

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/ Backlog), Nov.-Dec. 2015

B. Tech in Chemical Engineering, Semester III

Roll No.....

CHE 303: 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.

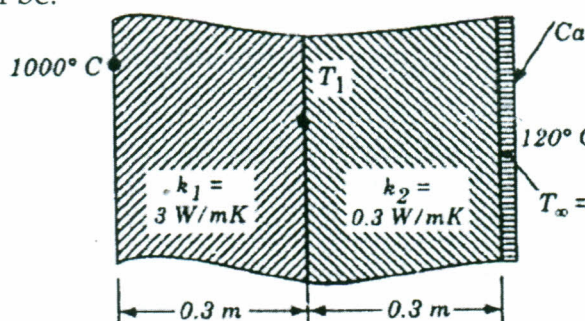
Q.1A Objective type multiple choice questions (10 questions @ 1 mark)

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- i. Which one of the following expresses the thermal diffusivity of a substance in terms of thermal conductivity (k), mass density (ρ) and specific heat (c_p)?

(a) $k^2/\rho c_p$ (b) $1/k\rho c_p$ (c) $k/\rho c_p$ (d) $\rho c_p/k^2$

- ii. The furnace wall is constructed as shown in the figure. The interface temperature T_1 will be:



(a) 560°C (b) 200°C (c) 920°C (d) 1120°C

- iii. In free convection motion of fluid is caused by

(a) the weight of the fluid element
(b) the hydrostatic force on the element
(c) the buoyancy forces arising from variation in density of fluid with the temperature
(d) none of these

- iv. Calculate the prandtl number for Liquid Sodium at 400 K with $\mu = 420 \times 10^{-6} \text{ kg/ms}$, $C_p = 1369 \frac{\text{J}}{\text{kg K}}$, $k = 86 \frac{\text{W}}{\text{mK}}$.

(a) 6.7 (b) 0.67 (c) 0.067 (d) 0.0067

- 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 nucleate boiling to form the nuclei of the bubbles there must be present

	(a) superheated vapour (b) dissolved gases (c) undissolved gases (d) superheated liquid
vii.	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/m ² (b) 3400 W/m ² (c) 5680 W/m ² (d) 7348 W/m ²
viii.	One dimensional unsteady state heat transfer equation for a sphere with heat generation at the rate of 'q' can be written as: (a) $\frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial T}{\partial r} \right) + \frac{q}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$ (b) $\frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial T}{\partial r} \right) + \frac{q}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$ (c) $\frac{\partial^2 T}{\partial r^2} + \frac{q}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$ (d) $\frac{\partial^2 (rT)}{\partial r^2} + \frac{q}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial t}$
ix.	In a condenser water enters at 30°C and flows at the rate 1500 kg/hr. The condensing steam is at a temperature of 120°C and cooling water leaves the condenser at 80°C. Specific heat of water is 4.187 kJ/kg K. If the overall heat transfer coefficient is 2000 W/m ² K, then the heat transfer area is (a) 0.707 m ² (b) 7.07 m ² (c) 70.7 m ² (d) 141.4 m ²
x.	Critical radius of hollow cylinder is defined as: (a) outer radius which gives maximum heat flow (b) outer radius which gives minimum heat flow (c) inner radius which gives minimum heat flow (d) inner radius which gives maximum heat flow

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

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- 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).
- Calculate the Nusselt number for a flow of gas (Pr = 0.71, $\mu = 4.63 \times 10^{-5} \frac{\text{kg}}{\text{ms}}$ and C_p = 1175 J/Kg K) over a turbine blade of chord length 20 mm, where the average heat transfer coefficient is 1000 W/m²K.
- It is proposed to coat a 1 mm diameter wire with enamel paint (K = 0.1 W/mK) to increase heat transfer with air. If air side heat transfer coefficient is 100 W/m²K, determine the optimum thickness of enamel paint.
- Define Stefan-boltzmann law and emissivity.

Q.3A Write the significance of the following:

05

- Reynolds number
- Nusselt number
- Prandlt number
- Rayleigh number

Q.3B For fully developed laminar flow in tubes show that velocity profile can be written as:

05

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

- Q.4A 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:

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

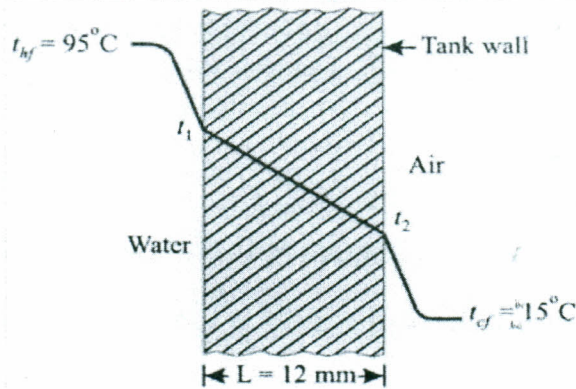
- Q.4B What is boiling? Differentiate between pool boiling and forced boiling? Explain pool boiling curve with neat sketch. 05

- Q.5A 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 $\rho = 1.025 \frac{\text{kg}}{\text{m}^3}$; $C_p = 0.96 \text{ KJ/Kg}^\circ\text{C}$; $\gamma = 15.06 \times 10^{-6}$; $k = 0.0892 \text{ KJ/mh}^\circ\text{C}$; $\beta = \frac{1}{928} \text{ K}^{-1}$. Assume $Nu = 0.12(Gr \cdot Pr)^{1/3}$ (the symbols have their usual meaning) 05

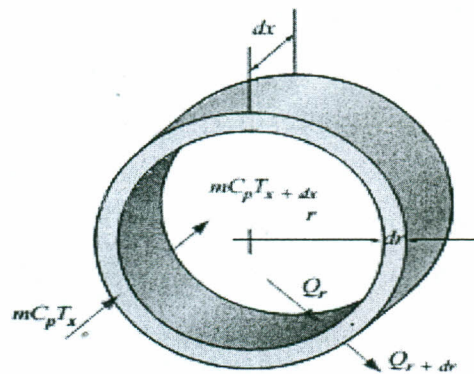
- Q.5B A horizontal tube of outer diameter 20 mm is exposed to dry steam at 100°C. The tube surface temperature is maintained at 84°C by circulating water through it. Calculate the rate of formation of condensate per meter length of the tube. 05

- Q.6A 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 W/m²K 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.7A A mild steel tank of wall thickness 12 mm contains water at 95°C. The thermal conductivity of mild steel is 50 W/m°C, and the heat transfer coefficients for the inside and outside the tank are 2850 and 10 W/m²°C, respectively. If the atmospheric temperature is 15°C, calculate: 05
(a) The rate of heat loss per m² of the tank surface area.
(b) The temperature of the outside surface of the tank.



- Q.7B Consider Forced convection steady laminar flow of a fluid in a circular tube of radius R . The fluid properties ρ , k , and C_p are constant, and the work done by viscous stresses is negligible. The fluid flows along the x -axis with velocity V . The flow is fully developed so that is independent of x and thus $V = V(r)$. Derive an energy equation for a differential volume element.



OR

- Q.7B 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 two layers.
- Q.8A (a) Differentiate between film condensation and dropwise condensation.
 (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:
 $\rho_l = 965.3 \frac{\text{kg}}{\text{m}^3}$; $k_l = 0.68 \text{ W/m}^\circ\text{C}$; $\mu_l = 3.153 \times 10^{-4} \frac{\text{Ns}}{\text{m}^2}$; $\rho_l \gg \rho_v$
- Q.9A Write the importance of heat exchangers in the industry. How they are classified? 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) Monochromatic emissive power at $1 \mu\text{m}$ wavelength.
- (ii) Wavelength at which emission is maximum and corresponding maximum emissive power
- (iii) Total emissive power

OR

- Q.9B (i) What do you understand by efficiency of the fin? 02 +
(ii) A steel rod ($k = 32 \text{ W/m } ^\circ\text{C}$), 12 mm in diameter and 60 mm long, with an insulated end, is to be used as a spine. It is exposed to surroundings with a temperature of 60°C and a heat transfer coefficient of $55 \text{ W/m}^2 ^\circ\text{C}$. The temperature at the base of fin is 95°C . Determine: 08
=10
(a) The Fin Efficiency
(b) The temperature at the edge of the spine;
(c) The heat dissipation

----- GOOD LUCK -----