AUE-502

HEAT TRANSFER

Time Allotted: 3 Hours Full Marks: 70

The questions are of equal value.
The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable

GROUP A
(Multiple Choice Type Questions)

1. Answer *all* questions. 10×1 = 10

(i) LMDT in case of parallel flow as compared to counterflow heat exchanger

(A) higher
(B) lower
(C) same
(D) dependent on temperature distribution

(ii) A composite plane wall is made of two different materials of same thickness with thermal conductivities K_1 and K_2. The equivalent thermal conductivity of the slab is

(A) $K_1 + K_2$ (B) K_1K_2
(C) $(K_1 + K_2)/K_1K_2$ (D) $2K_1K_2/(K_1 + K_2)$

(iii) The unit of the thermal diffusivity

(A) $m^2/hr°C$ (B) kcal/hr°C
(C) m^2/s (D) m/s^2

(iv) For a white body transmissivity is equal to

(A) reflectivity (B) one
(C) constant (D) zero

(v) In free convection, motion of the fluid is caused

(A) by the weight of the fluid element
(B) by the hydrostatic force on the element
(C) by the buoyancy force arising from density of fluid with the temperature
(D) none of these

(vi) Unit of kinematic viscosity is

(A) m/s^2 (B) m^2/s^2
(C) m^2/s (D) m^3/s^2

(vii) The velocity profile for fully developed laminar flow in a tube is

(A) linear (B) exponential
(C) hyperbolic (D) parabolic

(viii) The so called radiator of an automobile is a heat exchanger of

(A) parallel flow type (B) counter flow type
(C) cross flow type (D) open type

(ix) With increase fluid viscosity the boundary layer thickness will

(A) decrease (B) increase
(C) not change (D) first increase and then decrease

(x) Characteristic length in Biot number is the ratio of

(A) volume of solid to its surface area
(B) surface area to perimeter of the solid
(C) perimeter to surface area of solid
(D) none of these

GROUP B
(Short Answer Type Questions)

Answer any *three* questions. $3 \times 5 = 15$

2. (a) Define efficiency and effectiveness of a fin and show expressions for these for an infinitely long fin. How effectiveness of a fin can be increased? 3

   (b) What is thermal resistance of a fin? Write down expression for thermal resistance of an infinitely long fin. 2

3. Derive one dimensional heat conduction equation in Cartesian co-ordinates. 5

4. Derive an expression for "critical insulation radius" for a cylinder. 5

5. A steel ball 50 mm in diameter and at 900°C is placed in still atmosphere of 30°C, calculate the initial rate of cooling of the ball in °C/min. Assume ρ = 7800 kg/m^3 ; C_s=2 kJ/kg°C; h = 30 W/m^2°C. 5

6. (a) What is lumped capacity? What is the assumption for lumped capacity analysis? 2

   (b) What is mean by thermal contact resistance? Upon what parameters do this resistance depends? 3

GROUP C
(Long Answer Type Questions)

Answer any *three* questions. $3 \times 15 = 45$

7. (a) Consider a slab of thickness L in which the heat is generated at a constant rate q_0 W/m^3. The boundary surfaces at $x = 0$ and $x = L$ are maintained at T_1 and T_2 respectively. Develop an expression for the heat flux $q(x)$ and temp. $T(x)$ at any section of the slab. 6

   (b) A truncated solid cone is of circular cross-section, and its diameter is related to the axial coordinate by an expression of the form $D = ax^{3/2}$, where $a = 1.0$ m$^{-1/2}$. The sides are well-insulated, while the top surface of the cone at x_1 is maintained at T_1 and the bottom surface at x_2 is maintained at T_2. 9

   (i) Obtain an expression for the temperature distribution.

   (ii) What is the rate of heat transfer across the cone if it is constructed of pure aluminium (k = 235 W/m.K) with x_1 = 0.075 m, T_1 = 100°C, x_2 = 0.225 m and T_2 = 20°C?

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8. (a) Consider a plane composite wall that is composed of two materials whose conductivities are K_1 = 0.1 W/mK and K_2 = 0.04 W/mK and thickness L_1 = 1 cm and L_2 = 2 cm. The contact resistance at the interface between the two materials is known to be 0.3 m^{2}K/W. The material 1 adjoins a fluid at 200°C for which h = 10 W/m^{2}K and material 2 adjoins a fluid at 40°C for which h = 20 W/m^{2}K. Find: (i) The rate of heat transfer through the composite wall (ii) What is the temperature drop at the interface of two materials?

   (b) One end of a long rod is inserted into a furnace while the other projects into ambient air. Under steady state the temperature of the rod is measured at two points 75 mm apart and found to be 125°C and 88.5°C, respectively, while the ambient temperature is 20°C. If the rod is 25 mm in diameter and h is 23.36 W/m^{2}K, find the thermal conductivity of the rod material.

9. (a) Using a linear velocity profile $u/u' = y/\delta$. For flow over flat plate, obtain an expression for boundary layer thickness as a function of x.

   (b) Water flows through a tube of 2.2 cm in diameter with a velocity 2 m/s. The water is heated from 15°C by condensing the steam at 150°C on the outer surface of the tube. Using the equation $N_u = 0.023\, Re^{0.8}\, Pr^{0.4}$ find the heat transfer coefficient and length of the tube required for transferring the above amount of heat. Neglect the tube resistance as well as outer surface film resistance. Take the following properties of water at mean temperature of (15 + 60)/2 = 37.5, p = 990 kg/m^3, Cp = 4160 J/kgK, $\mu = 700 \times 10^{-6}$ kg/ms, k = 0.63 W/mK.

10. (a) Derive the expression for the temperature profile of a solid wall with heat generation such that the temperature at the walls are different. Locate the position of the maximum temperature and also the value of maximum temperature.

   (b) For a solid cylinder with heat generation show that the temperature distribution is given by $\dfrac{t - t_w}{t_{max} - t_w} = 1 - \left(\dfrac{r}{R}\right)^2$

11. (a) Establish a relation for the shape factor of a conical cavity of diameter d and depth h with respect to itself. The cavity is closed on its outer surface with a flat surface.

   (b) Define a gray body and monochromatic emissivity.

   (c) Derive Stefan Boltzmann Law from Planck's law of radiation.