BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2009-2010
CHE C351 HEAT TRANSFER OPERATIONS

COMPREHENSIVE EXAMINATION

DATE: 28-12-09
DURATION: 3 hours **MAXIMUM MARKS: 35**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1(a) A current of 325 amperes passes through a stainless steel wire of 2.5 mm diameter and k = 12 W/mK. The resistivity of the wire is 70 X 10^{-8} Ωm and the length of the wire is 1.2 m. If the wire is submerged in a fluid maintained at 45 ^{o}C and the convective heat transfer coefficient at the wire surface is 4000 W/m^{2}K, calculate the steady state temperature at the center and at the surface of the wire. [4]

1(b) A very long 6-mm diameter copper rod (k = 320 W/mK) extends horizontally from a plane heated wall at 100 ^{o}C. The temperature of the surrounding air is 20 ^{o}C and convective heat transfer coefficient is 12 W/m^{2}K.
(a) Determine the heat loss.
(b) How long the rod should be in order to be considered infinite? [4]

1 (c) The insulation boards for air conditioning purposes are made of three layers, middle being of packed glass 10 cm thick (k = 0.03 W/m.K) and the sides are made of plywood each of 5 cm thickness (k = 0.12 W/m.K). The outermost surface is at 45 ^{o}C and the innermost surface is at 20 ^{o}C. Determine the heat flow per unit area. Also calculate the interface temperatures. [5]

2 A solid copper sphere of 10 cm diameter (density = 8950 kg/m^{3}, heat capacity = 390 J/kg.K, thermal conductivity = 340 W/m.K), initially at a uniform temperature of 450 ^{o}C, is suddenly immersed in a fluid maintained at 35 ^{o}C. The heat transfer coefficient between the sphere and the fluid is 200 W/m^{2}.K. Determine the temperature of the copper block 2 minutes after immersion. [3]

3 Consider two large parallel plates, one at 1000 K with emissivity 0.8 and the other at 500 K having emissivity 0.6. A radiation shield is placed between them. The shield has emissivity 0.1 on the side facing hot plate and 0.3 on the side facing cold plate. Calculate the percent reduction in radiation heat transfer as a result of radiation shield. [4]

4 Air is flowing over a flat plate 10-m long and 2-m wide (maintained at 90 ^{0}C) with a velocity of 1.5 m/s at 25 ^{0}C. If Pr = 0.7, density = 1.27 kg/m^3, and kinematic viscosity = 1.45 X 10^{-5} m^2/s, k = 0.025 W/m.K,

(a) Calculate the length of the plate over which the boundary layer is laminar,

(b) Calculate the laminar boundary layer thickness at the point of transition, using Blausius' exact solution,

(c) Calculate the thickness of the thermal boundary layer at this point, assuming that the plate is being heated over its entire length.

(d) Average heat transfer coefficient. [6]

5 A vertical plate 0.6 m high and maintained at 25 ^{0}C is exposed to saturated steam at atmospheric pressure. Calculate the rate of heat transfer, and the condensate rate per hour per meter of the plate width for film-wise condensation. [4]

The properties of water film at the mean temperature are:
Density = 985.0 kg/m^3, thermal conductivity = 66.4 X 10^{-2} W/m.K,
Viscosity = 620 X 10^{-6} kg/m.s, h_{fg} = 2260 kJ/kg.
Assume vapor density is small compared to that of the condensate.

6 A counter flow heat exchanger is used to cool p-xylene from 130 ^{0}C, having a flow rate of 90,000 kg/h. In the same exchanger benzene is heated from 20 ^{0}C. The benzene flow rate is 100,000 kg/h. The overall heat transfer coefficient is 550 W/m^{20}C. In addition, following data is available:

Data:

	Properties	**Benzene**	**p-xylene**
1	Molecular formula	C_6H_6	$C_6H_4(CH_3)_2$
2	Molar mass	78.11 g/ mol	106.16 g/mol
3	Boiling point	80.1 °C	138 °C
4	Density	0.8765 g/cm^3	0.86 g/cm^3
5	Heat capacity	134.8 J/(mol K)	181.7 J/(mol K)
6	Thermal conductivity	0.16 (W/mK)	0.1216 16 (W/mK)
7	Viscosity	0.0652 kg·m^{-1}·s^{-1}	0.034 kg·m^{-1}·s^{-1}

Calculate the outlet temperature of p-xylene achievable in this exchanger. Also calculate exchanger duty. Heat exchanger area = 90 m^2. [5]

*** END OF PAPER ***

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
First SEMESTER 2009-2010

CHE C351: Heat Transfer Operations

TEST – II (Open Book)

DATE: 13.12.2009

DURATION: 50 MINUTES MAXIMUM MARKS: 15

Note: Attempt ALL questions. Make suitable design decisions wherever necessary, and mention them clearly. Do not alter any given data.

Question 1 [6 Marks]

Ambient air at 20 ^{O}C flows past a flat plate at 3 m/s. The plate is heated uniformly throughout its entire length and is maintained at a surface temperature of 40 ^{O}C. Calculate the distance from the leading edge at which the flow changes from laminar to turbulent.

Calculate following parameters at the location determined above:

a) Thickness of the hydrodynamic and thermal boundary layers, using Blausius' exact solution.
b) Local and average heat transfer coefficients.

Properties of air at mean temperature are:

Density = 1.2 kg/m^3, heat capacity = 1.01 kJ/kg.K,

Thermal conductivity = 0.031 W/m.K, viscosity = 2.286 X 10^{-5} kg.m/s

Question 2 [5 Marks]

In a heat exchanger oil (C_p = 3 kJ/kg.^{O}C) at a rate of 1400 kg/h is cooled from 100 ^{O}C to 30 ^{O}C by water that enters at 20 ^{O}C at a rate of 1300 kg/h. If the overall heat transfer coefficient is 350 J/m^2.^{O}C, calculate the heat exchanger area when the exchanger is a) parallel flow, b) counter flow.

Question 3 [4 Marks]

A vertical plate 30 cm wide and 1.2 m high is maintained at 80 ^{O}C and is exposed to saturated steam at 1 atmospheric pressure. Calculate the heat transfer and the total mass of steam condensed per hour.

The properties of water film at the mean temperature are:

Density = 970 kg/m^3, thermal conductivity = 66.4 X 10^{-2} W/m.K,

Viscosity = 414 X 10^{-6} kg/m.s, h_{fg} = 2257 kJ/kg.

Assume vapor density is small compared to that of the condensate.

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2009-2010

CHE C351 Heat Transfer Operations

TEST - 1

(Closed Book)

DATE: 25.10.2009

DURATION: 50 MINUTES **MAXIMUM MARKS: 15**

Note: Attempt ALL questions. Mention appropriate units in your answers. Without units, the answer will not be deemed as correct, even if the numerical value is correct.

1 A furnace wall consists of 3 layers: 13.5 cm thick inside layer of fire brick, 7.5 cm thick middle layer of insulating brick, and 11.5 cm thick outside layer of red brick. The furnace operates at 870 ^{o}C and outside wall temperature of outermost layer is maintained at 40 ^{o}C. Find the rate of heat loss from the furnace and the wall interface temperatures. [2+3= 5]

Data: Fire-brick, k_1 = 1.2 W/m.K
Insulating brick, k_2 = 0.14 W/m.K
Red-brick, k_3 = 0.85 W/m.K

2 A 66-kV transmission line is 20 mm in diameter. The surroundings are at 38 ^{o}C and the convective heat transfer coefficient is 14.2 W/m^2.K. If the rate of heat transfer per unit volume of the wire is 0.1726 MW/m^3, calculate:
(a) Surface temperature of the wire,
(b) Maximum temperature in the wire.
Given thermal conductivity of wire material = 380 W/m.K [1.5+1.5= 3]

3 Consider two fins of same volume but different shapes made of steel. One fin is 20 mm X 4 mm X 5 mm while the other is 20 mm X 2 mm X 10 mm. Assume fin tip to be insulated. Other data are same for both fins and are given below:

$k = 30$ W/m.K $\quad h = 50$ W/m^2.K $\quad T_o = 100$ °C $\quad T_\infty = 30$ °C

Compare the performance of these fins by computing:
a) The rate of heat dissipation,
b) Fin efficiency. [5]

4 During a heat treatment process, spherical steel balls of 12 mm diameter and at 540 ^{o}C are cooled to 100 ^{o}C by keeping them immersed in oil bath at 25 ^{o}C. If the time required for this cooling is 2 minutes, find the convective heat transfer coefficient between steel and oil. Assume Lumped System Analysis to be applicable. [2]
Data:
Density = 7750 kg/m^3, specific heat = 520 J/kg.K,
Thermal conductivity = 50 W/m.K

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2009-2010

CHE C351 HEAT TRANSFER OPERATIONS

QUIZ - 2 (Closed Book)

DATE: 25/11/2009

DURATION: 20 MINUTES **MAXIMUM MARKS: 7**

Name of the student: -------------------------------- I.D.: -----------------------

NOTE: ATTEMPT ALL QUESTIONS. Do rough work on the back of this sheet.

Question 1. Consider the following exchanger data: [1 + 1 = 2]

Flow arrangement	Fluid	Flow rate, kg/s	Heat capacity, J/kg.°C	Inlet temperature, °C	Outlet temperature, °C
Counter flow	Oil	12.5	2500	95	40
	Toluene	17.5	3150	25	?

Calculate:

Outlet temperature of toluene =

Heat load of the exchanger =

Question 2. Consider the following exchanger data: [1 + 2 = 3]

Flow arrangement	Fluid	Flow rate, kg/s	Heat capacity, J/kg.°C	Inlet temperature, °C	Outlet temperature, °C
Parallel flow	Methanol	3.5	2200	28	60
	Hot water		4200	95	65

Overall heat transfer coefficient, $U = 550\ W/m^2.K$

Calculate:

Hot water flow rate =

The heat transfer area of the exchanger =

Question 3. Inside the tube of an exchanger, Re = 20 000, and Pr = 5.0. If Sieder-Tate equation coefficient, C = 0.023, and viscosity correction is neglected, what is the value of Nu? [2]

Answer: Nu =

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BITS, PILANI – DUBAI

FIRST SEMESTER 2009 – 2010

Course Code: CHE C351 **THIRD YEAR** **Date: 07/10/2009**
Course Title: HEAT TRANSFER OPERATIONS **Max Marks: 8**
Duration: 20 minutes **Weightage: 8%**

Name: . . . . ID No: . . . .

QUIZ - 1

(Closed Book)

Instructions: Attempt all questions. Tick (√) the correct option.

Q	1	2	3	4	5	6	7	8	9	10	11
Marks	0.5	1.0	0.5	0.5	0.5	1.0	0.5	0.5	0.5	0.5	2.0

1. Thermal diffusivity, α, has the units of

   a) J/s.^{o}C b) J/m^2 c) m^2/s d) W/m^3

2. In Fourier equation, heat transfer rate is proportional to:

   a) A, ΔT, 1/x b) 1/A, ΔT, 1/x c) A, ΔT, x d) 1/A, ΔT, x

   Where, A= area of cross section for heat flow; ΔT= temperature difference; x= thickness.

3. In Newton's law of cooling, the heat transfer rate is proportional to:

   a) k/h b) ΔT/h c) AΔT d) ΔT/A

4. A pipe is insulated such that the outer radius of the insulation is less than the critical radius. Now the insulation is taken off. Will the rate of heat transfer from the pipe increase for the same pipe surface temperature?

   a) increase
   b) decrease
   c) will remain same
   d) will increase or decrease depending on the thermal conductivity of insulation

5. For heat generation within a cylinder, the wall temperature is given by:

   a) $T_w = T_\infty + \frac{\dot{q}R}{2h}$ b) $T_w = T_0 + \frac{\dot{q}R^2}{4k}$

   c) $T_w = T_\infty - \frac{\dot{q}R}{2h}$ d) $T_w = T_0 - \frac{\dot{q}R^2}{4h}$

6. With increasing the fin length,

   a) Fin effectiveness decreases and fin efficiency increases
   b) Fin effectiveness increases and fin efficiency decreases

c) Fin effectiveness decreases and fin efficiency is not affected

d) Fin effectiveness and fin efficiency both increase

7. The fin parameter m is defined as:

a) $\sqrt{\frac{hA}{kP}}$ b) $\sqrt{\frac{kA}{hP}}$ c) $\sqrt{\frac{hP}{kA}}$ d) $\sqrt{hPkA}$

8. The ratio of heat transfer from a finite length fin with insulated tip to a very long fin is given as,

a) $\tanh mL$ b) $\frac{\tanh mL}{mL}$ c) $\frac{1}{mL}$ d) $\sqrt{hPkA}$

9. Consider heat transfer between two identical solid bodies and the air surrounding them. The first solid is being cooled by a fan, while the second one is allowed to cool naturally. For which solid is L.S.A. to be more applicable?

a) Solid cooled by fan
b) Solid cooled naturally

10. Consider heat transfer between two identical hot solid bodies and their environments. The first solid is dropped in a large container filled with water, while the second one is allowed to cool naturally in the air. For which solid is the L.S.A. more likely to be applicable?

a) Solid dropped in water
b) Solid cooled naturally

11. Consider a medium in which the heat conduction equation is given in its simplest form as,

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}=\frac{1}{\alpha}\frac{\partial T}{\partial t}.$$

(i) Is heat transfer steady or transient?

a) steady b) transient

(ii) Is heat transfer one-, two-, or three-dimensional?

a) one-dimensional b) two-dimensional c) three-dimensional

(iii) Is there heat generation in the medium?

a) Yes b) No

(iv) Is the thermal conductivity of the medium constant or variable?

a) constant b) variable

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