Code: 9A23501

R9

B.Tech III Year I Semester (R09) Supplementary Examinations, May 2013

HEAT TRANSFER IN BIOPROCESSES

(Biotechnology)

Time: 3 hours Max Marks: 70

Answer any FIVE questions
All questions carry equal marks
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1 (a) What are the different modes of heat transfer? Give their governing equations.

(b) An annealing chamber has a composite wall made of 17 cm thick fire brick layer (k = 1.1 W/m ^oC) and 13 cm thick ordinary brick layer (k = 0.70 W/m ^oC). The inside and outside surface temperatures of the walls are 400 ^oC and 45 ^oC, respectively. Calculate the heat loss from 25 m^2 of furnace walls.

2 (a) Prove that heat rate equation for a cylinder takes the form $q = \frac{\Delta T}{B/kA}$ where A is logarithmic mean area.

(b) A cylindrical gas duct 0.5 m inside radius has an inner layer of fireclay bricks (k = 1.1 W/m ^oC) of 0.27 m thickness. The outer layer 0.14 m thick is made of a special brick (k = 0.92 W/m ^oC). The brick work is enclosed by an outer steel cover which has a temperature of 65 ^oC. The inside temperature of the composite cylindrical wall of the duct is 400 ^oC. Neglecting the thermal resistance of the steel cover; calculate the rate of heat loss per meter of the duct.

3 (a) Differentiate natural and forced convection with examples. Draw the schematic diagram of Colburn j factor versus Re and discuss the salient features of the plot.

(b) Warm water is required at the rate of 500 kg/h for washing filter cake, and it is decided to use a 25 mm steam heated tube for the purpose. The tube wall temperature is maintained at 130 ^oC by condensing steam on the outside surface. Calculate the heat transfer coefficient. The inner diameter of the tube is 21.2 mm. $\mu = 6.82 \times 10^{-4}$ kg/m.s, and k = 0.63 W/m ^oC, c_p = 4.174 kJ/kg ^oC. State the assumptions made.

4 (a) Prove that the coefficient of thermal expansion of an ideal gas equals the reciprocal of the absolute temperature.

(b) A furnace with a steel door having an inner lining of an insulating material is at a temperature of 65 ^oC. The door 1.5 m high and 1.0 m wide loses heat to an ambient at 25 ^oC. Calculate the rate of heat loss from the door at steady state. Use $Nu_f = 0.59\ (Gr\ Pr)_f^{0.25}$. The relevant properties of air at film temperature are: Pr = 0.695, v = 1.85 X 10^{-5} m^2/s and k = 0.028 W/m ^oC.

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5 (a) What are the different ways of vapor condensing on a cold surface? Compare them.

(b) A vertical square plate 30 cm by 30 cm is exposed to steam at atmospheric pressure. The plate temperature is 98 ºC. Calculate the heat transfer and the mass of steam condensed per hour. Properties of condensate at film temperature: ρ = 960 kg/m^3, μ = 2.82 X 10 $^{-4}$ kg/m.s, and k = 0.68 W/m ºC. At atmospheric pressure, saturation temperature of steam is 100 ºC and h_{fg} is 2255 kJ/kg.

6 (a) Derive the equation to find overall heat transfer coefficient for heat transfer between cylinder and fluids considering both convection coefficients.

(b) Calculate the overall heat transfer coefficient based on both inside and outside areas for the following case: Water at 12 ºC flowing in a ¾ inch 14 BWG condenser tube and saturated steam at 105 ºC condensing on the outside. h_i = 12 kW/m^2 ºC, h_o = 14 kW/m^2 ºC and k_m = 120 W/m ºC.

Condenser tube data:

Outer diameter inches	BWG Number	Wall thickness inches	Inside diameter inches
3/4	14	0.083	0.459

7 (a) What are the principal measures of the performance of steam heated tubular evaporators. Define each of them.

(b) An aqueous solution of a high molecular weight solute is concentrated from 5% to 40% at a rate of 100 m^3/day. The feed temperature is 25 ºC and the concentrated product leaves at its boiling point. Calculate the rate at which the heat must be supplied if evaporation occurs at one atmosphere. The density of feed is 1020 kg/m^3; specific heat of the feed 4.1 kJ/kg ºC and the specific heat of the product 3.9 kJ/kg ºC. Enthalpy of vapor generated at 100 ºC and one atmosphere pressure is 2680 kJ/kg.

8 (a) Write the analogy equations of heat, mass and momentum transfer.

(b) Write the principles in the design of continuous sterilizers.

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