BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE - PILANI
Department of Chemical Engineering, Pilani Campus, Rajasthan
II Semester 2017-2018
CHE F241 Heat Transfer

Comprehensive Examination (Closed Book + Open Book) **Date: 5.05.2018**
Duration: (90 + 90) Mins **Marks: 120**

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Duration: 90 minutes **Part – A (Closed Book)** **Maximum Marks: 60**

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Q.1 **[4 x 7 = 28]**

i. Compare the shell side equivalent diameter (hydraulic diameter) for the triangular and square pitch arrangement of tubes having OD = 19.05 mm, ID = 14.83 mm, Length = 5 m and pitch = 23.81 mm. Also compare the shell side cross flow area for the triangular and square pitch arrangement of tubes.

ii. For the natural convection vertical heated flat plate system (Wall temperature = T_w; Free stream fluid temperature = T_∞), Verify the temperature profile given below using appropriate boundary conditions.

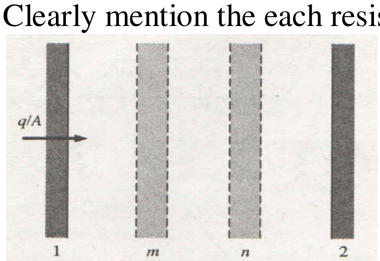
$$\frac{T - T_\infty}{T_w - T_\infty} = \left(1 - \frac{y}{\delta}\right)^2$$

Where, y = distance from the wall and δ = boundary layer thickness.
Using the above temperature profile, find the relation of Nusselt number with boundary layer thickness.

iii. Write the formula, physical significance and application of the following non dimensional numbers with proper nomenclature. Write your answers in a table form.

a. Grashof Number   c. effectiveness of heat exchanger
b. Prandtl Number   d. NTU

iv. Draw the thermal radiation network for two absorbing and transmitting medium between parallel walls. Clearly mention the each resistance in terms of appropriate variables.



Q 2 **[16]**

Two rectangles 50 by 50 cm are placed perpendicularly with a common edge. One surface is at 1000 K and has emissivity of 0.6, while the other surface (T_2 = 600 K) is insulated and in radiant balance with a large room. Determine the temperature of the room and the heat lost by the surface at 1000 K. Consider the radiation shape factor between two rectangles as 0.2 and Stefan Boltsmann's constant = 5.669 x 10^{-8} W/m^{2}K^4.

Q 3 **[16]**

A counter flow double pipe heat exchanger is used to heat 70 kg/s of water from 35 to 90 °C with an oil flow of 95 kg/s. The oil has a specific heat of 2.1 kJ/kg °C and enters the heat exchanger at a temperature of 175 °C. The overall heat transfer coefficient is 425 W/m^2°C. Calculate the area of the heat exchanger. If the flow rate of the water is reduced in half with the entrance temperatures of both the fluids remaining the same. What are the exit temperatures of both fluids under these new conditions and how much heat transfer rate reduced?

Table 10-3 | Heat-exchanger effectiveness relations.

$N = \text{NTU} = \dfrac{UA}{C_{min}}$ $\quad C = \dfrac{C_{min}}{C_{max}}$

Flow geometry	Relation
Double pipe:	
Parallel flow	$\epsilon = \dfrac{1 - \exp[-N(1+C)]}{1+C}$
Counterflow	$\epsilon = \dfrac{1 - \exp[-N(1-C)]}{1 - C\exp[-N(1-C)]}$
Counterflow, $C = 1$	$\epsilon = \dfrac{N}{N+1}$
Cross flow:	
Both fluids unmixed	$\epsilon = 1 - \exp\left[\dfrac{\exp(-NCn) - 1}{Cn}\right]$ where $n = N^{-0.22}$
Both fluids mixed	$\epsilon = \left[\dfrac{1}{1-\exp(-N)} + \dfrac{C}{1-\exp(-NC)} - \dfrac{1}{N}\right]^{-1}$
C_{max} mixed, C_{min} unmixed	$\epsilon = (1/C)\{1 - \exp[-C(1 - e^{-N})]\}$
C_{max} unmixed, C_{min} mixed	$\epsilon = 1 - \exp\{-(1/C)[1 - \exp(-NC)]\}$
Shell and tube:	
One shell pass, 2, 4, 6, tube passes	$\epsilon = 2\left\{1 + C + (1+C^2)^{1/2} \times \dfrac{1 + \exp[-N(1+C^2)^{1/2}]}{1 - \exp[-N(1+C^2)^{1/2}]}\right\}^{-1}$
Multiple shell passes, $2n$, $4n$, $6n$ tube passes ($\epsilon_p =$ effectiveness of each shell pass, $n =$ number of shell passes)	$\epsilon = \dfrac{[(1-\epsilon_p C)/(1-\epsilon_p)]^n - 1}{[(1-\epsilon_p C)/(1-\epsilon_p)]^n - C}$
Special case for $C = 1$	$\epsilon = \dfrac{n\epsilon_p}{1 + (n-1)\epsilon_p}$
All exchangers with $C = 0$	$\epsilon = 1 - e^{-N}$

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Q.1 **[10]**

Air at 400 K and 1 atm is forced in horizontal tube of 2.5 cm diameter tube 15 cm long. Calculate total heat transfer rate, where tube wall temperature is 600 K and flow velocity is 5 cm/s, including free convection effects.

Q.2 **[15]**

A triple effect evaporator is to be used to produce a 60 percent NaOH solution from a feed containing 15 percent NaOH. Steam is available at 280 °F, and the vapor from the last stage is condensed at 100 °F. Backward feed is used. If equal amounts of water are removed in each effect, find the followings:

a. the concentrations in the intermediate effects,
b. the boiling point elevation in each effect, and
c. the net temperature differences available for heat transfer

Assume 150 °F, 125 °F, and 100 °F as the boiling temperatures of water at the pressures in effects 1, 2, and 3.

Q3 **[25]**

A newly build shell and tube heat exchanger operates with two shell passes and four tube passes. The shell fluid is ethylene glycol, which enters at 100 °C and leaves at 60 °C with a flow rate of 30000 kg/hr. Water flows in the tubes, entering at 35 °C and leaving at 75 °C. The overall heat transfer coefficient for this arrangement is 425 W/m^2 °C.

a. Calculate the flow rate of water required and the area of the exchanger.
b. What should be the shell side cross flow area? (Tube details: 4 pass, 20 mm o.d., 16 mm i.d., 4.88m long tubes with triangular pitch arrangement; Shell details: 2 pass, split-ring floating head)
c. After six months of the operation, the flow rate of the glycol is reduced in half with the entrance temperature of the both fluids remaining the same. What is the water exit temperature under these new conditions? (Fouling factors for the glycol and water is 0.00005 and 0.0002 m^2/ °C W respectively).

Q 4 **[10]**

Condensing carbon dioxide at 20 °C is in contact with a horizontal 10 cm diameter tube maintained at 15 °C. Calculate the condensation rate per meter of length if h_{fg} = 153.2 kJ/kg at 20 °C.