KATHMANDU UNIVERSITY
End Semester Examination
July/August, 2024

Marks Scored:

Level : B.E.
Year : III

Course : CHEG 303
Semester : I

Exam Roll No. :

Time: 30 mins.

F. M. : 10

Registration No.:

Date : 05 AUG 2024

SECTION "A"

[20 Q. × 0.5 = 10 marks]

Choose and encircle in the most appropriate option from each set of choices

1. Heat is lost through a brick wall (k 5 0.72 W/m·K), which is 4 m long, 3 m wide, and 25 cm thick at a rate of 500 W. If the inner surface of the wall is at 22°C, the temperature at the midplane of the wall is...
   a. 7.5°C b. 11.0°C c. 14.8°C d. 22°C

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

3. 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

4. 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

5. 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

6. 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.

7. The concept of overall coefficiet of heat transfer is used in heat transfer problem of
   a. Conduction b. Convection
   c. Radiation d. Conduction and convection

8. Thermal diffusivity of a substance is
   a. proportional to thermal conductivity b. inversely proportional to k
   c. proportional to density d. proportional to specific heat capacity

9. Consider steady one-dimensional heat conduction through a plane wall, a cylindrical shell, and a spherical shell of uniform thickness with constant thermophysical properties and no thermal energy generation. The geometry in which the variation of temperature in the direction of heat transfer will be linear is
   a. Plane wall b. Cylindrical Shell c. Spherical Shell d. All of them

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

11. The variation of temperature in a plane wall is determined to be T(x) = 110-60x where x is in m and T is in °C. If the thickness of the wall is 0.75 m, the temperature difference between the inner and outer surfaces of the wall is
a. 30 °C b. 45 °C c. 60 °C d. 75 °C

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

13. A non-dimensional number generally associated with forced convection heat transfer is
a. Grashoff number
b. Stanton number
c. Weber number
d. Prandtl number

14. LMTD in case of conter flow heat exchanger as compared to parallel flow heat exchanger is
a. higher
b. lower
c. depends on the area of heat exchanger
d. depebds on temperature conditions

15. In an experiment to determine the thermal conductivity of a long solid 2.5 cm diameter rod, its base is placed in a furnace with a large portion of it projecting into the room air at 22 °C. After steady state condition prevails, the temperatures at two-point 10 cm apart are found to be 110 °C and 85 °C respectively. The convective heat transfer coefficient between the rod surface and the surrounding air is 28.4 W/m2K. Thermal conductivity of the rod material is ---------- (W/mK)? (Hint: Use $(T-T_\infty)/(Tb-T_\infty) = e^{-mx}$ and $m = \text{sqrt}(hP/KA_c)$)
a. 339 b. 209 c. 407 d. 429

16. Two finned surfaces with long fins are identical, except that the convection heat transfer coefficient for the first finned surface is twice that of the second one. What statement below is accurate for the efficiency and effectiveness of the first finned surface relative to the second one? [n_f=tanh(mL)/mL where m=sqrt(hP/kA$_c$)]
a. Higher efficiency and higher effectiveness
b. Higher efficiency but lower effectiveness
c. Lower efficiency but higher effectiveness
d. Lower efficiency and lower effectiveness

17. Lumped system analysis of transient heat conduction situations is valid when the Biot number is
a. Very small b. Approximately 1 c. Very large d. Any real number

18. 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

19. "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

20. A grey body is one whose absorptivity
a. varies with temperature
b. varies with wavelength of the incident ray
c. is equal to its emissivity
d. does not vary with temperature and wavelength of the incident ray

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SECTION "B"
[5 Q. × 8 = 40 marks]

Attempt *ALL* questions.

1. [1+3+2+1+1]

A flat plate with a thickness of 7 mm and a surface area of 0.040 m^2 has an initial surface temperature (T_i) of 25 °C, which is also the temperature of the surrounding air (T_∞). A heating element is attached to the back side of the plate. The element is used to increase the temperature of the plate surface, T. It can be assumed that no heat is lost via the back side of the plate since that side is well insulated (the heating element is placed between the plate and the insulation). The plate has a density of 2800 kg/m^3, a specific heat of 900 J/(kgK) and a thermal conductivity of 180 W/(mK). At t_i = 0 the heating element is switched on, leading to a constant heat flux of 12500 W/m^2 through the plate. The convection heat transfer coefficient, which characterizes the heat transfer from the surface to the surrounding air, is 10 W/(m^2K).

a. Calculate the heat transfer rate (W) from the plate to the surrounding air before the heating element is switched on.
b. Assuming that the lumped thermal capacitance method can be used, and that radiation heat loss to the surroundings can be neglected, show that the time t_f required to obtain a new surface temperature T can be expressed as $t_f = \frac{\rho VC}{hA_s} ln \frac{q" + h(T_\infty - T_i)}{q" + h(T_\infty - T_f)}$. Hint: Make and energy balance of the steel plate (start with $E_{in} + E_{gen} - E_{out} = E_{acc}$). (Bi = $\frac{hL_c}{k}$)($\int \frac{dx}{a-bx} = \frac{1}{-b} ln(a - bx)$), where a and b are constants and x is a variable).
c. Calculate the time required to reach a temperature of 135 °C.
d. Now assume that the surgace has reached a temperautre of 135 °C and then the heating element is switched off again. Hence, the surface temperature starts to drop. Calculate the time required to reach a new temperature of 50 °C.
e. Verify the assumption that the lumped capacitance method is valid for this problem.

2. [5+1+2]

a. Steam condensing on the outer surface of a thin-walled circular tube of diameter D = 50 mm and length L = 6 m maintains a uniform outer surface temperature of 1000 °C. Water flows through the tube at a rate of $\dot{m}$ = 0.25 kg/s, and its inlet and outlet temperatures are $T_{m,i}$ = 15 °C and $T_{m,o}$ = 57 °C. What is the average convection coefficient associated with the water flow? c_p of water at 36 °C = 4178 J/kg·K.
b. If the Nusselt number has the value 1, what does it tell you about the flow in the system?
c. Show that the thermal expansion coefficient for an ideal gas is equal to 1/T. [Hint: $\beta = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_p$]

P.T.O.

3. [5+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.

a. Estimate the convection heat rate from the fireplace to the room.
b. Assuming $\varepsilon = 1.0$ for the glass surface and Tsur = 23°C, what is the net rate of radiation heat transfer between the glass and the surroundings?

4. [3+2+2+1]

The bottom of a copper pan (polished), which is 0.3 m in diameter, is maintained at 118 °C. The pressure is 1 atm. Water is boiling in the pan. At the onset of boiling, the water level is 200 mm. When answering the following questions, the answers should be as accurate as possible. Describe any assumptions made. According to the boiling curve, nucleate pool boiling will occur.

a. What is the power required to boil water in this pan?
b. What is the evaporation rate?
c. Estimate the critical heat flux?
d. Draw a typical boiling curve for water at 1 atm: surface heat flux as a function of excess temperature. Clearly show ONB, Critical heat flux, Minimum heat flux and Boiling crisis

5. Heat exchanger [2+2+4]

A shell-and-tube heat exchanger with two shells and four tube passes shall be designed to cool 5 kg/s of engine oil from 150 to 100 °C. The cooling is to be accomplished by passing water through the shell side of the heat exchanger. The water inlet temperature is 15 °C, and its outlet temperature should be 85 °C. The overall heat transfer coefficient is 500 W/(m^{2}K). The specific heat of the oil is taken as constant and equal to 2000 J/(kg K).

a. What is the duty of the heat exchanger?
b. What is the required water flow rate?
c. Determine the heat transfer area using the graphical method.