MAULANA ABUL KALAM AZAD UNIVERSITY OF TECHNOLOGY, WEST BENGAL

ME-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.
All symbols are of usual significance.

GROUP A
(Multiple Choice Type Questions)

1. Answer *all* questions. 10×1 = 10

(i) Which of the following statement is wrong?

(A) The thermal conductivity of solid metals increases with rise in temperature.

(B) The amount of heat flow through a body is dependent upon the material of the body.

(C) Heat transfer in liquid and gases takes place according to convection

(D) Logarithmic mean temperature difference is not alwase equal to the arithmetic mean temperature difference.

(ii) A composite wall consist of three different material having thermal conductivities K, 2K, 4K respectively. The temperature drop across different materials will be in the ratio

(A) 1 : 1 :1 (B) 4 : 2 : 1 (C) 1 : 2 : 4 (D) 2 : 4 : 1

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(iii) For a current carrying wire of 20 mm diameter exposed to air ($h = 25$ W/m^2), maximum heat transfer occurs when the thickness of insulation ($k = 0.5$ W/m^2) is

(A) 20 mm (B) 10 mm
(C) 1.5 mm (D) 0 mm

(iv) The temperature distribution at a certain instant of time in a concrete slab during curing is given by $T = 3x^2 + 3x + 16$, where x in cm and T is in K. The rate of change of temperature with time is given by (assume diffusivity to be 0.0003 cm^2/s)

(A) + 0.0009 K/s (B) 0.0048 K/s
(C) – 0.0012 K/s (D) – 0.0018 K/s

(v) The mean temperature difference between hot fluid and cold fluid in a shell-and-tube heat exchanger is more accurately calculated by

(A) log mean (B) arithmetic mean
(C) geometric mean (D) none of these

(vi) In a stagnant fluid, the most probable mechanism of heat transfer is

(A) molecular transport (B) bulk transport
(C) both (A) and (B) (D) none of these

(vii) The ratio of kinetic energy of flow relative to boundary layer enthalpy difference is called

(A) Biot number (B) Eckert number
(C) Grashof number (D) Stantom number

(viii) Thermal conductivity of most metals with increase in temperature

(A) decreases (B) increases
(C) constant (D) none of these

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(ix) In free convection Nusselt number is the function of

(A) Reynolds Number and Prandtl number
(B) Reynolds number and Eckert number
(C) Reynolds number and Grashof number
(D) Prandtl number and Grashof number

(x) Transient conduction means

(A) heat transfer with small temperature difference
(B) variation of temperature with time
(C) heat transfer for short time
(D) very little heat transfer

GROUP B
(Short Answer Type Questions)

Answer any *three* questions. 3×5 = 15

2. Derive the three-dimensional heat conduction equation in spherical coordinates. 5

3. What is critical thickness of insulation of a small diameter pipe? Explain its physical significance and derive an expression for the same. 5

4. Furnace wall of area 2 m^2 consists of 2 cm thick M.S. plate, followed by 60 mm thick asbestos insulation. Two layers are held together with the help of 12 M.S. bolts of diameter 10 mm. Draw equivalent circuit for system and find rate of heat flow through it when temperature of gas inside furnace is 90°C and outside air is at 20°C. K_{MS} = 50 W/m-K, K_{abs} = 0.3 W/m-K, h = 20 W/m^2K on both sides. 5

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5. (a) Give a comparison of parallel-flow and counter-flow heat exchangers. 3

(b) Under what conditions is the effectiveness NTU method preferred over LMTD method as a method of analysis of a heat exchanger? 2

6. Air flow over a heated plate at a velocity of 60 m/s. The local skin friction co-efficient at a point on a plate is 0.004. Estimate the local heat transfer coefficient at this point. The following property data for air given: Density = 0.98 kg/m^3, Viscosity = 3.286×10^{-5} kg-m/s; Specific heat(C_P) = 1.0001 kJ/kg K; Conductivity = 0.035 W/m K.
User St $Pr^{1/3} = C_{fx}/2$. 5

GROUP C
(Long Answer Type Questions)

Answer any *three* questions. 3×15 = 45

7. (a) Derive the expression for temperature distribution from a fin of uniform cross sectional area and insulated at tip. 5

(b) An Aluminum rod 2.5 cm in diameter and 10 cm long, protrudes from a wall which is maintained at 250°C. The rod is exposed to an environment at 15°C. The convection heat transfer coefficient is 15 W/m^2K. Calculate the heat lost by rod. Assume rod end is insulated. Take thermal conductivity k for Aluminum = 200 W/mK. Also find the fin efficiency and temperature at the end of fin. 5

(c) A long copper plate, 4 cm thick and at an initial temperature of 200°C is held out on a water surface so that its one face is in contact with water at 30°C. The outer surface is exposed to air at 30°C. The heat transfer coefficients on air and water side are 10 W/m^2K and 100 W/m^2K respectively. Neglect radiation and heat transfer from edges. Find the time required to cool the plate to a temperature of 100°C. Properties of copper are ρ = 8800 kg/m^3, Cp = 400 J/kg, k = 360 W/mK. 5

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8. (a) Taking the velocity profile in the turbulent flow over a plane surface as $u = v_\infty \left(\frac{y}{\delta}\right)^{\frac{1}{7}}$ and wall shear stress as $\tau_w = 0.02228\, \rho u_\infty^2 \left(\frac{\nu}{u_\infty \delta}\right)^{\frac{1}{4}}$, show that the boundary layer thickness is given by $\frac{\delta}{x} = \frac{0.376}{(Re_x)^{\frac{1}{5}}}$. 8

(b) Air at 27°C and 1atm pressure flows over a heated plate with a velocity of 2 m/s. The plate is at uniform temperature of 60°C. Calculate the heat transfer rate from first 0.2 m of the plate. 7

9. (a) Show that the emissive power of a black body is π-times the intensity of emitted radiation. 7

(b) A cubical room 4m × 4m × 4m, heated through the ceiling by maintaining it at uniform temperature of 350 K while the walls and floor are at 300 K. Assuming that all the surface have an emissivity of 0.8. Determine the rate of heat loss from the ceiling by radiation. 8

10.(a) Define (i) black body and gray body, (ii) radiosity, (iii) viewfactor 4

(b) State and explain Stefan-Boltzmann law. 4

(c) A pipe carrying steam runs in a large room and exposed to air at 30°C. The pipe surface temperature is 200°C. Diameter of the pipe is 20 cm. If the total heat loss per meter length of the pipe is 1.919 kW/m, determine the emissivity of the pipe surface. 7

Given that : $Nu_D = 0.53(Gr_D Pr)^{1/4}$ and air properties at 30°C are :

$k_f = 0.03306$ W/m-K; $\upsilon = 24.93 \times 10^{-6}$ m^2/s; $Pr = 0.687$.

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11.(a) A thermocouple is used to measure the temperature of gas flowing through a duct, records 280°C. If the emissivity of the junction is 0.4 and the convection coefficient is 150 W/m^{2}K, find the true gas temperature. The duct wall temperature is 140°C. What should be the emissivity of the junction in order to reduce the error by 30%? 9

(b) For a radiatin shield, show that $\left(\frac{Q}{A}\right)_{\text{with } N \text{ shields}} = \frac{1}{N+1}\left(\frac{Q}{A}\right)_{\text{without shields}}$. 6

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