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10ME63

Sixth Semester B.E. Degree Examination, July/August 2021
Heat and Mass Transfer

Time: 3 hrs. Max. Marks:100

Note: 1. ***Answer any FIVE full questions.***
2. ***Use Heat and Mass transfer Data Hand Book is permitted.***
3. ***Assume missing data if any.***

1 a. Write basic laws governing each mode of heat transfer along with mathematical expressions. **(06 Marks)**

b. Write boundary conditions of first, second and third kinds. **(06 Marks)**

c. Consider a slab of thickness L. A fluid at a temperature 130°C with a heat transfer coefficient 250 $W/m^2{}^\circ C$ flows over the surface at x = 0, and another fluid at a temperature 30°C, with a heat transfer coefficient 500 $W/m^2{}^\circ C$ flows over the surface at x = L of the plate. Assuming K for the slab 20 W/m°C, calculate the heat flow rate per m^2 of slab if the slab thickness is 4 cm. Determine the slab thickness if the heat flow rate is to be reduced to 50%. **(08 Marks)**

2 a. Derive an expression for the temperature distribution T(x) and for heat flow through an area A of the slab of thickness L. Boundary conditions are at x = 0, $T = T_1$ and at x = L, $T = T_2$. There is no energy generation in the solid and thermal conductivity is constant. **(10 Marks)**

b. Explain (i) Critical thickness of insulation (ii) fin efficiency. **(04 Marks)**

c. A steel rod of diameter 2 cm, length 20 cm and thermal conductivity K = 50 W/m°C is exposed to ambient air at 20°C with a heat transfer coefficient 64 $W/m^2{}^\circ C$. If one end of the rod is at a temperature 115°C, calculate the heat loss from the rod. Assume long fin. **(06 Marks)**

3 a. Explain the significance of,
(i) Biot number (ii) Fourier number. (iii) Heisler charts. **(06 Marks)**

b. Explain the criteria for neglecting internal temperature gradients. **(04 Marks)**

c. The temperature of a gas stream is measured with a thermocouple. Junction may be approximated as a sphere of diameter D = 2 mm, with K = 30 W/m°C, $\rho = 8600$ kg/m^3, $C_p = 400$ J/kg°C. The heat transfer coefficient is $h = 280\ W/m^2{}^\circ C$. How long will it take for the thermocouple to record 98 percent of the applied temperature difference? **(10 Marks)**

4 a. Sketch and explain in brief each of the following:
(i) Velocity boundary layer for flow along a flat plate.
(ii) Thermal boundary layer for flow of a hot fluid over a cold wall.
(iii) Hydrodynamic entry region and hydrodynamically developed region. **(12 Marks)**

b. A square plate 0.4 by 0.4 m maintained at a uniform temperature of $T_W = 400$ K is suspended vertically in quiescent atmospheric air at $T_\infty = 300$ K.
(i) Determine the boundary layer thickness δ(x) at the trailing edge of the plate (at x = 0.4 m)
(ii) Calculate the average heat transfer coefficient h over the entire length of the plate by using the relations given below :
Properties of air at 350 K
$\gamma = 20.75\times10^{-6}\ m^2/s$, $P_r = 0.697$, $K = 0.03$ W/m°C
$\delta(x)|_{x=L} = 3.93\ P_r^{-\frac{1}{2}}(0.952+P_r)^{\frac{1}{4}}G_r^{-\frac{1}{4}}L$, $NU_m = 0.518(Gr_L P_r)^{\frac{1}{4}}$. **(08 Marks)**

5 a. What is the physical significance of,
(i) Reynolds number. (ii) Prandtl number. **(04 Marks)**

b. The convection heat transfer coefficients for flow of a fluid through a tube have been experimentally determined. Using dimensional analysis obtain the relationship
$Nu = f(Re \cdot Pr)$
The following physical quantities may be assumed to influence convection :
(i) Tube diameter, D (ii) Thermal conductivity, K
(ii) Velocity, u (iv) Density ρ.
(v) Viscosity, μ (vi) Specific heat, C_P and
(vii) Heat transfer coefficient, h **(08 Marks)**

c. Water flows with a mean velocity of $U_m = 2$ m/s inside a circular pipe of inside diameter D = 5 cm. Assume the pipe is smooth and maintained at uniform temperature $T_W = 100°C$ by condensing steam on its outer surface. At a location where the fluid is hydrodynamically and thermally developed, the bulk mean temperature of water is 60°C. Calculate the heat transfer coefficient h using (i) Dittus and Boelter equation (ii) Sieder-Tate equation.
Take properties at 60°C (mean T)
$K = 0.651$ W/m°C, $P_r = 3.02$, $\rho = 985$ kg/m^3, $\mu_m = 4.71\times10^{-4}$ kg/m.s (at mean T), $\mu_w = 2.82\times10^{-4}$ kg/m.s (at wall T)
(i) Dittus-Boelter equation is $Nu = 0.023 R_e^{0.8} P_r^n$, n = 0.4 for heating and 0.3 for cooling.
(ii) Sieder-Tate equation is, $Nu = 0.027 R_e^{0.8} P_r^{\frac{1}{3}} \left(\frac{\mu_m}{\mu_w}\right)^{0.14}$. **(08 Marks)**

6 a. How are heat exchangers classified? **(06 Marks)**

b. What is fouling? List the factors that cause fouling. **(04 Marks)**

c. A counter flow heat exchanger of heat transfer area $A = 12.5\text{ m}^2$ is to cool oil [C_{ph} = 2000 J/kg.S] with water [C_{PC} = 4170 J/kg.S]. The oil enters at T_{hi} = 100°C and m_h = 2 kg/s, while the water enters at T_{Ci} = 20°C and m_C = 0.48 kg/s. The overall heat transfer coefficient is $U_m = 400$ W/m^2°C. Calculate the exit temperature of water and the total heat transfer rate Q. **(10 Marks)**

7 a. Explain types of condensation. **(04 Marks)**

b. Sketch and explain regimes of pool boiling. **(06 Marks)**

c. A vertical square plate 30 by 30 cm, is exposed to steam at atmospheric pressure. The plate temperature is 98°C. Calculate the heat transfer and the mass of steam condensed per hour. What is the nature of flow?
Use the properties given below at 99°C
$\rho_f = 960$ kg/m^3, $\mu_f = 2.82\times10^{-4}$ kg/m.s, $K_f = 0.68$ W/m°C, T_{sat} = 100°C, $h_{fg} = 2255$ KJ/kg. **(10 Marks)**

8 a. Define the following with mathematical expressions:
(i) Spectral hemispherical emissivity. (ii) Hemispherical emissivity.
(iii) Spectral Black body emissive power. (iv)Blackbody emissive power. **(08 Marks)**

b. Explain concept of view factor and its physical significance. **(04 Marks)**

c. The emission of radiation from a surface can be approximated as a black body radiation at T = 1000 K.
(i) What fraction of the total energy emitted is below $\lambda = 5$ μm?
(ii) What is the wave length below which the emission is 10.5 % of the total emission at 1000 K?
(iii) What is the wavelength at which the maximum spectral emission occurs at T=1000 K? **(08 Marks)**

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