(Following Paper ID and Roll No. to be filled in your Answer Book)

PAPER ID : 4078 Roll No.

B.Tech.

FIFTH SEMESTER EXAMINATION, 2006-07

HEAT AND MASS TRANSFER

Time : 3 Hours *Total Marks : 100*

Note : *(i) Attempt **ALL** questions.*
(ii) All questions carry equal marks.
(iii) Assume suitable missing data, if any.
(iv) All symbols have usual meaing.
(v) Be precise in your answer.

1. Attempt ***any two*** of the following : **(10x2=20)**

(a) (i) Define thermal conductivity. How do thermal conductivities of gases and liquids vary with temperature ?

(ii) What do you understand by combined heat transfer mechanism ? Explain.

(b) Explain the term "overall heat transfer coefficient" and its significance in heat transfer.

A mild steel tank of wall thickness 10 mm, contains water at 90°C when the atmospheric temperature is 15°C. The thermal conductivity of the mild steel is 50 W/mK and heat transfer coefficients for the inside and outside of the tank are 2800 and 11 W/m^2K respectively. Calculate :

(i) rate of heat loss per unit area of tank surface.

(ii) temperature of the outside surface of the tank.

(c) A steel pipe of 100 mm bore and 7 mm wall thickness, carrying steam at 260°C, is insulated with 40 mm of glass wool covering, this covering in turn insulated with 60 mm of asbestos felt. The atmospheric temperature is 30°C. The heat transfer coefficients for the inside and outside surfaces are 550 and 15 W/m^2K respectively, and the thermal conductivities of steel, glass wool and asbestos felt are 50, 0.09 and 0.07 W/mK respectively. Calculate :

(i) rate of heat loss per unit length of pipe

(ii) temperatures at each X-section of the pipe.

Attempt *any two* of the following : **(10x2=20)**

(a) Explain the significance of fin effectiveness and fin efficiency.

A fin of circular X-section, diameter 2.5 cm is placed in a furnace with large portion of it projecting in a room where temperature is 28°C. After steady state conditions prevail, the temperature at two points 10 cm apart are found to be 110°C and 85°C. The convective heat transfer coefficient between the rod surface and the surrounding air is 28.4 W/m^2K. Determine the thermal conductivity of fin material.

(b) (i) Explain the importance of insulated tip solution for the fins used in practice.

(ii) How the transient heat conduction for a plane wall can be analysed with the help of Heisler charts.

(c) An aluminium sphere weighing 5.5 kg and initially at a temperature of 290°C is suddenly immersed in a fluid at 15°C. The convective heat transfer coefficient is 58 W/m^2K. Estimate the time required to cool the aluminium to 95°C using the lumped capacity method of analysis.

3. Attempt *any two* of the following : **(10x2=20)**

(a) What is boundary layer thickness ? What is laminar sublayer ? Water is heated while flowing through a 1.5 cm × 3.5 cm rectangular cross section tube at a velocity of 1.2 m/s. The entering temperature of water is 40°C and tube wall is maintained at 85°C. Determine the length of tube required to raise the temperature to 70°C. Properties of water at 55°C are :

$\rho = 985.5$ kg/m3, $C_p = 4.18$ kJ/kgK, $\gamma = 0.517 \times 10^{-6}$ m^2/s, $k = 0.654$ W/mK and $P_r = 3.26$

Use the equation $Nu_d = 0.023\, Re_d^{0.8}\, Pr^{0.4}$

(b) A 0.03 m long glass plate is hung vertically in the air at 27°C while its temperature is maintained at 77°C. Calculate the boundary layer thickness at trailing edge of the plate and average heat transfer coefficient. If the same plate is placed in a wind tunnel and air is blown over it at a velocity of 4 m/s, estimate the boundary layer thickness at its trailing edge and the average heat transfer coefficient. Properties of air at 52°C :

$\beta = 3.07 \times 10^{-3} K^{-1}$, $K = 28.15 \times 10^{3}$ W/mK,
$\gamma = 18.41 \times 10^{-6}$ m^2/s, $Pr = 0.7$

use for free convection

$$\delta = 3.93\, x\, (0.952 + Pr)^{1/4} . \frac{1}{Pr^{1/2} . (Gr_x)^{1/4}} \text{ and}$$

$$Nu_x = 0.508\, Pr^{1/2}\, (0.952 + Pr)^{-\frac{1}{4}}\, Gr_x^{\frac{1}{4}}$$

for forced convection : $Nu = 0.664\, Re_L^{1/2}\, (Pr)^{1/3}$

(c) Explain the following :

(i) Critical value of Rayleigh Number

(ii) Combined forced and natural convection

(iii) Drag coefficient and drag force

4. Attempt *any four* of the following : **(5x4=20)**

(a) Explain why radiation is usually treated as a surface phenomenon.

(b) Define the total and spectral blackbody emissive powers. How are they related to each other ? How they differ ?

(c) A thin aluminium sheet with an emissivity of 0.1 on both sides is placed between two very large parallel plates that are maintained at uniform temperatures $T_1 = 800$ K and $T_2 = 500$K and have emissivities 0.2 and 0.7 respectively. Determine the net rate of radiation heat transfer between the two plates per unit surface area of the plates and compare the result to that without the shield.

(d) What is the greenhouse effect ? Why is it a matter of great concern among environmental scientists ?

(e) What is solar radiation ? What is the effective sky temperature ?

(f) A 20 cm diameter spherical ball at 800 K is suspended in the air. Assuming that the ball closely approximates a black-body, determine :

(i) the total blackbody emissive power

(ii) the total amount of radiation emitted by the ball in 5 min.

5. Attempt *any two* parts of the following : **(10x2=20)**

(a) Water at the rate of 3.783 kg/s is heated from 37.78 to 54.36°C in a shell and tube heat exchanger. On the shell side one pass is used with water as heating fluid, 1.892 kg/s entering the heat exchanger at 93.33°C. The overall heat-transfer coefficient is 1419 W/m^2K and the average water velocity in 1.905 cm diameter tubes is 0.366 m/s. Because of space limitations the tube length must not be longer than 2.438 m. Calculate the number of tube passes, the number of tube per pass and length of tubes.

(b) How does filmwise condensation differ from dropwise condensation ? Which type has a higher heat transfer film coefficient and point out the reason thereof.

An electric wire of 1.25 mm diameter and 250 mm long is laid horizontally and submerged in water at 7 bar (saturation temperature of water at 7 bar is 165°C). The wire has an applied voltage of 2.2V and carries a current of 130 amperes. If the surface of wire is maintained at 200°C, make calculation for the heat flux and boiling heat transfer coefficient.

(c) What do you understand by the term rate of diffusion ? Show in which case the rate of diffusion is max (i) uni-component (ii) equi-molal.

Estimate the diffusion coefficient for ammonia in air at 25°C and one atmospheric pressure :

for ammonia : mol.weight = 17 and
mol.volume = 25.81 cm^3/gm mole

for air : mol.weight = 29 and
mol.volume = 29.89 cm^3/gm mole

The diffusion coefficient for binary mixture may be taken as

$$D = 0.0043 \frac{T^{3/2}}{pt\left(V_b^{1/3} + V_c^{1/3}\right)^2} = \left[\frac{1}{M_b} + \frac{1}{M_c}\right]^{1/2}$$

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