BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

FIRST SEMESTER 2010-2011

CHE C351 HEAT TRANSFER OPERATIONS

COMPREHENSIVE EXAMINATION

DATE: 28-12-10

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 spherical vessel of 50 cm outside diameter is insulated with 20 cm thickness of insulation (k = 0.04 W/m^{o}C). The surface temperature of the vessel is -195 ^{o}C and outside air is at 10 ^{o}C. Calculate the heat loss. [2]

1 (b) A slab of 12 cm thickness and generating heat uniformly at 1 MW/m^3 has thermal conductivity = 200 W/m^{o}C. Both surfaces of slab are maintained at 150 ^{o}C. Determine the maximum temperature and its location. [2]

2 An array of 10 fins (k = 180 W/m^{o}C) is used to cool a transistor in an environment with h = 12 W/m^{o}C and ambient temperature 350 ^{o}C. Each fin is 3 mm wide X 0.4 mm thick X 5 mm long and has base temperature 60 ^{o}C. Assume fin-tips to be insulated.

(a) Determine the power dissipated by the fin array.

(b) What is the efficiency of each fin?

(c) Now, if the length of each fin is doubled, what will be the power dissipated? [4+1=1=6]

3 A 12-mm diameter steel sphere (k = 42.5 W/m^{o}C) is exposed to air at 27 ^{o}C with h = 114 W/m^{2o}C. Determine:

(a) Time required to cool the sphere from 540 ^{o}C to 95 ^{o}C?

(b) Total heat transferred during this period. [3+1=4]

Given: density = 7850 kg/m^3, heat capacity = 475 J/kg^{o}C,

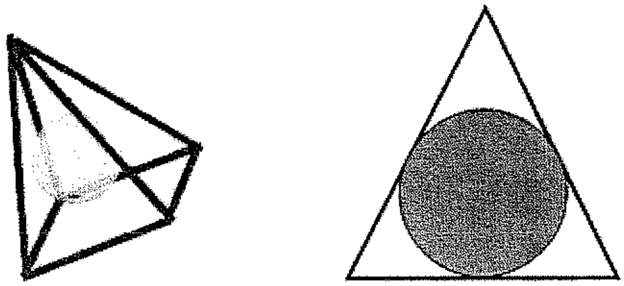
Thermal diffusivity = 1.2 X 10^{-5} m^2/s

4 A furnace emits radiation at 2000 K. Treating it as blackbody radiation, calculate: (a) monochromatic radiation flux at 1 micron wavelength, (b) total emissive power. Given Planck's Law equation,

$$E_{b,\lambda} = \frac{C_1 \lambda^{-5}}{\exp\left(\frac{C_2}{\lambda T}\right) - 1}$$

where $C_1 = 0.374 \times 10^{-15}$, $C_2 = 1.4388 \times 10^{-2}$ [1+1=2]

5 (a) Calculate all the shape factors for the configuration shown below (a sphere of diameter d inside an equilateral pyramidical box of length l = 2d). [3]



5 (b) Determine the net radiation heat exchange (per unit area) between two very large parallel plates held at 800 K and 500 K. emissivity is 0.6 for the hot plate and 0.4 for the cold plate. [2]

6 Air is flowing over a flat plate 5-m long and 2.5-m wide with a velocity of 2.5 m/s at 15 ^{o}C. If Pr = 0.7, density = 1.20 kg/m^3, and kinematic viscosity = 1.5 X 10^{-5} m^2/s, calculate

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

(b) Laminar boundary layer thickness at the point of transition,

(c) The thickness of the thermal boundary layer at the point of transition,

(d) Average heat transfer coefficient. [4]

7 (a) In a double pipe heat exchanger oil (C_p = 2.1 kJ/kg.^{o}C) at a rate of 90000 kg/h is cooled from 130 ^{o}C to 60 ^{o}C by water (C_p = 4.2 kJ/kg.^{o}C) that enters at 20 ^{o}C and leaves at 45 ^{o}C. If the overall heat transfer coefficient is 350 J/m^2.^{o}C, calculate the heat exchanger area when the exchanger is (i) parallel flow, (ii) counter flow. [4]

7 (b) In the counter-flow exchanger design in 7 (a) above, 60000 kg/h oil enters at 130 ^{o}C and 75000 kg/h water enters at 20 ^{o}C. What will be the outlet temperatures of oil and water achievable in this exchanger? [6]

*** END OF PAPER ***

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

First SEMESTER 2010-2011

CHE C351: Heat Transfer Operations

TEST – II (Open Book)

DATE: 05.12.2009

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]

Air at atmospheric pressure and 20 ^{o}C flows past a flat plate at 4 m/s. The plate is heated uniformly throughout its entire length and is maintained at a surface temperature of 60 ^{o}C. At 40 cm distance from the leading edge, calculate:

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

Properties of air at mean temperature are:

Density = 1.2 kg/m^3, heat capacity = 1.0 kJ/kg.K,

Thermal conductivity = 0.08 W/m.K, viscosity = 2.2 X 10^{-5} kg.m/s

Question 2 [4 Marks]

A vertical plate 30 cm wide and 1.5 m high is maintained at 70 ^{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 = 972 kg/m^3, thermal conductivity = 0.66 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.

Question 3 [5 Marks]

3000 kg/h of water is heated from 30 ^{o}C to 70 ^{o}C by pumping it through a heated pipe of 25 mm diameter. If the surface of the heated pipe is maintained at 110 ^{o}C, calculate:

a) heat transfer coefficient,
b) Length of the pipe, and
c) Rate of heat transfer from pipe to water.

Thermo-physical properties of water at mean bulk temperature (50 ^{o}C) are:

Density = 972 kg/m^3, viscosity = 0.355 X 10^{-3} kg/m.s

Thermal conductivity = 0.7 W/m.^{o}C, heat capacity = 4200 J/kg.^{o}C

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

First SEMESTER 2010-2011

CHE C351: Heat Transfer Operations

TEST – I (Closed Book)

DATE: 24.10.2010

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.**

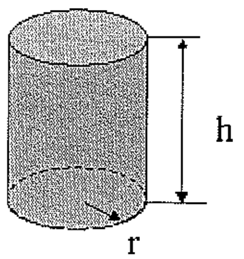
1 A thick-walled tube of stainless steel with 2-cm inner diameter and 4-cm outer diameter is covered with a 5-cm layer of insulation (k = 0.25 W/mK). If the inside wall temperature of the pipe is maintained at 740 ^{O}C, calculate the heat loss per meter of length. Also calculate the tube-insulation interface temperature. The temperature at the outside of insulation is 100 ^{O}C. Thermal conductivity of steel is 20 W/mk. [2+2=4]

2 A very long 4-mm diameter copper rod (k = 280 W/mK) extends horizontally from a plane heated wall at 100 ^{O}C. The temperature of the surrounding air is 25 ^{O}C and convective heat transfer coefficient is 15 W/m^{2}K. Determine the heat loss from the rod. [3]

3. A steel sphere [k = 20 W/m.^{O}C] of 4 cm diameter is exposed to a convection environment at 20 ^{O}C, h = 15 W/m^2.^{O}C. Heat is generated uniformly in the sphere at the rate of 1.2 MW/m^3. Calculate the steady state temperature for the center of the sphere? [3]

4. Consider a system of concentric spheres of radius r_1 and r_2 (r_2 > r_1). If r_1=6 cm, determine the radius r_2 if it is desired to have the value of shape factor F_{21} equal to 0.6. [2]

5 The radiation shape factor between two flat ends of a hollow cylinder of 10 cm diameter and 10 cm length is 0.17. What is the shape factor of the curved surface of the cylinder with respected to itself? [3]



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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2010-2011

CHE C351 HEAT TRANSFER OPERATIONS

QUIZ - 2 (Closed Book)

DATE: 09/12/2010

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

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

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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.^{o}C	Inlet temperature, ^{o}C	Outlet temperature, ^{o}C
Counter flow	A	12.5	2530	95	35
	B	17.5	4180	25	?

Calculate:

Outlet temperature of B =

Heat load of the exchanger =

Question 2. Consider the following exchanger data: [2]

Flow arrangement	Fluid	Flow rate, kg/s	Heat capacity, J/kg.^{o}C	Inlet temperature, ^{o}C	Outlet temperature, ^{o}C
Parallel flow	Methanol	3.5	2200	22	60
	Water	?	4200	95	65

Overall heat transfer coefficient, U = 550 W/m^2.K
Calculate:

The heat transfer area of the exchanger =

Question 3. Consider the following exchanger data: [3]

Flow arrangement	Fluid	Flow rate, kg/s	Heat capacity, J/kg.^{o}C	Inlet temperature, ^{o}C	Outlet temperature, ^{o}C
Counter flow	Toluene	4.5	2800	98	?
	Water	6.5	4200	15	?

Overall heat transfer coefficient, U = 500 W/m^2.K
Heat exchanger area = 90 m^2
Calculate:

Toluene outlet temperature =

BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

FIRST SEMESTER 2010-2011

CHE UC351 Heat Transfer Operations

QUIZ – I

(Closed Book)

DATE: 24-11-2010

DURATION: 20 MINUTES **MAXIMUM MARKS: 8**

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

Note: Attempt all questions.

1. Reynolds analogy is expressed as:

   a. $St = \dfrac{f}{8}$ b. $\dfrac{\tau}{\rho} = \left(\dfrac{\mu}{\rho} + \varepsilon_M\right)\dfrac{du}{dy}$ c. $f = \dfrac{0.316}{\mathrm{Re}_d^{0.25}}$

2. The empirical expression for calculation of heat transfer in fully developed turbulent flow in smooth tubes is:

   a. $Nu_d = 0.0395\,\mathrm{Re}_d^{3/4}$ b. $Nu_d = 0.036\,\mathrm{Re}_d^{0.8}\,\mathrm{Pr}^{1/3}\left(\dfrac{d}{L}\right)^{0.055}$

   c. $Nu_d = 0.023\,\mathrm{Re}_d^{0.8}\,\mathrm{Pr}^n$ d. $Nu_d = \dfrac{hd_0}{k} = 4.364$

3. $\dfrac{\theta}{\theta_\infty} = \dfrac{3}{2}\dfrac{y}{\delta_t} - \dfrac{1}{2}\left(\dfrac{y}{\delta_t}\right)^3$ is the equation of thermal boundary layer:

   a. Of laminar flow on a plate
   b. Of turbulent flow on a flat plate
   c. Of laminar flow in a tube
   d. Of turbulent flow in a tube.

4. Which of the following equations is valid for liquid metal heat transfer?

   a. $\dfrac{\delta}{x} = 0.381\,\mathrm{Re}_x^{-0.2} - 10256\,\mathrm{Re}_x^{-1}$ b. $\dfrac{\delta}{\delta_t} = 1.64\sqrt{\mathrm{Pr}}$

   c. $\xi = \dfrac{\delta_t}{\delta} = \dfrac{1}{1.026}\mathrm{Pr}^{-1/3}$ d. $\dfrac{\delta}{x} = \dfrac{5.0}{\mathrm{Re}_x^{0.5}}$

5. The dimensionless number defined as the product of Grashof number and Prandtl number, (Gr.Pr), is called

a. Peclet number b. Stanton number

c. Rayleigh number d. Schmidt number

6. In a blackbody radiation curve, the maximum occurs at λ_{max} . With increasing temperature,

a) λ_{max} will increase

b) λ_{max} will decrease

c) λ_{max} will remain same

d) λ_{max} will increase or decrease depending on the surface properties

7. For a black body

a) space resistance is equal to zero
b) space resistance is equal to unity
c) surface resistance is equal to zero
d) surface resistance is equal to unity

8. Identify the correct statement regarding radiation shape factors

a) $F_{11} = 0$ for plane surface, $F_{11} > 0$ for convex surface, $F_{11} < 0$ for concave surface
b) $F_{11} > 0$ for plane surface, $F_{11} = 0$ for convex surface, $F_{11} = 0$ for concave surface
c) $F_{11} < 0$ for plane surface, $F_{11} > 0$ for convex surface, $F_{11} > 0$ for concave surface
d) $F_{11} = 0$ for plane surface, $F_{11} = 0$ for convex surface, $F_{11} > 0$ for concave surface

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