KATHMANDU UNIVERSITY
End Semester Examination
January/February 2024

Level : B.E.
Year : III
Time : 2 hrs. 30mins.

21 JAN 2024

Course : CHEG 303
Semester : I
F. M. : 40

SECTION "B"
[5Q × 8 = 40 marks]

Attempt *ALL* questions.

1. A rotary kiln is a rotating (almost) horizontal cylinder with a hot gas flowing in one direction while heating solid particles moving in the opposite direction. Hence there is direct contact between the gas and the solids inside the kiln. The cylindrical kiln shell is typically made of carbon steel, and the shell is protected against the hot gas by a layer of heat-resistant refractory material. Hence, the rotary kiln can be seen as a cylindrical composite wall with two layers. In this problem, the outer diameter of the steel shell is 4.4 m, the thickness of the steel shell is 50 mm and the refractory layer thickness is 150 mm. The thermal conductivity of the steel (material B) is taken as constant and equal to 40 W/(m·K), and that of the refractory lining (material A) is taken as constant and equal to 0.5 W/(m·K). In a certain longitudinal section of the kiln, the temperature on the interface between the refractory and the hot gas is taken as 1400 °C. The length of this section is 5 m. Outside the kiln shell there is ambient air at 1 atm and 15 °C. The heat convection heat transfer coefficient characterizing the boundary layer on the outer surface is taken as constant and equal to 7 W/(m²K). Radiation between the outer steel shell and the surroundings is neglected. The system is at steady state. [4+2+2]

   a. The heat rate from the inner surface to the surrounding ambient air can be expressed as: $q = U_1 A_1 \Delta T$, where $U_1 = \frac{1}{\frac{r_1}{k_A} ln\frac{r_2}{r_1} + \frac{r_1}{k_B} ln\frac{r_3}{r_2} + \frac{r_1}{hr_3}}$, A_1 is the heat transfer area based on the inside of the refractory material and $\Delta T = T_1 - T_\infty$. Calculate the heat rate through the wall.

   b. Calculate the temperature [°C] on the outside of the steel shell.

   c. Fourier's law for a cylindrical wall is $q = \frac{2\pi Lk(T_{inside} - T_{outside})}{ln\frac{r_{outside}}{r_{inside}}}$. Calculate the temperature [°C] on the interface between the steel shell and the refractory layer.

2. Air at 27 °C with a free stream velocity of 10 m/s is flowing in parallel with a long horizontal plate. The plate, which is 2 m wide, is temperature controlled and has a constant temperature of 227 °C. The pressure in the system is 1 atm. [3+1+4]
   a. What is the heat flux at a position 0.5 m downstream from the leading edge?

   b. What is the thickness of the velocity boundary layer [mm] and the thermal boundary layer [mm] at that position?

   c. Now consider a plate section of length 3 m, starting 1 m downstream of the leading edge and ending 4 m downstream. What is the heat loss [W] from this section?

3. A glass-door fire screen, used to reduce exfiltration of room air through a chimney, has a height of 0.71 m and a width of 1.02 m and reaches a temperature of 232 °C. [4+2+2]

a. Estimate the convection heat rate from the fireplace to the room.

b. Assuming $\varepsilon = 1.0$ for the glass surface and $T_{sur} = 23°C$, what is the net rate of radiation heat transfer between the glass and the surroundings?

A surface has a reflectivity of 0.15 and a transmissivity of 0. The surface is "grey". The surface temperature is 400 °C, and the surface is completely enclosed in large isothermal surroundings with a temperature of 15 °C. What is the net heat flux from the surface to the surroundings?

4. Water flows at a pressure of 9.319 bars inside a smooth vertical stainless-steel tube with an inner diameter of 0.1 m. Saturated liquid water is flowing into the tube (axial position x=0) with a mean velocity of 0.05 m/s. The tube is heated from outside by a combustion process providing a constant heat flux of 100 000 W/m^2. Hence, the liquid starts to boil when it enters the heated tube. Assume f = 0.023 for smooth surface from Moody diagram. [1+1+2+3+1]

a. Determine the water mass flow rate [kg/s].

b. Determine the steam quality (vapor fraction) X(x) at the axial position x = 15 m applying this formula: $\bar{X}(x) = \frac{q_s'' \pi D x}{\dot{m} h_{fg}}$

c. Determine the convection heat transfer coefficient for single phase liquid flow.

d. Determine the convection heat transfer coefficient in the tube at x = 15 m.

e. Compare the values in c) and d) and explain.

5.

a. Hot exhaust gases, which enter a finned-tube, cross-flow heat exchanger at 300 °C and leave at 100 °C, are used to heat pressurized water at a flow rate of 1 kg/s from 35 to 125 °C. The overall heat transfer coefficient based on the gas-side surface area is U_h = 100 W/m^2 K. Determine the required gas-side surface area A_h using the NTU method. [5]

b. Show that the thermal expansion coefficient for an ideal gas is equal to 1/T. [1]

c. What is the difference between irradiation and emissive power? [1]

d. If the Nusselt number has the value 1, what does it tell you about the flow in the system? [1]

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Registration No.:

Date :

SECTION "A"
[20Q. × 0.5 = 10 marks]

Choose and encircle in the appropriate option

1. Why fins are provided on a heat transfer surface?
   a. Pressure drop of the fluid should be minimized
   b. Increase turbulence in flow for enhancing heat transfer
   c. Surface area is maximum to promote the rate of heat transfer
   d. Increase temperature gradient so as to enhance heat transfer

2. The radiant heat transfer from a plate of 2.5 cm^2 area at 1250 K to a very cold enclosure is 5.0 W. Determine the emissivity of the plate at this temperature
   a. 0.544 b. 0.144 c. 0.044 d. 0.244

3. The convective heat transfer coefficient in the laminar flow over a flat plate _____?
   a. Decreases with increase in free stream velocity
   b. Increases if a denser fluid is used
   c. Increases with distance
   d. Increases if a higher viscosity fluid is used

4. The condensate film runs down a vertical flat surface where saturated steam is allowed to condense. Condensation's local coefficient of heat transfer.
   a. Increases with increasing thickness of film.
   b. Increases with increasing temperature differential between the surface and vapour.
   c. Decreases with increasing distance from the top of the surface.
   d. Remains constant at all heights of the surface.

5. The insulation ability of an insulator with the presence of moisture would
   a. Increase
   b. Decrease
   c. Remain unaffected
   d. May increase or decrease depending on temperature and thickness of insulation

6. Which of the following has least value of conductivity?
   a. Plastic b. Rubber c. Air d. Glass

7. Unit of thermal diffusivity is
   a. m^2/hr b. $m^2/hr\ °C$ c. $kcal/m^2\ °C$ d. $kcal/m^2hr\ °C$

8. The value of Prandtl number for air is about
   a. 0.1 b. 0.3 c. 0.7 d. 1.7

9. The rate of energy transferred by convection to that by conduction called
   a. Stanton number b. Nusselt number c. Biot number d. Peclet number

10. The product of Reynold's number and Prandtl number is known as
   a. Stanton number b. Peclet number c. Biot number d. Grashoff number

11. Joule sec is the unit of
   a. Universal gas constant
   b. Kinematic viscosity
   c. Thermal conductivity
   d. Planck's constant

12. Heat transfer by the natural convection is enhanced in systems with
   a. High viscosity
   b. High coefficient of thermal expansion
   c. Low temperature gradient
   d. Low density change with temperature

13. In a shell and tube heat exchanger, baffles are provided on the shell side to
   a. Improve heat transfer
   b. Provide support for tubes
   c. Prevent stagnation of shell side fluid
   d. All of these

14. The ratio of heat transfer with fins to heat transfer without fins is called
   a. Efficiency of the fins
   b. Capacity of the fins
   c. Effectiveness of the fins
   d. Coefficient of the performance of the fins

15. It is the ratio of internal thermal resistance of a solid to the boundary layer thermal resistance
   a. Lewis number b. Grashof number c. Biot number d. Schmidt number

16. What is buoyancy force to viscous force?
   a. Biot number b. Schmidt number c. Grashof number d. Prandtl number

17. Water always boils when its
   a. Temperature reaches 100 °C
   b. Vapor pressure equal to 760 mmHg
   c. Saturated vapor pressure equal to external pressure on its surface
   d. Saturated vapor pressure is less than the atmospheric pressure

18. "The ratio of the total emissive power to the absorptivity for all bodies is same at thermal equilibrium" is given by
   a. Kirchoff's law
   b. Planck's law
   c. Wien's displacement law
   d. Stefan Boltzman law

19. In the laminar flow of air (Pr=0.7) over a heated plate if δ and δ_T denote, respectively, the hydrodynamic and thermal boundary layer thickness, then?
   a. $\delta = \delta_T$ b. $\delta > \delta_T$ c. $\delta < \delta_T$ d. $\delta = 0$ but $\delta_T \neq 0$

20. Heat is transferred by all three modes of transfer, viz, conduction, convection and radiation in
   a. Electric heater
   b. Steam condenser
   c. Melting of ice
   d. Boiler