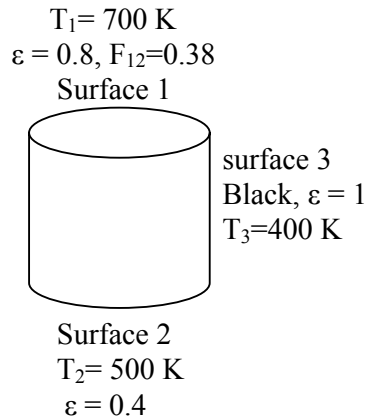


GUJARAT TECHNOLOGICAL UNIVERSITY
BE - SEMESTER-VI • EXAMINATION – SUMMER 2013

Subject Code: 161906**Date: 31-05-2013****Subject Name: Heat and Mass Transfer****Time: 10.30 am - 01.00 pm****Total Marks: 70****Instructions:**

1. Attempt all questions.
2. Make suitable assumptions wherever necessary.
3. Figures to the right indicate full marks.
4. Illustrate your answer with neat sketches wherever required.
5. Notations carry usual meanings.

- Q.1 (a)** Write general heat conduction equation for non-homogeneous material, self heat generating and unsteady three-dimensional heat flow in cylindrical coordinates. Name and state the unit of each variable. **07**
 Step 1. Reduces above equation to one dimensional
 Step 2. Reduces step 1 equation for steady and without heat generation
 Step 3. Reduces step 2 equation for homogeneous and isotropic material
 Step 4. Reduces step 3 equation to $r(dt/dr) = \text{constant}$.
- (b)** Derive a general mass diffusion equation in stationary media having N_{Ag} as mass generation rate of species A in Cartesian coordinates. **07**
- Q.2 (a)** Consider a cylindrical furnace with radius = 1m and height = 1m as shown in fig. Take $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$ **07**



Determine the net rate of radiation heat transfer at each surface during the steady operation and explain how these surfaces can be maintained at specified temperatures.

- (b)** Derive the governing differential equation for temperature distribution of constant cross-sectional area fin. Hence derive expression for temperature distribution for long fin stating the assumption made. **07**

OR

- (b)** A cold storage room has walls made of 200 mm of brick on the outside, 80 mm of plastic foam, and finally 20 mm of wood on the inside. The outside and inside air temperatures are 25°C and -3°C respectively. If the outside and inside convective heat transfer coefficients are respectively 10 and $30 \text{ W/m}^2^\circ\text{C}$, **07**

and the thermal conductivities of brick, foam and wood are 1.0, 0.02 and 0.17 W/m °C respectively.

Determine:

- (a) overall heat transfer coefficient
- (b) the rate of heat removed by refrigeration if the total wall area is 100 m²
- (c) outside and inside surface temperatures and mid-plane temperatures of composite wall.

- Q.3 (a)** Water at 10 °C, flows over a flat plate (at 90 °C) measuring 1 m X 1 m, with a velocity of 2 m/s. Properties of water at 50 °C are $\rho=988 \text{ kg/m}^3$, $\nu = 0.556 \times 10^{-6} \text{ m}^2/\text{s}$, $C_p = 4.18 \text{ kJ/kg } ^\circ\text{C}$ and $k = 0.648 \text{ W/m } ^\circ\text{C}$. **08**
- Determine (a) The length of plate over which the flow is laminar
 (b) The rate of heat transfer upto the above length
 (c) The rate of heat transfer from the entire plate.

Useful co-relation:

$Nu = 0.332 (Re_x)^{1/2} (Pr)^{1/3}$ local Nusselt number for laminar flow

$\bar{Nu} = [0.036 (Re_L)^{0.8} - 836](Pr)^{1/3}$ average Nusselt number for mixed flow

- (b)** Differentiate: **06**
- 1. Mean film temp and bulk mean temp
 - 2. Velocity and thermal boundary layer

OR

- Q.3 (a)** By dimensional analysis show that for natural convection heat transfer the Nusselt number can be expressed as a function of Grashof number and Prandtl number. **07**

- (b)** Water ($C_p=4.2 \text{ kJ/kg } ^\circ\text{C}$) is heated at the rate of 1.4 kg/s from 40 °C to 70 °C by an oil ($C_p=2 \text{ kJ/kg } ^\circ\text{C}$) entering at 110 °C and leaving at 60 °C in a counter flow heat exchanger. If $U = 350 \text{ W/m}^2 \text{ } ^\circ\text{C}$, calculate the surface area required. **07**
- Using the same entering fluid temperatures and the same oil flow rate, calculate the exit temperature of oil and water and the rate of heat transfer, when the mass flow rate of water is halved.

- Q.4 (a)** What do you mean by critical radius of insulation? Derive critical radius of insulation $r_c = k / h_o$ **07**

- (b)** A steel rod ($k=30 \text{ W/m } ^\circ\text{C}$), 12 mm in diameter and 60 mm long, with an insulated end is to be used as spine. It is exposed to surrounding with a temperature of 60 °C and heat transfer coefficient of $55 \text{ W/m}^2 \text{ } ^\circ\text{C}$. The temperature at the base is 100 °C. Determine : **07**
- (i) The fin effectiveness
 - (ii) The fin efficiency
 - (iii) The temperature at the edge of the spine
 - (iv) The heat dissipation

OR

- Q.4 (a)** Derive the relation for temperature variation with respect to time, instantaneous heat transfer rate and total heat transfer using lumped parameter analysis. **07**

- (b)** A refrigeration suction line having outer diameter 30 mm is required to be thermally insulated. The outside air convective heat transfer coefficient is $12 \text{ W/m}^2 \text{ } ^\circ\text{C}$. The thermal conductivity of the insulating material is $0.3 \text{ W/m } ^\circ\text{C}$. **07**

Determine:

- (i) Whether the insulation will be effective
- (ii) Estimate the maximum value of thermal conductivity of insulating material to reduce heat transfer
- (iii) The thickness of cork insulation to reduce the heat transfer to 20% ($k=0.04 \text{ W/m } ^\circ\text{C}$)

- Q.5 (a)** The temperature of an air stream flowing with a velocity of 3 m/s is measured by a copper-constantan thermocouple which may be approximated as sphere of 3 mm in diameter. Initially the junction and air are at a temperature of 25 °C. The air temperature suddenly changes to and is maintained at 200 °C. Take $\rho=8685 \text{ kg/m}^3$, $C_p = 383 \text{ J/kg } ^\circ\text{C}$ and $k=29 \text{ W/m } ^\circ\text{C}$ and $h=150 \text{ W/m}^2 ^\circ\text{C}$. Determine:

- (i) Thermal time constant and temperature indicated by the thermocouple at that instant
- (ii) Time required for the thermocouple to indicate a temp. of 199 °C
- (iii) Discuss the suitability of this thermocouple to measure unsteady state temperature of fluid then the temperature variation in the fluid has a time period of 30 seconds.

- (b)** (i) Define: Emissivity, Radiosity, Monochromatic emissive power, Irradiation **04**
(ii) Draw : labeled boiling curve for water **03**

OR

- Q.5 (a)** Derive an expression for LMTD for counter flow heat exchanger stating the assumption made. **07**

- (b)** A condenser is to be designed to condense 2500 kg/h of dry and saturated steam at a pressure of 10 kPa. A square array of 400 tubes each of 6 mm in diameter, is to be used. If the tube surface temperature is to be maintained at 24 °C, calculate the length of each tube assuming single pass. **07**
Properties of dry and saturated steam at 10 kPa :

$$t_{\text{sat}} = 45.8 \text{ } ^\circ\text{C}, \rho_v = 0.068 \text{ kg/m}^3 \text{ and } h_{\text{fg}} = 2393 \text{ kJ/kg}$$

Properties of steam at mean film temp:

$$\rho_l = 994.0 \text{ kg/m}^3, k = 0.6253 \text{ W/m } ^\circ\text{C}, \mu = 728.15 \times 10^{-6} \text{ kg/ms}$$

Useful correlation:

$$\bar{h} = 0.725 [(\rho_l (\rho_l - \rho_v) k^3 g h_{\text{fg}}) / (N \mu (t_{\text{sat}} - t_s) D)]^{1/4}$$
