

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Special), Nov.-Dec. 2015

B. Tech in Chemical Engineering, Semester III

Roll No.....

CHE303: Heat Transfer Operations

Time: 3 hours

Max. Marks: 100

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.

Q.1A Objective type multiple choice questions (10 questions @ 1 mark)

10

- i. A furnace wall of thickness 1 m and of surface area 2 m², is made of a material whose thermal conductivity is 1 KJ/hr m°C. The temperature of inner surface of the wall is 1000 °C and of outer surface is 200 °C, heat flow through the wall in KJ/hr will be
(a) 2000 (b) 1600 (c) 1200 (d) 800
- ii. A metal rod of 2cm diameter has a conductivity of 40 W/mK, which is to be insulated with an insulating material of conductivity of 0.1 W/mK. If the convective heat transfer coefficient with the ambient atmosphere is 5 W/m²K, the critical thickness of insulation will be
(a) 1cm (b) 2cm (c) 7 cm (d) 8 cm
- iii. In a free convection heat transfer transition from laminar to turbulent flow is governed by the critical value of the
(a) Reynolds number
(b) Grashoff's number
(c) Reynolds number and Grashoff's Number
(d) Grashoff's Number and Prandlt number
- iv. Calculate the prandlt number for water at 90°C with $\rho = 965 \frac{kg}{m^3}$, $\nu = 3.22 \times 10^{-7} m^2/s$, $C_p = 4208 \frac{J}{kg K}$, $k = 0.676 \frac{W}{mK}$.
(a) 1.93 (b) 0.193 (c) 19.3 (d) 193
- v. In nucleate boiling, bubbles always originate
(a) in the bulk of the liquid
(b) on the heating surface
(c) where the liquid superheat is minimum
(d) where the liquid is saturated
- vi. In boiling heat transfer, the most significant regime of boiling is
(a) Convection boiling (b) Film Boiling
(c) Nucleate boiling (d) transition boiling
- vii. A Flat plate has thickness 5 cm, thermal conductivity 1 W/mK, convective heat transfer coefficients on its two flat faces of 10 W/(m²K) and 20 W/(m²K). The overall heat transfer coefficient for such a flat plate is:
(a) 5 W/(m²K) (b) 6.33 W/(m²K) (c) 30 W/(m²K) (d) 0.2 W/(m²K)

viii. Nusselt number for a pipe flow heat transfer coefficient is given by the equation $Nu = 4.36$. Which one of the following combinations of conditions do exactly apply for use of this equation?

- (a) Laminar Flow and Constant wall Temperature
- (b) Turbulent Flow and Constant wall heat flux
- (c) Turbulent flow and constant wall temperature
- (d) Laminar flow and Constant wall heat flux

ix. Unit of Thermal Diffusivity is:

- (a) $m/s \text{ } ^\circ C$ (b) m^2/s (c) m/s (d) $m^2/s \text{ } ^\circ C$

x. Consider a hydrodynamically fully developed flow of cold air through a heated pipe of radius r_0 . The velocity and temperature distributions in the radial direction are given by $u(r)$ and $T(r)$ respectively. If u_m is the mean velocity at any section of the pipe, then the bulk mean temperature at that section is given by

$$(a) \int_0^{r_0} u(r)T(r)r^2 dr \quad (b) \int_0^{r_0} \frac{u(r)}{3r} \frac{T(r)}{2r} dr \quad (c) \frac{4 \int_0^{r_0} u(r)T(r)dr}{2\pi r_0^2} \quad (d) \frac{2}{u_m r_0^2} \int_0^{r_0} u(r)T(r)r dr$$

Q.2 Short answer type questions (4 questions @ 2.5 marks)

10

(a) Calculate the Grashof number and state if the flow is laminar or turbulent for a horizontal oil sump, with a surface temperature of $40^\circ C$, $0.4m$ long and $0.2m$ wide containing oil at $75^\circ C$. Given parameters are:

$$(\rho = 854 \text{ kg/m}^3, Pr = 546, \beta = 0.7 \times 10^{-3} \text{ K}^{-1} \text{ and } \mu = 3.56 \times 10^{-2} \text{ kg/m s})$$

(b) It is proposed to coat a 1 mm diameter wire with enamel paint ($K = 0.1 \text{ W/mK}$) to increase heat transfer with air. If air side heat transfer coefficient is $100 \text{ W/m}^2 K$, determine the optimum thickness of enamel paint.

(c) Write the significance of Rayleigh number and Nusselt number.

(d) Explain the phenomenon of thermal boundary layer.

Q.3A (i) What are the mechanisms of heat transfer? How are they distinguished from each other?

03 +

02 =

(ii) Define the fourier's law of heat conduction and Newtons law of cooling.

05

Q.3B Derive the expression for temperature distribution, under one dimensional steady state heat conduction for the Composite plane wall consisting of three layers.

05

Q.4A A metal plate of 4 mm thickness ($k = 95.5 \text{ W/m } ^\circ C$) is exposed to vapour at $100^\circ C$ on one side and cooling water at $25^\circ C$ on the opposite side. The heat transfer coefficients on vapour side and water side are $14500 \text{ W/m}^2 \text{ } ^\circ C$ and $2250 \text{ W/m}^2 \text{ } ^\circ C$ respectively. Determine:

05

(i) the rate of heat transfer

(ii) the overall heat transfer coefficient, and

(iii) Temperature drop at each side of heat transfer

Q.4B An electric hot plate is maintained at a temperature of $350^\circ C$ and is used a solution boiling at $95^\circ C$. The solution is in metallic vessel of wall thickness 25 mm , which is

05

enameled inside to a thickness 0.8 mm. the heat transfer coefficient of boiling solution is $5.5 \text{ KW/m}^2\text{K}$. thermal conductivity of the material of vessel and enamel are 50 and 1.05 W/mK . Determine:

- (a) The overall heat transfer coefficient
- (b) The rate of heat transfer per unit area.

Q.5A For fully developed laminar flow in tubes show that velocity profile can be written as: 05

$$u(r) = 2V_{avg}\left(1 - \frac{r^2}{R^2}\right)$$

Q.5B A counterflow heat exchanger is to heat air entering at 400°C with flow rate of 6 kg/s by the exhaust gas entering at 800°C with a flowrate of 4 kg/s . The overall heat transfer coefficient is $100 \text{ W/m}^2\text{K}$ and the outlet temperature of the air is 551.5°C . Specific heat at constant pressure for both air and exhaust gas can be taken as 1100 J/kg K . Calculate: 05

- (i) The heat transfer area needed;
- (ii) The number of transfer units

Q.6A (i) Explain the mechanism of natural convection. 02 +
 (ii) A cylindrical body of 300 mm diameter and 1.6 m height is maintained at a constant temperature of 36.5°C . The surrounding temperature is 13.5°C . Calculate heat loss by free convection from the body per hour if $\rho = 1.025 \frac{\text{Kg}}{\text{m}^3}$; $C_p = 0.96 \text{ KJ/Kg}^\circ\text{C}$; $\nu = 15.06 \times 10^{-6}$; $k = 0.0892 \text{ KJ/mh}^\circ\text{C}$; $\beta = \frac{1}{928} \text{ K}^{-1}$. Assume $Nu = 0.12(Gr.Pr)^{1/3}$ (the symbols have their usual meaning) 03 = 05

Q.6B What is boiling? Differentiate between pool boiling and forced boiling? Explain pool boiling curve with neat sketch. 05

OR

Q.6B Derive expression for temperature distribution and heat dissipation in a straight fin of rectangular profile for Infinitely long fin. 05

Q.7A Gasoline at the mean bulk temperature of 27°C flows inside a circular tube of 19mm inside diameter. The average bulk velocity is 0.061 m/s and the tube is 1.5m long. The flow starts at the heated tube inlet and the tube surface temperature is constant at 38°C . Determine the average heat transfer coefficient over 1.5m length of the tube. 05

Take the following fluid properties:

$$\begin{aligned}\mu_s &= 5.223 \times 10^{-4} \text{ Pas}; \mu_b = 5.892 \times 10^{-4} \text{ Pas}; k_b = 0.1591 \frac{\text{W}}{\text{m}^\circ\text{C}}; \rho_b \\ &= 876.6 \frac{\text{kg}}{\text{m}^3}; c_{pb} = 1757 \frac{\text{J}}{\text{kgK}}; Pr_b = 6.5\end{aligned}$$

Use the following formula:

$$Nu = 1.86 \left[\frac{Re_b \cdot Pr_b}{\frac{L}{D}} \right]^{0.33} \left[\frac{\mu_b}{\mu_s} \right]^{0.14}$$

Q.7B One end of a long rod, 35 mm in diameter, is inserted into a furnace with the other end projecting in the outside air. After the steady state is reached, the temperature of the rod is measured at two points 180 mm apart and found to be 180 °C and 145 °C. The atmospheric air temperature is 25 °C. if the heat transfer coefficient is 65 W/m² °C, Calculate the thermal conductivity of the rod. (Assume that end of the fin is insulated) 05

OR

Q.7B Air moving at 0.3 m/s blows over the top of a chest-type freezer. The top of the freezer measures 0.9m by 1.5m and is poorly insulated so that the surface remains at 10°C. If the temperature of air is 30°C, make calculations for the maximum heat transfer by forced convection from the top of the freezer. 05

Q.8A Derive an expression for log mean temperature difference (LMTD) for counter flow in double pipe heat exchanger. 10

Q.9A (a) Define intensity of radiation and prove that the intensity of normal radiation is $1/\pi$ times the total emissive power. 10
(b) A furnace emits radiation at 2000 K. treating it as a black body radiation, calculate the

- (i) Monochromatic emissive power at 1 μm wavelength.
- (ii) Wavelength at which emission is maximum and corresponding maximum emissive power
- (iii) Total emissive power

Q.9B What is evaporation? How it is different from boiling? How we can classify evaporators on the basis of method of operation? 10

OR

Q.9B (a) Differentiate between film condensation and dropwise condensation. 10
(b) A vertical cooling fin approximating a flat plate 40 cm in height is exposed to saturated steam at atmospheric pressure ($t_{\text{sat}} = 100^\circ\text{C}$, $h_{\text{fg}} = 2257 \text{ kJ/kg}$). The fin is maintained at a temperature of 90°C. Estimate the following:

- (i) Thickness of the film at the bottom of the fin
- (ii) Overall heat transfer Coefficient; and
- (iii) Heat transfer rate after incorporating McAdam's correction.

The relevant fluid properties are:

$$\rho_l = 965.3 \frac{\text{kg}}{\text{m}^3}; k_l = 0.68 \text{ W/m}^\circ\text{C}; \mu_l = 3.153 \times 10^{-4} \frac{\text{Ns}}{\text{m}^2}; \rho_l \gg \rho_v$$