Code :R7322303 **1**

III B.Tech II Semester(R07) Regular & Supplementary Examinations, April/May 2011
HEAT TRANSFER IN BIOPROCESSES
(Biotechnology)

Time: 3 hours **Max Marks: 80**

Answer any FIVE questions
All questions carry equal marks
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1. (a) Identify the various modes of heat transfer in the following cases.
   i. Loss of heat from a hot liquid, half full in thermos flask.
   ii. Heating of water in a bucket with immersion heater.
   iii. Condensation of steam in condenser.
   iv. Protection of body by warm clothing in winter.
   v. Heat transfer from an auto radiator.
   vi. Drying of a wet plate in atmosphere.

   (b) Derive an expression for steady state heat conduction through composite wall consisting of two layers.

2. (a) Explain briefly heat transfer through fins.

   (b) A steam pipe having an outside diameter of 2cm is to be covered with two layers of insulation, each having a thickness of 1 cm. The average conductivity of one material is 5 times that of the other, assuming that the inner and outer surface temperatures of the composite insulation are fixed, calculate by how much percentage the heat transfer will be reduced when the better insulating material is next to the pipe than when it is away from the pipe.

3. (a) Establish the relationship between the overall and individual film heat transfer coefficients.

   (b) Explain briefly applications of dimensional analysis.

4. A horizontal 40 W fluorescent tube which is 3.8 cm in diameter and 120 cm long stands in still air at 1 atm and 20^0 C. If the surface temperature is 40^0 C and radiation is neglected, what percentage of power is being dissipated by convection?
   $P = 1.1514 kg/m^3$, $\Pr = 0.706$,
   $k = 26.52X10^3 W/mK, v = 16.19X10^{-6} m^2/s$
   $Nu = 0.53(Gr.\Pr)^{1/4}$

5. (a) Write short notes on film boiling.

   (b) Explain the effect of pressure on maximum boiling heat flux and critical temperature drop.

6. Water at the rate of 15,000 kg/hr is heated from 50 to 65^0 C in a 1-2 shell and tube heat exchanger. The shell side fluid is water which enters at 90^0 C and flows at the rate of 7500 kg/hr. the overall het transfer coefficient is 1200 kcal/hr m^2 ^{0}C. If the correction factor for LMTD is 0.9, calculate the heat transfer area required.

7. (a) Write the important characteristics of evaporating liquids.

   (b) Write short notes on applications of evaporation.

   (c) Write merits and demerits of multiple effect evaporators compared to single effect evaporator.

8. (a) Define Prandtal number and Schmidt number.

   (b) Write the few analogies between heat and momentum transfer.

   (c) What are the different methods of air sterilization?

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Code :R7322303 **2**

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1. (a) Derive an expression for steady state heat conduction through compound resistances a series of a cylinder.
   (b) Explain in detail about the radiation with suitable examples.
2. (a) Tube 60 mm OD is insulated with a 50 mm layer of silica followed by 40 mm layer of cork. If the outer surface of pipe is 150^0C and steady state heat loss per unit is 30 w/m, calculate the outer surface temperature of cork. Thermal conductivity: Silica=0.055 w/m^{0}C; Cork =0.05w/m^{0}C.
   (b) Write short notes on unsteady state heat transfer.
3. (a) What is viscosity correction factor? When and where this factor is employed?
   (b) What is the effect of roughness of tube on heat transfer coefficient?
   (c) A thin plate, 2.5 m length and 1.5 m breadth, is exposed to a flow of air (2m/s) parallel to its surface. Calculate the coefficient of heat transfer from the plate to the air and the amount of heat transferred. The data is given as:
   Thermal conductivity of air at 20^0C=2.59X10^{-2} w/m^{0}C. The surface temperature of plate is 100^0C and the bulk temperature of air is 20^0C.
4. (a) Differentiate between natural convection and forced convection.
   (b) Write the important dimensionless numbers that are important in natural convection.
   (c) Write few situations that we will come across natural convection in day to day life.
5. (a) Draw heat flux versus temperature curve for pool boiling of saturated liquids and identify various points in it.
   (b) Explain in detail about the applications of condensation heat transfer.
6. (a) In a counter heat flow heat exchanger, the hot stream is cooled from 120 to 30^0C while the cold stream temperature changes from 20 to 60^0C. If the same exchanger was operated with parallel flow, what would be the exit temperature of the two streams?
   (b) Write short notes on 1-2 shell & tube type exchanger with neat sketch.
7. 5000 kg/hr of a 20% aqueous sodium hydroxide solution enters an evaporator with an inlet temperature of 333 K. It is concentrated to a product of 50% solids. Calculate the steam used, steam economy and the heating surface area using the following data.
   Overall heat transfer coefficient=1560 W/m^{2}K
   Temperature of saturate steam used=114.6^{0}C
   Latent heat of steam used =2214 kJ/kg
   Enthalpy of 20% NaoH at 60^0C=214kJ/kg
   Enthalpy of 50% NaoH at 90^0C=50kJ/kg
   Boiling point of 50% NaoH=90^0C
   Enthalpy of saturated steam 90^0C=2667kJ/kg
8. (a) Describe the process of continuous sterilization.
   (b) Explain briefly the important applications of heat transfer in bioprocess.

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1. (a) A plane wall 0.15 cm thick of a homogeneous material with k=0.40 W/m.K has steady and uniform temperatures $T_1=20^0$C and $T_2=70^0$C. determine the heat transfer rate in the positive x-direction per square meter of surface area.

   (b) Derive an expression for steady state heat conduction through compound resistances a series of a cylinder.

2. (a) Explain briefly unsteady state heat transfer in rectangular slabs with suitable equations to find the time required to each particular temperature.

   (b) Write short notes on heat transfer in extended surfaces.

3. (a) Discuss the advantages and limitations of Buckingham's Pi method over the other methods.

   (b) Crude oil at 160^0C is flowing through a 0.075 m diameter tube at the rate of 1600 kg/h. The pipe is 20 m long and its surface temperature is maintained at a temperature of 100^0C.
   The properties of oil are:
   Thermal conductivity is 0.1163 W/m^0K
   Kinematic viscosity is $5X10^{-6}$ m^2/s
   Density is 800 kg/m^3
   Pr=80
   μ at 160^0C =$4X10^{-3}$kg/m.s
   μ at 100^0C=$8.9X10^{-3}$kg/m.s

4. Estimate the heat loss from a vertical wall exposed to nitrogen at one atmosphere and 4^0C. The wall is 1.8 m high and 2.45m wide. It is maintained at 50^0C. For nitrogen at a mean film temperature the physical properties is as follows:
   $\rho = 101421 kg/m^3$ $\quad k = 0.02620 W/m.K$
   $v = 15.63X10^{-6} m^2/s$ Pr = 0.713

5. (a) A vertical square pipe (0.4mX0.4m) is exposed to steam atmospheric pressure. The wall temperature is 96^0C. Calculate the heat transfer coefficients of condensate film. The physical properties are viscosity $0.6X10^{-3}$kg/ms. Density 960kg/m^3. Thermal conductivity 0.62w/m^0C. Latent heat of condensation $2X10^6$J/kgK.

   (b) Explain why higher heat transfer rates are experienced in drop-wise condensation than in film condensation.

6. (a) Draw a 1-2 pass shell and tube heat exchanger. Mention all the important parts. Indicate the temperature profiles.

   (b) Explain co-current and counter current operations with temperature profiles.

7. An evaporator is being operated at atmospheric pressure. It is desired to concentrate the feed from 5% solute to 20% solute (by weight) at a rate of 5000Kg/h. Dry saturated steam at a pressure corresponding to saturation temperature of 399 K is used. The feed is at 298K. Boiling point rise may be neglected. Overall heat transfer coefficient is 2350 W/m^2K. Calculate the economy of evaporation and area of heat transfer to be provided? Treat the solution as pure water and neglected BPR.
   Data:
   Latent heat of condensation of steam at 399K=2185KJ/Kg.
   Latent heat of vaporization of water at 101.325Kpa and 373K=2257KJ/Kg
   Specific heat of feed=4.287KJ/Kg.

8. (a) Describe the process of batch sterilization.

   (b) Describe thermal sterilization methods for heat labile components in the culture media.

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1. (a) Write few situations for heat by conduction.
   (b) Determine the steady state rate of heat transfer per unit area through a 4.0 cm thick homogeneous slab with its two faces maintained at uniform temperatures of 38^0C and 21^0C. The thermal conductivity of the material is 0.19 W/m.K.
   (c) Write the effect of temperature on thermal conductivity of gases and liquids.
2. (a) Differentiate between log mean radius and arithmetic radius. When these two are equal?
   (b) Explain briefly unsteady state heat transfer in rectangular slabs with suitable equations to find the time required to reach particular temperature.
3. (a) Explain Buckingham's Pi theorem of dimensional analysis.
   (b) Cold water at the rate of 4kg/s is heated from 30^0C to 50^0C in a single shell and two tube pass heat exchanger. Heating medium is hot water supplied at 95^0C at the rate of 2 kg/s. Cold water flows through the tubes. The overall heat transfer coefficient is 1330 W/m^2 ^{0}C. The average water velocity is 0.38 m/s inside the tubes. The diameter of tube is 2cm. calculate.
   (i) Number of tubes in each pass.
   (ii) Length of tube in each pass.
   Take specific heat of water to be constant at 4.17 kJ/kg.K
4. A vertical plate at 180^0 C is 30 cm wide and 50 cm high and rests in still air at 1 atm and 20^0C. Estimate the rate of heat transfer from the plate. Pr=0.692; v=23.44X$10^{-6}$$m^2$/s; and k=31.75X$10^{-3}$ w/mK. For this situation Nu_X=0.508 $Pr^{1/2}(0.952+4.85)^{-1/4}Gr^{-1/4}$.
5. (a) Explain the merits and demerits of dropwise and filmwise condensations.
   (b) Saturated steam under atmospheric pressure condenses on a vertical plate of 100 cm high. If the surface temperature is 80^0C, calculate the heat flow per hour per hour per meter width of the plate and the rate of condensation per hour. The properties of water at 90^0C are?
6. (a) What do you mean by fouling of heat exchangers? Give some remedies.
   (b) Explain briefly 2-4 heat exchanger with neat sketch.
7. A solution of organic colloids is to be concentrated from 20 to 70 percent solids, in a vertical tube evaporator. The specific heat of the feed is 0.92. saturated steam at a gauge pressure of 19 kgf/m^2 (125^0C) is available. A pressure of 2.3 psia is to be maintained in the vapor space (55^0C). The feed enters at 25^0C. The overall heat transfer coefficient is 1500 w/m^2 K. The unit must evaporate 25000 kg of water/hr. The solution has negligible elevation in boiling point. Radiation losses may be neglected. Calculate steam consumption, the economy and heating surface required.
   $\lambda_s = 2500 kJ/kg$
   $\lambda = 2600 kJ/kg$
   Density =965.3kg/m^3
8. (a) What are the various methods of sterilization?
   (b) Write the importance of sterilization in bio-processing.

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