BITS PILANI, DUBAI CAMPUS
FIRST SEMESTER 2012 – 2013
CHE C351 HEAT TRANSFER OPERATIONS
COMPREHENSIVE EXAMINATION (OPEN BOOK)

DATE: 6 – 1 – 2013

DURATION: 3 hours **MAXIMUM MARKS: 35**

Note: ***Attempt ALL questions. Answer question sequentially.*** *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 certain insulation material having a thermal conductivity of 3×10^{-4} W/m.K is used to insulate a tank of liquid nitrogen that is maintained at -196 ^{o}C. The amount of heat required to vaporize 1 kg mass of nitrogen at this temperature is 199 kJ. The tank is spherical with diameter (ID) of 0.61 m. Estimate the amount of nitrogen vaporized per day for an insulation thickness of 2.5 cm and an ambient temperature of 21 ^{o}C. The outer temperature of insulation is 21 ^{o}C. [3]

2. A spherical tank, 90 cm in diameter, is maintained at a temperature of 130 ^{o}C and exposed to a convection environment with h = 25 W/m^2.K and ambient temperature of 15 ^{o}C. What thickness of urethane foam (thermal conductivity = 0.3 W/m.K) should be added to ensure that the outer temperature of the insulation does not exceed 40 ^{o}C? [3]

3. An aluminum rod (k = 290 W/m.K) 2.25 cm in diameter and 18 cm long protrudes from a wall which is maintained at 240 ^{o}C. The rod is exposed to an environment at 16 ^{o}C. The convection heat transfer coefficient is 15 W/m^2.K. Calculate the heat loss by the rod. [4]

4. A very large slab of copper (k = 310 W/m.K, thermal diffusivity = 2.4×10^{-5} m^2/s) is initially at a temperature of 330 ^{o}C. The surface temperature is suddenly lowered to 45 ^{o}C. What is the temperature at a depth of 5 cm, 4 min after the surface temperature is changed? [3]

5. Water at 21 ^{o}C flows across a 0.2 X 0.2 m-square flat plate at a velocity of 1.1 m/s. The plate is maintained at a constant temperature of 52 ^{o}C. Calculate the heat loss by the plate. Water properties at film temperature are: density = 980 kg/m^3, k = 0.65 W/m.K, specific heat = 4.18 kJ/ kg.K, viscosity = 4.8×10^{-4} kg/m.s. [4]

6. A pipeline of 70-cm diameter in the Arctic carries hot oil at 55 ^{O}C. A strong wind blows across the pipe at a velocity of 4.8 m/s and a temperature of -30 ^{O}C. Estimate the heat loss per meter of pipe length. Air properties at mean temperature are: density = 2.2 kg/m^3, viscosity = 2.2 X10^{-5} kg/m.s, k = 0.032 W/m.K, Pr = 0.7. [3]

7. Liquid sodium is to be heated from 120 to 155 ^{O}C at a rate of 2.5 kg/s. A 2.5-cm-diameter electrically heated tube is available (constant heat flux). If the tube wall temperature is 40 ^{O}C higher than the sodium temperature, calculate the minimum length required. Properties of sodium at average bulk temperature are: viscosity = 1.85 X 10-3 kg/m.s, specific heat = 0.16 kJ/kg.K, k = 21 W/m.K. [4]

8. Assuming solar radiation is like a blackbody at 5775 K, calculate the fraction of energy in the wavelength band 0.2 to 0.38 microns. [2]

9. Two parallel concentric disks have d_1 = 20 cm, d_2 = 40 cm and are spaced 10 cm apart. Determine F_{12} and F_{21}. [2]

10. A counter flow heat exchanger is to be used to heat 0.6 kg/s of water from 35 to 85 ^{O}C with an oil [specific heat = 2.1 kJ/kg.K] flow of 0.9 kg/s. The oil enters the heat exchanger at a temperature of 175 ^{O}C. Calculate the area of the exchanger. Given that overall heat transfer coefficient is 350 W/m^2.K. [3]

11. Now, in the above heat exchanger, water enters at 25 ^{O}C and 0.5 kg/s flowrate, while oil enters at 175 ^{O}C and 0.6 kg/s flowrate. What exit temperature of water will be achieved in this case? [4]

*** END OF PAPER ***

BITS, PILANI, DUBAI CAMPUS, ACADEMIC CITY, DUBAI

First SEMESTER 2012-2013

CHE C351: Heat Transfer Operations

TEST – II (Open Book)

DATE: 09-12-2012

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. Do not alter any data.*

1. Air at 1 atm and 120 ^{O}C is heated as it flows through a tube with 3.8 cm diameter at a velocity of 15 m/s. Calculate the heat transfer per unit length of tube if a constant-flux condition is maintained at the wall and the wall is 25 ^{O}C above the air temperature, all along the length of the tube. Use Sieder and Tate equation, neglect viscosity correction. [5]
   Given: Air properties at bulk temperature:
   Pr = 0.68, density = 1.42 kg/m^3, specific heat = 1.1 kJ/kg.K
   kinematic viscosity = 1.95 X 10^{-5} m^2/s, k = 0.035 W/m.K,

2. Air at 2 atm and 10 ^{O}C blows across a 20-cm diameter cylinder at a velocity of 25 m/s. The cylinder surface is maintained at 80 ^{O}C. Calculate the heat loss per unit length of the cylinder. [4]
   Given: Air properties at film temperature:
   Viscosity = 2.14 X 10-5 kg/m.s, k = 0.0312 W/m.K,
   Density = 1.35 kg/m^3, Pr = 0.695

3. Air is flowing over a flat plate 5-m long and 1.5-m wide with a velocity of 4.5 m/s at 15 ^{O}C. If k = 0.04, density = 1.21 kg/m^3, and kinematic viscosity = 1.45 X 10^{-5} m^2/s, specific heat = 1.1 kJ/kg.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, use exact solution,
   (c) Calculate the thickness of the thermal boundary layer at 1.5 m distance from the leading edge, assuming that the plate is being heated over its entire length. [6]

*** END OF PAPER ***

BITS, PILANI, DUBAI CAMPUS, ACADEMIC CITY, DUBAI
First SEMESTER 2012-2013
CHE C351: Heat Transfer Operations
TEST – I (Closed Book)

DATE: 16-10-2012

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) 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. 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. other data are same for both fins and are given below:

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

Compare the performance of these fins by computing: [3]
a) The rate of heat dissipation,
b) Fin efficiency.

3. 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. [4]

4. 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 cooling the sphere from 540 ^{O}C to 95 ^{O}C?
(b) Total heat transferred during this period.
© verify if lumped system assumption is applicable. [4]
Given: density = 7850 kg/m^3, heat capacity = 475 J/kg^{O}C,
Thermal diffusivity = 1.2 X 10^{-5} m^2/s

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BITS PILANI, DUBAI CAMPUS, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2012-2013
CHE C351 Heat Transfer Operations
QUIZ – II (Closed Book)

DATE: 20-11-2012

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

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

Consider two large parallel plates, one at 1000 ^{O}C with emissivity 0.75 and the other at 500 ^{O}C having emissivity 0.55. A radiation shield is placed between them. The shield has emissivity 0.1 on the side facing hot plate and 0.05 on the side facing cold plate. Calculate:

1) Heat transfer between the plates when there is no shield between them, [1]
2) Heat transfer between the plates after the shield is placed between them, [2]
3) Temperature of the shield. [2]
4) If the shield is reversed, what will be the temperature of the shield? [2]

BITS PILANI, DUBAI CAMPUS, ACADEMIC CITY, DUBAI

FIRST SEMESTER 2012-2013

CHE C351 Heat Transfer Operations

QUIZ – I (Closed Book)

DATE: 06-11-2012

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

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

Note: Attempt all questions. This quiz consists of 13 questions. Q 1 to 12 carries ½ marks each, while Q 13 carries 1 mark.

1. Thermal radiation lies in the wavelength range

   a) 0.1 – 100 mm b) 0.1 – 100 μm

   c) 0.1 – 100 nm d) 0.1 – 100 cm

2. 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

3. A gray body is defined such that

   a) Its monochromatic emissivity ε_λ is *independent* of wavelength

   b) Its total emissivity ε is *independent* of wavelength

   c) Its total emissivity ε is *independent* of direction

   d) Its absorptivity is *independent* of direction

4. The emissive power of a blackbody is given as

   a) $\varepsilon\sigma T^4$ b) σT^4

   c) εT^4 d) $F_{12}\varepsilon\sigma T^4$

5. The speed of electromagnetic radiation in vacuum is given as

a) $c = 3\times10^{8}\, km/s$ b) $c = 3\times10^{6}\, km/s$

c) $c = 3\times10^{6}\, m/s$ d) $c = 3\times10^{8}\, m/s$

6. If the angle of incidence of radiation is equal to the angle of reflection, it is called

a) Black body radiation c) Gray body radiation

b) Diffuse radiation d) Specular radiation

7. In a blackbody radiation curve, the maximum occurs at $\lambda_{\max}$. With increasing temperature,

a) $\lambda_{\max}$ will increase

b) $\lambda_{\max}$ will decrease

c) $\lambda_{\max}$ will remain same

d) $\lambda_{\max}$ will increase or decrease depending on the surface properties

8. The reciprocity relation for radiation shape factors is given as,

a) $E_{b1}/A_1 = E_{b2}/A_2$ b) $F_{12} = F_{21}$

c) $A_1 F_{12} = A_2 F_{21}$ d) $F_{12}/A_1 = F_{21}/A_2$

9. The intensity of radiation is defined as

a) the radiation emitted per unit time per unit area

b) the radiation emitted per unit area and per unit of solid angle in a certain specified direction

c) total radiation incident upon a surface per unit time per unit area

d) total radiation which leaves a surface per unit time per unit area

10. Kirchhoff's identity can be expressed as

a) $\varepsilon = \alpha$ b) $\alpha + \rho + \tau = 1$

c) $\varepsilon = \dfrac{E}{E_b}$ d) $\varepsilon_\lambda = \dfrac{E_\lambda}{E_{b\lambda}}$

11. Wein's displacement law is written as

a) $\lambda_{\max} T = \text{constant}$ b) $E_{b\lambda} = \dfrac{u_\lambda c}{4}$

c) $\varepsilon = \varepsilon_\lambda$ d) $E_b = \sigma T^4$

12. When a sphere is heated to incandescent temperatures, and it is electrically conducting, it will appear

a) bright around the rim,

b) bright at the center.

13. For a spherical ball of 20-cm diameter and 800 K, the total blackbody emissive power will be equal to

a) 5.67 kW/m^2 b) 4.096 X 10^8 kW/m^2

c) 1.6 X 10^5 kW/m^2 d) 23.2 kW/m^2

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