

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/Backlog), November 2016

B. Tech in Chemical Engineering, Semester V

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 Plane wall is 25 cm thick with an area of 1 m^2 , and has a thermal conductivity of 0.5 W/mK . If a temperature difference of 60°C is imposed across it, what is the heat flow?
(a) 120 W (b) 140 W (c) 160 W (d) 180 W
- ii. The co-relation $Nu = f(Gr, Pr)$ is a case of
(a) Internal Forced Convection (b) External Forced Convection
(c) Free Convection (d) combined free and forced convection
- iii. The properties of mercury at 300 K are: density = 13529 kg/m^3 , specific heat at constant pressure = 0.1393 kJ/kg-K , dynamic viscosity = $0.1523 \times 10^{-2} \text{ N.s/m}^2$ and thermal conductivity = 8.54 W/m-K . The Prandtl number of mercury at 300 K is:
(a) 0.0248 (b) 2.48 (c) 24.8 (d) 248
- iv. Match the dimensionless numbers in **Group-1** with the ratios in **Group-2**.

Group-1

Group-2

P Biot number

I

buoyancy force

viscous force

Q Schmidt number

II

internal thermal resistance of a solid

boundary layer thermal resistance

R Grashof number

III

momentum diffusivity

mass diffusivity

(A) Q-I R-III

(B) P-I Q-III R-II

(C) Q-I R-II

(D) P-II Q-III R-I

v. Consider the following phenomenon:

1. Boiling
2. Free Convection in air
3. Forced Convection
4. Conduction in air

Their correct sequence in increasing order of heat transfer coefficient is:

- (a) 4,2,3,1 (b) 4,1,3,2 (c) 4,3,2,1 (d) 3,4,1,2

vi. In pool boiling, the highest heat transfer coefficient occurs in

- (a) Subcooled boiling zone (b) nucleate boiling zone
(c) Partial film boiling zone (d) film boiling zone

- vii. A composite wall having three layers of thickness 0.3m, 0.2m and 0.1m and of thermal conductivities 0.6, 0.4 and 0.1 W/mK, respectively, is having surface area 1m². If the inner and outer temperatures of the composite wall are 1840K and 340K, respectively, what is the rate of heat transfer?
 (a) 150 W (b) 1500 W (c) 75W (d) 750W
- viii. Which one of the following numbers represents the ratio of kinematic viscosity to the thermal diffusivity?
 (a) Grashoff number (b) Prandlt number
 (c) Mach number (d) Nusselt number
- ix. A spherical aluminum shell of inside diameter 2m is evacuated and used as a radiation test chamber. If the inner surface is coated with carbon black and maintained at 600K, the irradiation on a small test surface placed inside the chamber is (Stefan boltzmann constant = 5.67×10^{-8})
 (a) 1000 W/m² (b) 3400 W/m² (c) 5680 W/m² (d) 7348 W/m²
- x. An outer wall of a furnace is at T_w kelvins and it faces an environment at T_e , the wall's average convective heat transfer coefficient h is 4W/m² K. for radiative heat transfer the walls emissivity is equals 0.8. The ratio of net heat loss by radiation to heat loss by convection from the wall is closet to
 (a) $5\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$ (b) $2.5\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$ (c) $0.5\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$ (d) $0.2\sigma \frac{T_w^4 - T_e^4}{T_w - T_e}$

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

10

- i. Define Stefan-boltzmann law and emissivity.
- ii. In a counter flow heat exchanger,
For the hot fluid
 Heat capacity = 2 kJ/kg K; mass flow rate = 5 kg/sec; Inlet temperature = 150°C; Outlet temperature = 100°C;
For the cold fluid
 Heat capacity = 4 kJ/kg K; mass flow rate = 10 kg/sec; Inlet temperature = 20°C;
 Neglecting heat transfer to the surrounding, find outlet temperature of the cold fluid in °C.
- iii. Assuming the sun to be a black body emitting radiation with maximum intensity at $\lambda = 0.49 \mu m$, calculate the surface temperature of the sun.
- iv. A bulb of diameter 10 cm (d) is heated internally with an electric heater of 100 W (Q). The bulb dissipates the heat to the atmosphere by convection. The convection heat transfer coefficient between the air and the bulb (h) is 65 W/m²°C. If the atmosphere is at 35°C (T_a), determine the bulb surface temperature (T_s).

Q.3A Define Fourier's law of conduction. Derive the expression for temperature distribution, under one dimensional steady state heat conduction for the Composite plane wall consisting of three layers.

05

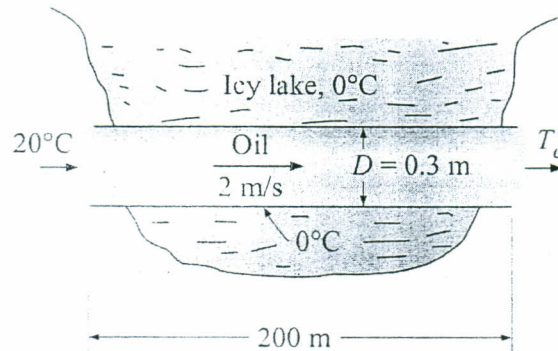
Q.3B Write the significance of the following:

05

- (a) Reynolds number
 (b) Nusselt number

- (c) Prandlt number
(d) Rayleigh number

- Q.4A Consider the flow of oil at 20°C in a 30-cm diameter pipeline at an average velocity of 2 m/s. A 200 m long section of the horizontal pipeline passes through icy waters of a lake at 0°C. Measurements indicate that the surface temperature of the pipe is very nearly 0°C. Disregarding the thermal resistance of the pipe material, determine: 05
- (a) The temperature of the oil when pipe leaves the lake,
(b) The rate of heat transfer from the oil.



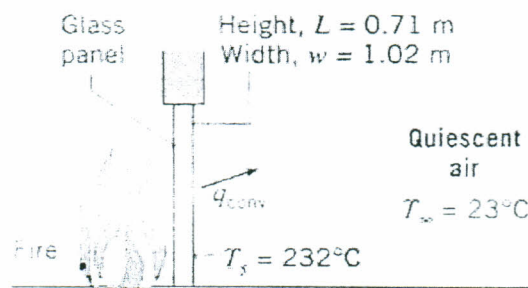
The value of Nusselt number is 33.7

Given properties:

$$\rho = 888.1 \text{ kg/m}^3; \nu = 9.429 \times 10^{-4} \text{ m}^2/\text{s}; k = 0.145 \text{ W/m}\cdot\text{K};$$

$$c_p = 1880 \text{ J/kg}\cdot\text{K}; \text{Pr} = 10,863$$

- Q.4B A wire of radius 3mm and 1.25m length is to be maintained at 60°C by insulating it by a material of thermal conductivity 0.175 W/mK. The temperature of surrounding air is 20°C with heat transfer coefficient 8.5 W/m²K. For maximum heat dissipation, determine the minimum thickness of insulation and the heat loss. 05
- Q.5A What is boiling? Differentiate between pool boiling and forced boiling? Explain pool boiling curve with neat sketch. 05
- Q.5B (a) Explain the mechanism of Natural Convection. 02 +
(b) A glass door firescreen, used to reduce exfiltration of room air through a chimney, has a height of 0.71m and a width of 1.02m and reaches a temperature of 232°C. If the room temperature is 23°C, estimate the convection heat rate from the fireplace to the room. [refer table A4] 03 = 05



Q.6A Derive expression for temperature distribution and heat dissipation in a straight fin of rectangular profile for a fin insulated at the tip. 05

Q.6B A fin 5 mm thick and 45 mm long has its base on a plane plate which is maintained at 125 °C. The ambient temperature is 25 °C. The conductivity of the fin material is 55 W/m °C and the heat transfer coefficient is 145 W/m² °C. Determine: 05

- (i) Temperature at the middle of the fin, and
- (ii) Heat dissipated by the fin (per meter width)

OR

Q.6B A metal plate of 4 mm thickness ($k = 95.5 \text{ W/m } ^\circ\text{C}$) is exposed to vapour at 100 °C on one side and cooling water at 25 °C on the opposite side. The heat transfer coefficients on vapour side and water side are 14500 W/m² °C and 2250 W/m² °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.7A A horizontal tube of outer diameter 20 mm is exposed to dry steam at 100°C. The tube surface temperature is maintained at 84°C by circulating water through it. Calculate the rate of formation of condensate per meter length of the tube. 05

Given Properties of saturated liquid at mean film temperature (92°C) are:

$$\rho_l = 963.4 \text{ kg/m}^3; \mu_l = 306 \times 10^{-6} \text{ Ns/m}^2; k = 0.677 \text{ W/m}^\circ\text{C}$$

Properties of Saturated vapour at $t_{sat} = 100^\circ\text{C}$ are:

$$\rho_v = 0.596 \text{ kg/m}^3; h_{fg} = 2257 \text{ kJ/kg}$$

Average heat transfer coefficient is given by:

$$\bar{h} = 0.725 \left[\frac{\rho_l(\rho_l - \rho_v)k^3gh_{fg}}{\mu_l(t_{sat} - t_s)D} \right]^{1/4}$$

Q.7B A Process industry employs a counter flow heat exchange to cool 0.8 kg/s of oil ($c_p = 2.5 \text{ kJ/kgK}$) from 120°C to 40°C by the use of water entering at 20°C. The overall heat transfer coefficient is estimated to be 1600 W/m²K. It is assumed that the exit temperature of water will not exceed 80°C. Using NTU method and taking NTU = 4 in this case, calculate the following: 01 + 02 + 02 = 05

- (i) Mass of flow rate of water
- (ii) Effectiveness of heat exchanger
- (iii) Surface area required

OR

Q.7B A counter flow double pipe heat exchanger using superheated steam is used to hot water at the rate of 10500 kg/h. the steam enters the heat exchanger at 180°C and leaves at 130°C. The inlet and exit temperatures of water are 30°C and 80°C respectively. If overall heat transfer coefficient from steam to water is 814 W/m²°C, calculate the heat transfer area. 05

Given: $\theta_m = \frac{\theta_1 + \theta_2}{2}$

Q.8A In a straight tube of 60mm diameter, water is flowing at a velocity of 12 m/s. The tube surface temperature is maintained at 70°C and the flowing water is heated from the inlet temperature 15°C to an outlet temperature of 45°C. calculate the following:

(i) the heat transfer coefficient from the tube surface to the water

(ii) the rate of heat transferred

(iii) the length of the tube

Given: Thermophysical properties of water are:

$$\rho = 995.7 \text{ kg/m}^3; c_p = 4.174 \text{ kJ/kg}^\circ\text{C}; k = 61.718 \times 10^{-2} \text{ W/m}^\circ\text{C};$$

$$\nu = 0.805 \times 10^{-6} \text{ m}^2/\text{s}; Pr = 5.42$$

Q.9A Write the importance of heat exchangers in the industry. Derive an expression for log mean temperature difference (LMTD) for parallel flow in double pipe heat exchanger.

Q.9B (a) Define intensity of radiation and prove that the intensity of normal radiation is $1/\pi$ times the total emissive power.

(b) A furnace emits radiation at 2000 K. treating it as a black body radiation, calculate the

(i) Wavelength at which emission is maximum

(ii) Total emissive power

OR

Q.9B (a) Differentiate between film condensation and dropwise condensation.

(b) Saturated steam at 120 °C condenses on a 2 cm OD vertical tube which is 20 cm long. The tube wall is maintained at a temperature of 119°C. Calculate the average heat transfer coefficient and the thickness of the condensate film at the base of the tube. Given:

$$P_{\text{sat}} = 1.985 \text{ bar}; \rho_l = 943 \text{ kg/m}^3; h_{fg} = 2202.2 \text{ kJ/kg}; k = 0.686 \text{ W/mK};$$

$$\mu = 237.3 \times 10^{-6} \text{ Ns/m}^2; \rho_l \gg \rho_v$$

***** GOOD LUCK *****

TABLE A.4 Thermophysical Properties
of Gases at Atmospheric Pressure^a

T (K)	ρ (kg/m ³)	c_p (kJ/kg · K)	$\mu \cdot 10^7$ (N · s/m ²)	$\nu \cdot 10^6$ (m ² /s)	$k \cdot 10^3$ (W/m · K)	$\alpha \cdot 10^6$ (m ² /s)	Pr
Air							
100	3.5562	1.032	71.1	2.00	9.34	2.54	0.786
150	2.3364	1.012	103.4	4.126	13.8	5.84	0.758
200	1.7458	1.007	132.5	7.590	18.1	10.3	0.757
250	1.3947	1.006	159.6	11.44	22.3	15.9	0.726
300	1.1614	1.007	184.6	15.89	26.3	22.5	0.707
350	0.9950	1.009	208.2	20.92	30.0	29.9	0.700
400	0.8711	1.014	230.1	26.41	33.8	38.3	0.690
450	0.7740	1.021	250.7	32.39	37.3	47.2	0.686
500	0.6964	1.030	270.1	38.79	40.7	56.7	0.684
550	0.6329	1.040	288.4	45.87	43.9	66.7	0.683
600	0.5804	1.051	305.8	52.69	46.9	76.9	0.685
650	0.5356	1.063	322.5	60.21	49.7	87.5	0.690
700	0.4975	1.075	338.8	68.10	52.4	98.0	0.695
750	0.4643	1.087	354.6	76.37	54.9	109	0.702
800	0.4354	1.099	369.8	84.93	57.3	120	0.709
850	0.4097	1.110	384.3	93.80	59.6	131	0.716
900	0.3868	1.121	398.1	102.9	62.0	143	0.720
950	0.3666	1.131	411.3	112.2	64.3	155	0.723
1000	0.3482	1.141	424.4	121.9	66.7	168	0.726
1100	0.3166	1.159	449.0	141.8	71.5	195	0.728
1200	0.2902	1.175	473.0	162.9	76.3	224	0.733
1300	0.2679	1.189	496.0	185.7	82	238	0.737
1400	0.2488	1.207	530	213	91	303	0.743
1500	0.2322	1.230	557	240	100	350	0.685
1600	0.2177	1.248	584	268	106	390	0.688
1700	0.2049	1.267	611	298	113	435	0.692
1800	0.1935	1.286	637	329	120	487	0.696
1900	0.1833	1.307	663	362	128	534	0.700
2000	0.1741	1.337	689	396	137	589	0.697
2100	0.1658	1.372	715	431	147	646	0.667
2200	0.1582	1.417	740	468	160	714	0.653
2300	0.1513	1.478	766	506	175	783	0.647
2400	0.1448	1.558	792	547	196	869	0.630
2500	0.1389	1.665	818	589	222	960	0.613
3000	0.1135	2.726	955	841	486	1570	0.536