



## B.E. Sem. VI (Mech.)

June - 2009

### Heat and Mass Transfer

5 JUN 2009

Time : 3 Hours]

[Max. Marks : 100

- Instructions :**
- (1) Figures to the right indicate full marks.
  - (2) Use of calculator is only permitted.
  - (3) Assume usual notations and suitable data wherever necessary.

1. (a) What is meant by thermal conductivity and thermal resistance ? Explain their importance in conduction heat transfer problems. 16
- (b) Derive general heat conduction equation in Cartesian coordinates.
- (c) The walls of a refrigerated truck consist of 1.5 mm thick steel sheet ( $k = 18 \text{ W/m-K}$ ) at the outer surface, 20 mm thick timber lining ( $k = 0.11 \text{ W/m-K}$ ) on the inner surface and 25 mm thick cork ( $k = 0.04 \text{ W/m-K}$ ) in between. The temperatures at the inside and outside surfaces of the truck are  $0^\circ\text{C}$  &  $30^\circ\text{C}$  respectively. Calculate
- (i) necessary refrigeration capacity of the plant.
  - (ii) timber-cork interface temp.

OR

- (a) Explain Briefly the significance of "Critical thickness of insulation" and its usefulness. 16
- (b) Derive an expression for "Critical thickness of insulation" for a pipe.
- (c) A wire of 6.5 mm diameter at a temperature of  $60^\circ\text{C}$  is to be insulated by a material having  $K = 0.174 \text{ w/m-k}$ . Convection heat transfer coefficient =  $8.7 \text{ w/m}^2\text{-k}$ . The ambient temperature is  $20^\circ\text{C}$ . For maximum heat loss, what is the minimum thickness of insulation ? What is the heat loss per meter length, without insulation & with insulation ?
2. (a) Define and Explain significance of fin efficiency. 16
- (b) Derive the expression for temperature distribution and heat dissipation in a straight fin when the fin is infinitely long.
- (c) A turbine blade made of stainless steel ( $k = 29 \text{ w/m-k}$ ) is 60 mm long,  $500 \text{ mm}^2$  cross-sectional area and 120 mm perimeter. The temperature of the root of the blade is  $475^\circ\text{C}$  and it is exposed to products of combustion passing through the turbine at  $825^\circ\text{C}$ . If the film coefficient between the blade and the combustion gases is  $320 \text{ w/m}^2\text{-K}$ , determine :
- (i) temperature at the middle of the blade
  - (ii) rate of heat flow to the blade

OR

- (a) Explain lumped heat capacity method in brief and state its assumptions. Estimate the time required to cook a carrot in boiling water at atmospheric pressure. The carrot is initially at room temp  $25\text{ }^{\circ}\text{C}$  and the cooking requirement stipulates that a minimum temp, of  $95\text{ }^{\circ}\text{C}$  is reached at the center of carrot. Treat the carrot as a long cylinder of 20 mm diameter and having the following properties: 16  
 $\rho=1025\text{ kg/m}^3$ ,  $C_p = 4000\text{ J/kgK}$ ,  $k= 0.48\text{ W/m-K}$   
convective heat transfer coefficient  $h = 2000\text{ W/m}^2\text{-K}$
- (b) What is condensation and when does it occur ? Distinguish between mechanism of filmwise condensation and dropwise condensation. Which type has the highest heat transfer coefficient and explain why this is so.
- (c) Draw and Explain boiling curve for water. Explain Nucleate boiling.
3. (a) What are the fouling factors ? Explain their effect in Heat Exchanger design. 18  
(b) Define Heat Exchanger Effectiveness & explain its significance.  
(c) Steam condenses at atmospheric pressure on the external surface of the tubes of a steam condenser. The tubes are 12 in numbers and each tube is 30 mm in diameter and 10 m long. The inlet and outlet temperatures of cooling water flowing inside the tubes are  $25\text{ }^{\circ}\text{C}$  and  $60\text{ }^{\circ}\text{C}$  respectively, if its flow rate is 1.1 kg/s, Calculate:  
(i) the rate of condensation of steam  
(ii) overall heat transfer coefficient based on inner surface area  
(iii) Number of transfer units  
(iv) Effectiveness of the condenser  
Take latent heat of steam at atmospheric pressure as  $2257\text{ kJ/kg}$ .
4. (a) Explain the criterion for deciding type of convection (free or forced) in any given situation. 16  
(b) Using dimensional analysis, obtain a general form of equation for Natural Convective heat transfer  
(c) The surface of a 2.5 m long flat plate is maintained at  $50\text{ }^{\circ}\text{C}$ . Water at a temp. of  $10\text{ }^{\circ}\text{C}$  and a velocity of  $0.65\text{ ms}^{-1}$  flows over the surface. Calculate the heat transfer rate per unit width of plate.
5. (a) Derive energy equation for thermal boundary equation. 16  
(b) A plate of length 750 mm and width 250 mm has been placed longitudinally in a stream of crude oil which flows with a velocity of 4.9 m/s. If the oil has a specific gravity of 0.81 and kinematic viscosity of  $0.0001\text{ m}^2/\text{s}$ , calculate  
(i) boundary layer thickness at the middle of plate  
(ii) Shear stress at the middle of the plate  
(iii) Friction drag on one side of the plate

**OR**

- (a) State & Explain the Wien Displacement Law. Show that  $E_{b\lambda}$  will be maximum when  $\lambda_{\max} T = 2900 \mu\text{k}$  16
- (b) A thermos flask has a double walled bottle and the space between the walls is evacuated so as to reduce the heat flow. The bottle surfaces are silver plated and the emissivity of each surface is 0.03. If the contents of the bottles are at 110 °C. Find the rate of heat loss from the thermos bottle to the ambient air at 25 °C. What thickness of cork ( $k = 0.03 \text{ W/m-K}$ ) would be required if the same insulating effect is to be achieved by the use of cork ?

6. Attempt any two : 18

- (a) (i) Explain diffusion mass transfer and convective mass transfer by giving two examples of each.  
(ii) State and explain the Fick's law of diffusion.  
(iii) What are analogies between heat and mass transfer ?
- (b) A 30 mm deep pan is filled with water to a level of 16 mm and is exposed to dry air at 40 °C. Assuming the mass diffusivity as  $0.255 \times 10^{-4} \text{ m}^2/\text{s}$ , calculate the time required for all the water to evaporate. Partial pressure of water vapour for sat. temp. of 40 °C = 0.074 bar. Atmospheric pressure is 1.013 bar.
- (c) Write Von-karman integral momentum equation, for the hydrodynamic laminar boundary layer of fluid flowing over stationary plate. Using this equation, derive the expression for hydrodynamic boundary layer thickness considering the cubic velocity profile.