BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009

CHE UC351 Heat Transfer Operations

Test - 1
(Closed Book)

DURATION: 50 MINUTES **DATE: 12.10.2008**
MAXIMUM MARKS: 30

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 current of 300 amperes passes through a stainless steel wire of 2.5 mm diameter and k = 20 W/mK. The resistivity of the wire is 70 X 10^{-8} Ωm and the length of the wire is 2m. If the wire is submerged in a fluid maintained at 50 ^{0}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. [08]

2 A very long 25-mm diameter copper rod (k = 300 W/mK) extends horizontally from a plane heated wall at 120 ^{0}C. The temperature of the surrounding air is 25 ^{0}C and convective heat transfer coefficient is 9.0 W/m^{2}K.
(a) Determine the heat loss.
(b) How long the rod should be in order to be considered infinite?
[06]

3 The temperature of air stream is to be measured by a thermocouple whose junction can be approximated as a 1.5 mm diameter sphere with following properties: k = 15 W/mK, ρ = 7200 kg/m^3, C_p = 410 J/kgK. The convection heat transfer coefficient between the junction and the air is 520 W/m^{2}K. Determine how long will it take for the thermocouple to read 63.2% of the initial temperature difference? [06]

4 (a) What are the physical assumptions necessary for a lumped system analysis to apply to unsteady state conduction? [02]
4 (b) Define and differentiate fin efficiency from fin effectiveness. [04]
4 (c) Define Biot number and Fourier number. What is their physical significance? [04]

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BITS, PILANI-DUBAI CAMPUS, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009

CHE UC351 Heat Transfer Operations
TEST – II (Open Book)

DURATION: 50 minutes | **DATE: 23-11-08**
MAXIMUM MARKS: 30

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

1 Air at 25 ^{0}C and at atmospheric pressure flows over a flat plate at a velocity of 1.7 m/s. the length of the plate is 2.0 m and it is maintained at 100 ^{0}C. Calculate the heat transfer rate per unit width using Blasius' exact solution. [10]
Properties of air at mean temperature are:
Density = 1.1 kg/m^3, heat capacity = 1.01 kJ/kg.K, Pr = 0.728
Thermal conductivity = 0.02894 W/m.K,
Kinematic viscosity = 18.97 X10^{-6} m^2/s

2 A vertical plate 0.5 m high and maintained at 27 ^{0}C is exposed to saturated steam at atmospheric pressure. Calculate the rate of heat transfer, and the condensate rate per second per meter of the plate width for film-wise condensation. [10]
The properties of water film at the mean temperature are:
Density = 980.3 kg/m^3, thermal conductivity = 66.4 X 10^{-2} W/m.K, viscosity = 434 X 10^{-6} kg/m.s, h_{fg} = 2257 kJ/kg.
Assume vapor density is small compared to that of the condensate.

3 Stream data for a heat exchange problem is given as follows:

	Mass flow rate	***Inlet temperature***	***Heat capacity***
Process fluid	45 900 kg/h	103 ^{0}C	1985 J/kg.K
Cooling Water	100 800 kg/h	27 ^{0}C	4180 J/kg.K

Overall heat transfer coefficient = 450 W/m^2.K,
Heat exchanger area = 150 m^2
Assume a suitable exchanger configuration (parallel/ counter) and calculate outlet temperatures of process fluid and cooling water. [10]

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009

CHE UC351 Heat Transfer Operations

Surprise QUIZ - 1
(Closed Book)

DURATION: 20 MINUTES **DATE: .../.../...**
MAXIMUM MARKS: 10

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

Q	1	2	3	4	5	6	7	8	9
Marks	1	1	1	1	1	2	1	1	1

1. Thermal diffusivity, α, has the units of

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

2. 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

3. Thermal conductivity of a gas

   a) Increases with increasing temperature
   b) Decreases with increasing temperature
   c) Is independent of temperature
   d) None of the above

4. The driving force for heat transfer is

   a) internal energy b) specific heat
   c) temperature gradient d) thermal conductivity

5. 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

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

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

(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

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. 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) $T_w = T_0 -+ \frac{\dot{q}R^2}{4h}$

9 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) $\sqrt{hPkA}$

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009

CHE C351 HEAT TRANSFER OPERATIONS

SURPRISE QUIZ - 2
(Closed Book)

DURATION: 30 MINUTES **DATE: 02/11/2008**
MAXIMUM MARKS: 10

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

NOTE: ATTEMPT ALL QUESTIONS. [Marks = 2 + 2 + 4 + 2 = 10]

1. Crude oil (flow rate = 22 kg/s, C_p = 2.9 kJ/kg.K) is being cooled from 105 °C to 60 °C in a counter flow exchanger, where toluene (flow rate = 15 kg/s, C_p = 2.7 kJ/kg.K) is entering the exchanger at 32 °C. What will be the exit temperature of toluene?

Answer:

2. In a parallel flow exchanger, caustic soda solution enters at 25 °C and leaves at 60 °C. The flow rate of caustic soda solution is 500 kg/h and heat capacity is 4.3 kJ/kg.K. Hot water (heat capacity = 4.2 kJ/kg.K) enters the exchanger at 98 °C and leaves at 35 °C. What is the heat load of exchanger in kW?

Answer:

3. For a counter flow exchanger, following data are given:

Fluid	C_p, kJ/kg.K	Flow rate, kg/h	Inlet temp, °C	Outlet temp, °C
Methanol	2.2	12900	95	55
Water	4.2	-	23	38

Overall heat transfer coefficient, U = 550 W/m^2.K
What is the heat transfer area of the exchanger?

Answer:

4. A copper sphere of 4 cm diameter is initially at a uniform temperature of 50 °C. It is suddenly immersed in an air stream at 10 °C with h = 20 W/m^2.K. Find the time constant of the system.

Answer:

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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI
FIRST SEMESTER 2008-2009

CHE UC351 Heat Transfer Operations

Surprise QUIZ – III
(Closed Book)

DURATION: 20 MINUTES | **DATE: .../.../...**
MAXIMUM MARKS: 15

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

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Part A

1. The heat transfer rates in dropwise/ filmwise condensation are higher.

2. In condensation heat transfer, average heat transfer coefficient is given by:

   a. $\bar{h} = \frac{4}{3} h_{x=L}$ b. $\bar{h} = \frac{3}{2} h_{x=L}$ c. $\bar{h} = \frac{1}{2} h_{x=L}$ d. $\bar{h} = 2h_{x=L}$

3. Condensation Number Co, is defined as

   a. $Co = \frac{\bar{h}A(T_{sat} - T_w)}{h_{fg}}$

   b. $Co = \left[\frac{\rho(\rho - \rho_v)k^3 g \sin\phi A / L}{\mu\dot{m}}\right]^{1/4}$

   c. $Co = \left[\frac{\rho(\rho - \rho_v)k^3 g \sin\phi h_{fg}}{\mu L(T_g - T_w)}\right]^{1/4}$

   d. $Co = \bar{h}\left[\frac{\mu^2}{\rho(\rho - \rho_v)k^3 g}\right]^{1/3}$

4. Reynolds analogy is expressed as:

   a. $St = \frac{f}{8}$ b. $\frac{\tau}{\rho} = -\left(\frac{\mu}{\rho} + \varepsilon_M\right)\frac{du}{dy}$ c. $f = \frac{0.316}{Re_d^{0.25}}$

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

   a. $Nu_d = 0.0395 Re_d^{3/4}$

   b. $Nu_d = 0.036 Re_d^{0.8} Pr^{1/3}\left(\frac{d}{L}\right)^{0.055}$

   c. $Nu_d = 0.023 Re_d^{0.8} Pr^n$

   d. $Nu_d = \frac{hd_0}{k} = 4.364$

a) $E_b - J$ b) $J_1 A_1 F_{12}$ c) $(1-\varepsilon)/\varepsilon A$ d) $1/A_m F_{m-n}$

5. Net heat transfer between two infinite parallel planes is given as

a) $q_{1-2} = \dfrac{(J_1 - J_2)}{1/A_1 F_{12}}$

b) $q = \dfrac{\sigma A(T_1^4 - T_2^4)}{\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1}$

c) $q = \dfrac{\sigma A_1(T_1^4 - T_2^4)}{\dfrac{1}{\varepsilon_1} + \dfrac{A_1}{A_2}\left(\dfrac{1}{\varepsilon_2} - 1\right)}$

d) $q = \sigma A_1 \varepsilon_1 (T_1^4 - T_2^4)$

6. The quantity that represents the rate at which radiation energy leaves a unit area of a surface in all directions is called

a) emissivity b) transmissivity c) radiosity d) intensity

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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BITS, PILANI-DUBAI, ACADEMIC CITY, DUBAI

FIRST SEMESTER 2008-2009

CHE UC351 Heat Transfer Operations

Comprehensive Examination

DATE: 23-12-08

DURATION: 3 hours **MAXIMUM MARKS: 70**

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.**

Question 1: [10 marks]

During a heat treatment process, spherical steel balls of 12 mm diameter are initially heated to 800 ^oC in a furnace. Then they are cooled to 100 ^oC by keeping them immersed in an oil bath at 350 ^oC, with a convective heat transfer coefficient 20 $W/m^2.^oC$.

(a) Determine the time required for the cooling process.

(b) If it is desired to complete the cooling process in a period of 10 minutes, what will be the required value of convective heat transfer coefficient?

Properties of steel balls:

Density = 7750 kg/m^3, specific heat = 520 J/kg.^oC,

Thermal conductivity = 50 W/m.^oC

Question 2: [10 marks]

A plane composite wall is made of two materials A and B of thermal conductivities k_a = 735 W/m.^oC and k_b = 165 W/m.^oC and thicknesses x_a = 5 cm, x_b = 2.5 cm. Material A is exposed to hot fluid at 150 ^oC for which h_a = 42 $W/m^2.^oC$ and material B is exposed to cold fluid at 30 ^oC and h_b = 85 $W/m^2.^oC$.

(a) Sketch the equivalent electrical network, showing all resistances,

(b) Calculate rate of heat transfer through the wall per unit cross-sectional area,

(c) Calculate overall heat transfer coefficient,

(d) Calculate the temperature at the interface of two materials.

Question 3: [10 marks]

Which of the following arrangements of pin fins will give higher heat transfer rate from a hot surface? (a) 6 fins of 10 cm length, (b) 12 fins of 5 cm length.

The base temperature of fin is maintained at 200 ^oC and the fin is exposed to a convection environment at 25 ^oC with h = 25 $W/m^2.^oC$. Each fin has cross-sectional area 2.5 cm^2 and perimeter 5 cm. Fin material thermal conductivity is 250 W/m.^oC. Neglect heat loss from the tip of the fin.

Question 4: [5 + 5 marks]

(a) A vertical square plate, 30 by 30 cm, is exposed to steam at atmospheric pressure. The plate temperature is 98 ^{o}C. Calculate the heat transfer and mass of steam condensed per hour?

Properties: ρ_f = 960 kg/m^3, μ_f = 2.82 X 10^{-4} kg/m.s, k_f = 0.68 W/m.^{o}C, h_{fg} = 2255 kJ/kg.

(b) A steel sphere [k = 16 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 1.0 MW/m^3. Calculate the steady state temperature for the center of the sphere?

Question 5: [3 + 3 + 6 marks]

(a) Calculate the shape factors for the following configuration: a sphere of diameter d inside a cubical box of edge length l = d.

(b) Consider a system of concentric spheres of radius r_1 and r_2 ($r_2 > r_1$). If r_1 = 5 cm, determine the radius r_2 if it is desired to have the value of shape factor F_{21} equal to 0.6.

(c) Consider radiative heat transfer between two large parallel planes of surface emissivities 0.8. How many radiation shields of emissivity 0.05 be placed between the surfaces to reduce the radiation heat transfer by a factor of 75?

Question 6: [6 + 4 marks]

Air at atmospheric pressure and 20 ^{o}C flows over a flat plate with a velocity of 4 m/s. the plate is 30 cm wide heated uniformly throughout is entire length and maintained at a temperature of 60 ^{o}C. Calculate the following at 40 cm distance from the leading edge:

(a) Thickness of hydrodynamic and thermal boundary layers,

(b) Local and average heat transfer coefficients.

Properties of air: ρ = 1.18 kg/m^3, ν = 17 X 10^{-6} m^2/s, C_p = 1007 J/kg.^{o}C, k = 0.0272 W/m.^{o}C.

Question 7: [8 marks]

In a counter flow heat exchanger, process fluid is cooled from a temperature of 103 ^{o}C with cooling water available at 27 ^{o}C. The heat exchanger area is 150 m^2 and the overall heat transfer coefficient is 450 W/m^2.OC. The flow rates are: process fluid = 12.75 kg/s, cooling water = 28 kg/s. Heat capacity of process fluid is 1986 J/kg.^{o}C, and that of cooling water is 4180 J/kg.^{o}C. Calculate:

(a) The exit temperature of process fluid,

(b) The exit temperature of cooling water,

(c) The heat transfer rate.

*** END OF PAPER ***