiveness and NTU for a heat exchanger.	6
(b)	Show that for a counter flow heat exchanger, effectiveness is given by	14

	$\varepsilon = \dfrac{1-\exp\left[-NTU\left(1-C\right)\right]}{1-C\exp\left[-NTU\left(1-C\right)\right]}$	
8 (a)	Derive the expression for *LMTD* of a parallel heat exchanger.	10
(b)	In a double pipe counter flow heat exchanger hot water flows at a rate of 4000 *kg/hr* and gets cooled from 90 ^0C to 60 ^0C. Cooling is achieved by circulating 6000 kg/hr of water, which enters the heat exchanger at 25 ^0C. Assuming specific heat for both the streams c_p = 4.18 *kJ/kgK* and an overall heat transfer coefficient U = 2000 W/m^2K, calculate the heat transfer area required for the heat exchanger.	10