

KATHMANDU UNIVERSITY  
End Semester Examination [C]  
December, 2024

Marks Scored:

Level : B.Tech.

Year : III

Exam Roll No. :

Registration No.:

24 DEC 2024

Time: 30 mins.

Course : MEEG 306

Semester : I/II

F. M. : 20

Date : 24 DEC 2024

SECTION "A"

[20 Q. × 1 = 20 marks]

Choose the most appropriate answer and mark [X].

- When heat is transferred from one particle of hot body to another by actual motion of the heated particles, it is referred to as heat transfer by:  
 Conduction  Convection  
 Radiation  Both Conduction and Radiation
- Unit of thermal conductivity is:  
 J/m °K  W/m °K  J/m<sup>2</sup> °K  W/m<sup>2</sup> °K
- The variation of temperature in a plane wall is determined to be  $T(x) = 65x + 25$  where  $x$  is in m and  $T$  in °C. If the temperature at one surface is 38 °C, the thickness of the wall is  
 2 m  0.4 m  0.2 m  0.1 m
- In the case of insulating materials with thermal conductivity of 0.04 W/m°C, the contact resistance:  
 May or may not be significant  Very significant, so cannot be ignored  
 Can be ignored  Depends on the base material
- Heat transfer through a hollow pipe can be modeled as one-dimensional because:  
 The temperature of the pipe depends on axial direction only  
 The temperature of the pipe depends on tangential direction only  
 The temperature of the pipe depends on radial direction only  
 Hollow pipes cannot be modeled as one-dimensional
- At the outer radius of the pipe less than the critical radius of insulation:  
 The rate of heat transfer reaches a maximum value  
 The rate of heat transfer decreases with the addition of insulation  
 The rate of heat transfer from the cylinder increases with addition of insulation  
 There is no effect on the rate of heat transfer after increasing the insulation
- Which of the following relation can be used for corrected fin length in the case of a cylindrical fin with diameter  $L$ ?  
  $L + D/2$    $L + D$    $L + D/4$    $L + D/3$
- The 700 m<sup>2</sup> ceiling of a building has a thermal resistance of 0.2 m<sup>2</sup>K/W. The rate at which heat is lost through the ceiling on a cold winter day when the ambient temperature is -10°C and the interior is at 20°C is  
 150 MW  105 MW  118 MW  87 MW
- Which of the following equation cannot be used to calculate the friction factor based on the Reynold's number and roughness of the materials:  
 Moody Chart  Colebrook Equation  
 S E Haaland Relation  Darcy-Weisbach Equation

10. Which of the following is a correct representation of the excess temperature in boiling?  
  $(T_s - T_{sat})$         $(T_{sat} - T_s)$         $(T_f - T_{sat})$         $(T_{sat} + T_s)$
11. Which of the following statement is true for an internal flow with  $Pr > 1$   
 Thermal entry length is larger than the hydrodynamic entry length  
 Thermal entry length is less than the hydrodynamic entry length  
 Thermal entry length and hydrodynamic entry length are equal  
 The higher value between thermal entry length and hydrodynamic entry length depends on the property of fluid
12. Water ( $\mu = 9.0 \times 10^{-4} \text{ kg/m}\cdot\text{s}$ ,  $\rho = 1000 \text{ kg/m}^3$ ) enters a 2-cm-diameter, 3-m-long tube whose walls are maintained at  $100^\circ\text{C}$ . The water enters this tube with a bulk temperature of  $25^\circ\text{C}$  and a volume flow rate of  $3 \text{ m}^3/\text{h}$ . The Reynolds number for this internal flow is  
 59,000       105,000       178,000       236,000
13. Water enters a 2-cm-diameter, 3-m-long tube whose walls are maintained at  $100^\circ\text{C}$  with a bulk temperature of  $25^\circ\text{C}$  and volume flow rate of  $3 \text{ m}^3/\text{h}$ . Neglecting the entrance effects and assuming turbulent flow, the Nusselt number can be determined from  $Nu = 0.023 Re^{0.8} Pr^{0.4}$ . The convection heat transfer coefficient in this case is: (For water, use  $k = 0.610 \text{ W/m}\cdot^\circ\text{C}$ ,  $Pr = 6.0$ ,  $\mu = 9.0 \times 10^{-4} \text{ kg/m}\cdot\text{s}$ ,  $\rho = 1000 \text{ kg/m}^3$ )  
  $4140 \text{ W/m}^2\cdot\text{K}$         $6160 \text{ W/m}^2\cdot\text{K}$         $8180 \text{ W/m}^2\cdot\text{K}$         $9410 \text{ W/m}^2\cdot\text{K}$   
 (For water, use  $k = 0.610 \text{ W/m}\cdot^\circ\text{C}$ ,  $Pr = 6.0$ ,  $\mu = 9.0 \times 10^{-4} \text{ kg/m}\cdot\text{s}$ ,  $\rho = 1000 \text{ kg/m}^3$ )
14. How can the arithmetic mean temperature difference and LMTD of a same heat exchanger be compared?  
 the arithmetic mean temperature difference is less than LMTD of a same heat exchanger  
 the arithmetic mean temperature difference is more than LMTD of a same heat exchanger  
 the arithmetic mean temperature difference and LMTD of a same heat exchanger are equal  
 depends on the type of heat exchanger
15. In a parallel-flow heat exchanger, the NTU is calculated to be 2.5. The lowest possible effectiveness for this heat exchanger is  
 10%       27%       41%       50%
16. A counter-flow heat exchanger is used to cool oil ( $cp = 2.20 \text{ kJ/kg}\cdot^\circ\text{C}$ ) from  $110^\circ\text{C}$  to  $85^\circ\text{C}$  at a rate of  $0.75 \text{ kg/s}$  by cold water ( $cp = 4.18 \text{ kJ/kg}\cdot^\circ\text{C}$ ) that enters the heat exchanger at  $20^\circ\text{C}$  at a rate of  $0.6 \text{ kg/s}$ . If the overall heat transfer coefficient is  $800 \text{ W/m}^2\cdot^\circ\text{C}$ , the heat transfer area of the heat exchanger is (in  $\text{m}^2$ )  
 0.745       0.760       0.775       0.790
17. What is the approximate wavelength range of thermal radiation?  
 0.1 to  $100 \mu\text{m}$        0.1 to  $100 \text{ nm}$        0.1 to  $100 \text{ cm}$        1 to  $100 \mu\text{m}$
18. The wavelength at which the blackbody emissive power reaches its maximum value at  $300 \text{ K}$  is  
  $5.1 \mu\text{m}$         $9.7 \mu\text{m}$         $15.5 \mu\text{m}$         $38.0 \mu\text{m}$
19. Thermal radiation takes place from a body by electromagnetic waves as a result of  
 the weight of the body       the magnetic property of the body  
 the temperature of the body       does not require any property
20. Solar radiation is incident on a semi-transparent body at a rate of  $500 \text{ W/m}^2$ . If  $150 \text{ W/m}^2$  of this incident radiation is reflected back and  $225 \text{ W/m}^2$  is transmitted across the body, the absorptivity of the body is  
 0       0.25       0.30       0.45

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F. M. : 55

SECTION "B"

[5 Q. × 11 = 55 marks]

*Attempt ALL questions. Assume suitable data if missing. Figures in the bracket refer to marks the question carries. Use of a data book is **ALLOWED**.*

1.
  - a. A 10 cm dia copper ball is to be heated from 100°C to an average temperature of 150°C in 30 minutes. Taking  $\rho = 8950 \text{ kg/m}^3$  and  $c_p = 0.395 \text{ kJ/kg } ^\circ\text{C}$ , determine [3]
    - i. Total amount of heat transfer to the copper ball
    - ii. Average rate of heat transfer to the ball
    - iii. Average heat flux
  - b. The steady-state temperature distribution in a one-dimensional wall of thermal conductivity  $k$  and thickness  $L$  is of the form  $T = ax^3 + bx^2 + cx + d$ . Derive expressions for the heat generation rate per unit volume in the wall and the heat fluxes at the two wall faces ( $x=0, L$ ). [3]
  - c. The composite wall of an oven consists of three materials, two of which are of known thermal conductivity,  $k_A = 20 \text{ W/m.K}$  and  $k_C = 50 \text{ W/m.K}$ , and known thickness,  $L_A = 0.30 \text{ m}$  and  $L_C = 0.15 \text{ m}$ . The third material, B, which is sandwiched between materials A and C, is of known thickness,  $L_B = 0.15 \text{ m}$ , but unknown thermal conductivity  $k_B$ . [5]
2.
  - a. Aluminum fins of triangular profile are attached to a plane wall whose surface temperature is 25°C. The fin base thickness is 2 mm, and its length is 6 mm. The system is in ambient air at a temperature of 20°C, and the surface convection coefficient is 40  $\text{W/m}^2\text{.K}$ . [5]
    - i. What are the fin efficiency and effectiveness?
    - ii. What is the heat dissipated per unit width by a single fin?
  - b. What does it signify when the effectiveness of the fin is less than 1? [1]
  - c. A pin fin of 10-mm diameter dissipates 30 W by forced convection to air in cross flow with a Reynolds number of 4000. If the diameter of the fin is doubled and all other conditions remain the same, estimate the fin heat rate. Assume the pin to be infinitely long. [5]
3.
  - a. A 3 mm thick glass window transmits 90% of the radiation between  $\lambda = 0.3$  and  $3 \mu\text{m}$  and is essentially opaque for radiation at other wavelengths. Determine the rate of radiation transmitted through a 2 m x 2 m glass window from blackbody sources at  
i) 5800 K and ii) 1000 K. [5]
  - b. Calculate all the view factors associated with a cylinder of diameter and height, both measuring 10 cm. [4]
  - c. Explain Wien's Displacement Law. [2]

P.T.O.

4.

- a. Water is boiled at the saturation (or boiling) temperature of  $T_{\text{sat}} = 90^\circ\text{C}$  by a horizontal brass heating element. Calculate the maximum heat flux in the nucleate boiling regime. [4]
- b. How does the value of heat transfer coefficient vary along a flat plate? Illustrate the distribution through a sketch. [2]
- c. A thick-walled steel pipe ( $k = 60 \text{ W/m.K}$ ) carrying hot water is cooled externally by a cross-flow airstream at a velocity of  $20 \text{ m/s}$  and a temperature of  $25^\circ\text{C}$ . The inner and outer diameters of the pipe are  $D_i = 20 \text{ mm}$  and  $D_o = 25 \text{ mm}$ , respectively. At a certain location along the pipe, the mean temperature of the water is  $80^\circ\text{C}$ . Assuming the flow inside the tube is fully developed with a Reynolds number of  $20,000$ , find the heat transfer rate to the airstream per unit pipe length. [5]

5.

- a. A counterflow, concentric tube heat exchanger is designed to heat water from  $20$  to  $80^\circ\text{C}$  using hot oil, which is supplied to the annulus at  $160^\circ\text{C}$  and discharged at  $140^\circ\text{C}$ . The thin-walled inner tube has a diameter of  $D_i = 20 \text{ mm}$ , and the overall heat transfer coefficient is  $500 \text{ W/m}^2\text{.K}$ . The design condition calls for a total heat transfer rate of  $3000 \text{ W}$ . [7]
  - i. What is the length of the heat exchanger?
  - ii. After 3 years of operation, performance is degraded by fouling on the water side of the exchanger, and the water outlet temperature is only  $65^\circ\text{C}$  for the same fluid flow rates and inlet temperatures. What are the corresponding values of the heat transfer rate, the outlet temperature of the oil, the overall heat transfer coefficient, and the waterside fouling factor,  $R''_{f,c}$ ?
- b. Illustrate the temperature distribution of hot and cold fluid in Parallel and Counter flow heat exchangers through a sketch. [2]
- c. Explain the significance of Grashof number in convection. [2]