Code: 9A23501

R09

B.Tech III Year I Semester (R09) Supplementary Examinations December 2015

HEAT TRANSFER IN BIOPROCESSES

(Biotechnology)

Time: 3 hours Max. Marks: 70

Answer any FIVE questions

All questions carry equal marks

(Use of steam tables are permitted in the examination hall)

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1 (a) Explain the mechanism of heat transfer by convection. Discuss the governing equation.

(b) A flat furnace wall is constructed of a 100 mm layer of sil-o-cel brick with a thermal conductivity 0.138 W/m℃ backed by a 260 mm layer of common brick of thermal conductivity 1.38 W/m℃. The temperature of the inner face of the wall is 860℃, and that of the outer face is 69℃. What is the heat loss through the wall? What is the temperature of the interface between the refractory brick and the common brick?

2 (a) Derive the partial differential equation for one dimensional unsteady state heat conduction with constant surface temperature.

(b) A tube of 60 mm outer diameter is insulated with a 50 mm layer of silica foam, for which the conductivity is 0.055 W/m℃ followed with a 40 mm layer of cork with a conductivity of 0.05 W/m℃. If the temperature of the outer surface of the pipe is 120℃ and the temperature of the outer surface of the cork is 36℃, calculate the heat loss in watts per meter of the pipe.

3 (a) Identify the dimensionless groups for correlating the variables that influence forced convection heat transfer to a fluid flowing through a circular pipe.

(b) Ethylene glycol enters a 5 m length of 100 mm diameter hard drawn copper tube in a cooling system at a velocity of 5 m/s. What is the heat transfer rate if the average bulk fluid temperature is 20 ℃ and the tube wall is maintained at 100℃? At mean bulk temperature of 20℃, the fluid properties are v = 1.92 x 10^{-5} m^2/s, k = 0.249 W/m℃, Pr = 204.

4 (a) Prove by dimensional analysis for free convection Nusselt number is a function of Grashof and Prandtl numbers. State the assumptions made.

(b) Estimate the heat loss from a vertical wall exposed to nitrogen at one atmosphere and 5℃. The wall is 6 ft high and 8 ft wide. It is maintained at 49℃. For nitrogen at a mean film temperature of 27℃, $\rho = 1.14\ kg/m^3$, v = 1.563 x 10^{-5} m^2/s, k = 0.0262 W/m k, Pr = 0.713.

5 (a) Explain the different regimes of pool boiling with the help of schematic diagram. Give relevant equations for finding heat transfer coefficient in the different regimes.

(b) A vertical plate 6 ft high is maintained at 60℃ in the presence of saturated steam at atmospheric pressure. Estimate the heat transfer per unit width and the condensation rate per unit width. The parameters which will be required, with the condensate properties evaluated at the mean film temperature, 80 ℃ are: $\rho_1 = 974.176\ kg/m^3$, $C_{pl} = 4.196\ kJ/kg.k$, $\mu_1 = 3.541 \times 10^{-4}\ (N.s)m^2$, $k_1 = 0.668\ W/m\,k$, $h_{fg} = 2257.15\ kJ/kg, \rho_v = 0.0597\ kg/m^3$.

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6 (a) Discuss the general design of shell and tube heat exchanger with the help of neat schematic diagrams.

(b) In a double pipe counter flow heat exchanger, water at the rate of 0.6 kg/s is heated from 18℃ to 35℃ by an oil having a specific heat of 1.51 kJ/kg.k. The oil enters the exchanger at 93℃ and leaves at 60℃. Determine the heat exchanger area for an overall heat transfer coefficient of 270 W/m^2.K.

7 (a) Discuss how performance of a single effect evaporator is evaluated. Give the advantages and disadvantages of multiple effect evaporation.

(b) A solution of organic colloids in water is to be concentrated from 8 to 45 % solids in a single effect evaporator. Steam is available at a gauge pressure of 1.03 atm (120.5℃). A pressure of 102 mm Hg abs is to be maintained in the vapor space. The feed rate to the evaporator is 20,000 kg/h. The overall heat transfer coefficient can be taken as 2,800 W/m^2℃. The solution has negligible elevation in boiling point and a negligible heat of dilution. Calculate the steam consumption, the economy, and the heating surface required if the temperature of the feed is 51.7℃. The specific heat of the feed solution is 3.77 J/g.℃ and the latent heat of vaporization of the solution may be taken equal to that of water. Radiation losses may be neglected. Boiling point of water at 102 mm Hg is 52℃. The enthalpy of water vapor at 102 mm Hg is 2.596 kJ/kg.

8 (a) What are analogy equations? Discuss the analogy between heat, mass and momentum transfer.

(b) Give the general design of a continuous sterilizer.

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