**B.E Food Technology and Biochemical Engineering**
**Second Year, Second Semester 2017**

**Subject: HEAT TRANSFER** **Time: 3 hrs** **Full Marks : 100**

## PART I ( 60 Marks)

**Use separate answer script for each part**
**Answer any three questions**

1.(a) Derive an expression for simultaneous conduction and convection through a plane wall on either side of which are fluids at different temperatures. 10

(b) A thick walled tube of stainless steel (k=21.6 W/mK) with dimensions of 0.028 m internal diameter and 0.0630 m outer diameter is covered with a 0.0254 m thick layer of insulation (k= 0.02423 W/mK). The inside wall temperature of the pipe is 810 K and the outside surface of insulation is at 310K. For a 0.305 m length of pipe, calculate the heat loss and also the temperature ar the interface between the metal and the insulation. 10

2.(a)What is meant by critical thickness of insulation? Deduce an expression for the critical thickness considering hot fluid flowing through an insulated pipe which is exposed to ambient air. 2+8

(b) Steam at 100°C condenses on the outside of a tube (thermal conductivity = 185 W/mK) through which water flows at a velocity such that the tube side film heat transfer coefficient is 4200 $W/m^2K$. The film heat transfer coefficient for condensing steam may be assumed to be 10,300 $W/m^2K$. The tube is 6 m long, has an external diameter of 25 mm and wall thickness is 1 mm. If the mean temperature of water is 20°C, calculate the rate of heat transfer to the water. 10

3.(a) In food industry, what are the reasons of fouling when various types of fluids flow through pipelines. How can they be minimized? 6+2

(b) Water flowing at a velocity of 2 m/s in a 0.032 m diameter tube is heated to a mean bulk temperature of 30°C. Determine the film heat transfer coefficient using the Dittus-Boelter equation.
Data: At 30°C, for water –
$\rho = 995.6\ kg/m^3$, $\mu = 7.97X10^{-4}$ Pa.S, $C_p = 4197$ J/kg K, k = 0.618 W/mK 12

4.(a) While deriving a correlation by dimensionless analysis by Buckingham Pie method, what are the three rules to be applied while selecting the group of core variables? 5

(b) For unsteady state conduction in a solid the following variables are involved: $\rho$, $C_p$, L (dimension of solid), t, k and z (location in solid). Determine the dimensionless groups relating the variables. The symbols have their usual meanings. 15

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B.E. FOOD TECHNOLOGY AND BIO-CHEMICAL ENGINEERING

SECOND YEAR SECOND SEMESTER - 2017

HEAT TRANSFER

Time: 3 hours FM: 100

Part: II

(Answer any two questions: 20x2=40)

1. In a steam jacketed pan explain the position of steam inlet pipe and water outlet pipe.
Steam condensing on a vertical tube 0.45 m long having an outer diameter of 0.035 m and a surface temperature of $87^0$ C. If steam saturated at 70.1 kPa, calculate the average heat-transfer coefficient using SI units. Use the following data for properties of water and steam
$T_{sat}$ =$90^0$ C, $h_{fg}$ = $2.283x10^6$ J/kg, $\rho_l$ =966.7 kg/$m^3$, $\rho_v$ =0.391 kg/$m^3$, $\mu_l$ = $3.24x10^{-4}$ Pa.s, $\kappa_l$ =0.675 W/m.K.

5+15=20

2 Edible oil is to be cooled in a double-tube counter-flow heat exchanger. The copper inner tubes have a diameter of 2 cm and negligible thickness. The inner diameter of the outer tube is 3.2 cm. Water flows through tube at a rate of 0.5 kg/s, and the oil through the shell at a rate of 0.79 kg/s. taking the average temperature of water and the oil to be $45^0$C and $80^0$C, respectively, determine the overall heat transfer coefficient of this heat exchanger.
The properties of oil and water is constant and as follow
For water: $\rho$ =990 kg/$m^3$, $\kappa_l$ =0.637 W/m.K., $v=\mu/\rho= 0.602x10^{-6}$ $m^2$ /s, $P_r$ = 3.91
For sunflower oil: $\rho$ =852 kg/$m^3$, $\kappa_l$ =0.138 W/m.K., $v=\mu/\rho= 3.794x10^{-6}$ $m^2$ /s, $P_r$ = 499.3
$Nu_i$ for corresponding Di/Do = 0.625 is 5.42
Discuss how do fouling factor affects heat transfer. 16+4=20

3. a) Explain flow pattern of plate heat exchanger with net sketch.

b) With neat sketches explain the life history of a bubble in a boiling liquid

c) Draw a curve to explain heat transfer during pool boiling phenomenon on horizontal wire at atmospheric pressure.

d) Perfectly pure liquid in contact with flat heating surface requires infinite time to start boiling-explain.

e) Discuss how regeneration of energy takes place in plate heat exchanger?

(4x5=20)

(All symbol carry its usual meaning, relevant assumption can be made)