KATHMANDU UNIVERSITY
End Semester Examination
July/August, 2024

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

13 AUG 2024

Course : MEEG 306
Semester : I
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. Consider heat conduction equation as [2]

$$\frac{d^2T}{dx^2}+\frac{d^2T}{dy^2}=\frac{1}{\alpha}\frac{\partial T}{\partial t}$$

i. Is heat transfer steady or transient?

ii. Is heat transfer one-, two-, or three-dimensional?

iii. Is there heat generation in the medium?

iv. Is the thermal conductivity of the medium constant or variable?

b. Yesterday you were waking up late at night to solve heat transfer problems. To wake up, you needed a cup of coffee. Coffee was prepared by pouring milk in pan placed over an electric stove. To heat the milk as fast as possible without burning it, you turned the stove on high and stirred the milk continuously. As a student of heat transfer, what approach would you take to model the problem with proper reasoning. Also state, the various assumptions you will make while modeling. Is it possible to bring the entire bulk of the milk up to the burn temperature without burning part of it? [3+1]

c. In subsea oil and natural gas production, hydrocarbon fluids may leave the reservoir with a temperature of 70°C and flow in subsea surrounding of 5°C. As a result of the temperature difference between the reservoir and the subsea surrounding, the knowledge of heat transfer is critical to prevent gas hydrate and wax deposition blockages. Consider a subsea pipeline with inner diameter of 0.5 m and wall thickness of 8 mm is used for transporting liquid hydrocarbon at an average temperature of 70°C, and the average convection heat transfer coefficient on the inner pipeline surface is estimated to be 250 $W/m^2 \cdot K$. The subsea surrounding has a temperature of 5°C and the average convection heat transfer coefficient on the outer pipeline sur face is estimated to be 150 $W/m^2 \cdot K$. If the pipeline is made of material with thermal conductivity of 60 $W/m \cdot K$, (a) obtain the temperature variation in the pipeline wall, (b) determine the inner surface temperature of the pipeline, (c) obtain the mathematical expression for the rate of heat loss from the liquid hydrocarbon in the pipeline, and (d) determine the heat flux through the outer pipeline. [7]

2.

Explain the typical pool boiling curve with an appropriate diagram. Show various regimes and write their major features. [4]

P.T.O.

3.

a. To defrost ice accumulated on the outer surface of an automobile windshield, warm air is blown over the inner surface of the windshield. Consider an automobile wind shield with thickness of 5 mm and thermal conductivity of 1.4 W/m·K. The outside ambient temperature is 210°C and the convection heat transfer coefficient is 200 $W/m^2 \cdot K$, while the ambient temperature inside the automobile is 25°C. Determine the value of the convection heat transfer coefficient for the warm air blowing over the inner surface of the windshield necessary to cause the accumulated ice to begin melting. Also determine missing temperature at the interfaces. [4]

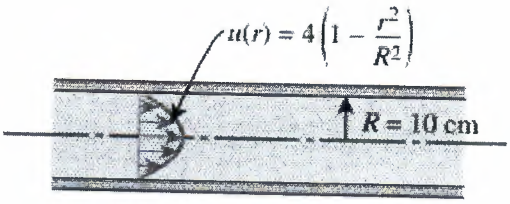
b. Consider a very long rectangular fin attached to a flat surface such that the temperature at the end of the fin is essentially that of the surrounding air, i.e. 20°C. Its width is 5.0 cm; thickness is 1.0 mm; thermal conductivity is 200 W/m·K; and base temperature is 40°C. The heat transfer coef ficient is 20 $W/m^2 \cdot K$. Estimate the fin temperature at a distance of 5.0 cm from the base and the rate of heat loss from the entire fin. [4]

4.

a. Consider a 0.6-m × 0.6-m thin square plate in a room at 30°C. One side of the plate is maintained at a temperature of 90 °C, while the other side is insulated. Determine the rate of heat transfer from the plate if the plate is vertical. [3]

b. Air at 27◦C blows over a flat surface with a sharp leading edge at 1.5 m/s. Calculate the average shear stress and the overall friction coefficient for the surface in if its total length is L = 0.5 m. Com pare $\overline{\tau_w}$ with τ_w at the trailing edge. At what point on the surface does $\overline{\tau_w}$ = τw? Finally, estimate what fraction of the surface can legitimately be analyzed using boundary layer theory.[4]

c. The velocity profile in fully developed laminar flow in a circular pipe of inner radius R = 10 cm, is given in m/s, . Determine the mean and maximum velocities in the pipe, and the volume flow rate. [6]



d. Experimental results for the local heat transfer coefficient h_x for flow over a flat plate with an extremely rough surface were found to fit the relation

$$h_x(x) = ax^{-0.1}$$

where a is a coefficient ($W/m^{1.9}.K$) and x (m) is the distance from the leading edge of the plate. Develop an expression for the ratio of the average heat transfer coefficient $\overline{h_x}$ for a plate of length x to the local heat transfer coefficient h_x at x. [3]

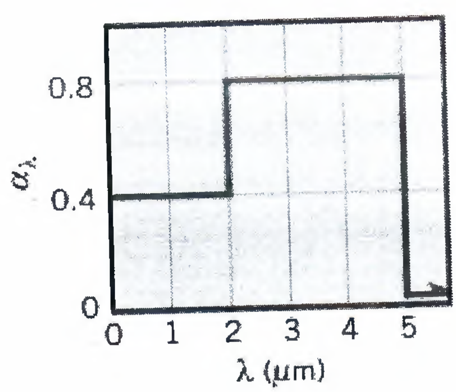
5.

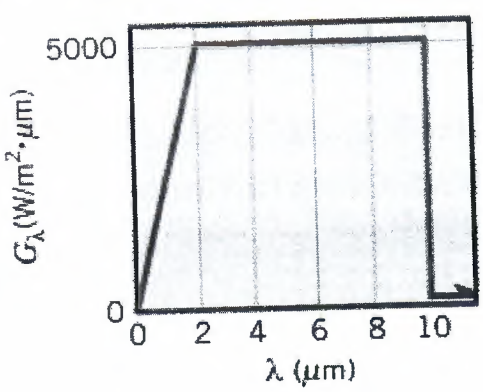
Ethanol is classified by the National Fire Protection Association (NFPA) as a flammable fluid because of its low flash point of 17 ^{0}C. This means that at 17 ^{0}C or higher, ethanol can vaporize and become a mixture in air that would ignite when an ignition source is present. Thus, in an environment that ignition sources are present, keeping ethanol at a temperature below its flash point can help to prevent fire hazard. Consider a process where ethanol is cooled by water in a 1-shell-pass heat exchanger that can accommodate a maximum of 14-tube-passes. The tubes are made of copper and thin-walled with an inner diameter of 1.5 cm. The length of each tube pass that can be fitted inside the heat exchanger is 3 m, and the overall heat transfer coeffi cient is 700 W/m^2·K. Ethanol (cp = 2630 J/kg·K) enters the heat exchanger at 55°C and flows through the shell at a rate of 0.28 kg/s. Water enters the heat exchanger at 28^{0}C and flows through the tubes at a rate of 1.3 kg/s. To prevent fire hazard, the ethanol is to be cooled to 15°C, which is below its flash point. Determine the number of tube passes that is necessary inside the shell-and tube heat exchanger to cool the ethanol to the prescribed temperature. Discuss whether or not this heat exchanger is suitable for this application. Evaluate any required property of water at 5^{0}C. Is this a good assumption? [6]

6.

a. A thin aluminum sheet with an emissivity of 0.1 on both sides is placed between two very large parallel plates that are maintained at uniform tempera tures T_1 = 800 K and T_2 = 500 K and have emissivities ϵ_1 = 0.2 and ϵ_2 = 0.7, respectively. Determine the net rate of radiation heat transfer between the two plates per unit surface area of the plates and com pare the result to that without the shield. [4]

b. Consider an opaque, diffuse surface for which the spectral absorptivity and irradiation are as shown. What is the total absorptivity of the surface for the prescribed irradiation? If the surface is at a temperature of 1250 K, what is its emissive power? How will the surface temperature vary with time, for the pre scribed conditions? What is the maimum wavelength? [4]





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Time: 30 mins.

F. M. : 20

Registration No.:

Date : 13 AUG 2024

SECTION "A"

[20 Q. × 1 = 20 marks]

Choose the most appropriate answer and ***mark [X].***

1. The unit of thermal conductivity k and heat transfer coefficient h are __________ respectively.
[ ] $\frac{W}{mK}$ and $\frac{W}{m^2K}$ [ ] $\frac{W}{m^2K}$ and $\frac{W}{mK}$ [ ] $\frac{W}{K}$ and $\frac{W}{m^2K}$ [ ] $\frac{W}{mK}$ and $\frac{W}{K}$

2. Critical insulation radius for a cylinder is
[ ] $r_{o,c} = \frac{k}{h}$ [ ] $r_{o,c} = \frac{2k}{h}$ [ ] $r_{o,c} = \frac{h}{k}$ [ ] $r_{o,c} = \frac{2h}{k}$

3. The temperature of the fin in case of long fin varies
[ ] Linearly [ ] Hyperbolically [ ] Exponentially [ ] Parallel

4. 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
[ ] Plane wall [ ] Cylindrical shell [ ] Spherical shell [ ]All of them

5. Consider two walls, *A* and *B*, with the same surface areas and the same temperature drops across their thicknesses.The ratio of thermal conductivities is $k_A/k_B = 4$ and the ratio of the wall thicknesses is $L_A/L_B = 2$. The ratio of heat transfer rates through the walls Q_A/Q_B
[ ] 1 [ ] 2 [ ] 4 [ ] 8

6. The Nusselt number for the flow of water at 25 ^{0}C (velocity = 2 m/s) over a hot metallic sphere (d= 5 cm) of 95 ^{0}C can be expressed as

$$Nu = 1 + \left[0.4 \times \sqrt{\text{Re}} + 0.06 \times \text{Re}^{\frac{2}{3}}\right] \text{Pr}^{0.4} \left(\frac{\mu}{\mu_w}\right)^{0.25}$$

What will be the value of Nusselt number if the plate is placed in a stagnant pool of water at 25 ^{0}C? Where Pr = 7.86 (at 25 ^{0}C) ; $\left(\frac{\mu}{\mu_w}\right) = 1.15$ (at 25 ^{0}C)

[ ] 2 [ ] 3.65 [ ] 1 [ ] none of the options

7. A spherical block of dry ice at –79°C is exposed to atmospheric air at 30°C. The general direction in which the air moves in this situation is
[ ] recirculation around the sphere [ ] up
[ ] down [ ] Need more information to answer

8. For laminar flow of a fluid along a flat plate, one would expect the largest local convection heat transfer coefficient for the same Reynolds and Prandl numbers when

[ ] The same temperature is maintained on the surface
[ ] The same heat flux is maintained on the surface
[ ] The plate has an unheated section
[ ] The plate surface is polished

9. The variation of temperature in a plane wall is determined to be $T(x) = 110\text{-}48x$ 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

[ ] 55°C [ ] 36°C [ ] 18°C [ ] 9°C

10. 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?

[ ] Higher efficiency and higher effectiveness
[ ] Higher efficiency but lower effectiveness
[ ] Lower efficiency but higher effectiveness
[ ] Lower efficiency and lower effectiveness

11. The thermal conductivity of a solid depends upon the solid's temperature as $k = aT + b$ where a and b are constants. The temperature in a planar layer of this solid as it conducts heat is given

(a) $aT + b = x + C_2$
(b) $aT + b = C_1 x^2 + C_2$
(c) $aT^2 + bT = C_1 x + C_2$
(d) $aT^2 + bT = C_1 x^2 + C2$

[ ] a [ ] b [ ] c [ ] d

12. Water enters a circular tube whose walls are maintained at a constant temperature at a specified flow rate and temperature. For fully developed turbulent flow, the Nusselt number can be determined from $Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$. The correct temperature difference to use in Newton's law of cooling in this case is

[ ] The difference between the inlet and outlet water bulk temperature.
[ ] The difference between the inlet water-bulk temperature and the tube-wall temperature.
[ ] The log mean temperature difference.
[ ] The difference between the average water bulk temperature and the tube temperature

13. Air enters a duct at 20°C at a rate of 0.08 m^3/s, and is heated to 150°C by steam condensing outside at 200°C. The error involved in the rate of heat transfer to the air due to using arithmetic mean temperature difference instead of logarithmic mean temperature difference is

[ ] 5.4% [ ] 8.1% [ ] 10.6% [ ] 13.3%

14. Internal force flows are said to be thermally fully developed once the ____ at a cross-section no longer changes in the direction of flow

[ ] Temperature distribution
[ ] Velocity distribution
[ ] The given condition is not enough to determine
[ ] Energy distribution

15. Air at 20 ^{0}C flows over a 4-m long and 3-m wide surface of a plate whose temperature is 80 ^{0}C with a velocity of 5 m/s. The length of the surface for which the flow remains laminar is (For air, use $k = 0.02735$ W/m.K, Pr = 0.7228, $\vartheta = 2.2\times 10^{-5}$ m^2/s)

[ ] 1.3m [ ] 1.8 m [ ] 2.2 m [ ] 3.7 m

16. In film condensation, maximum velocity is obtained at which of the following conditions?

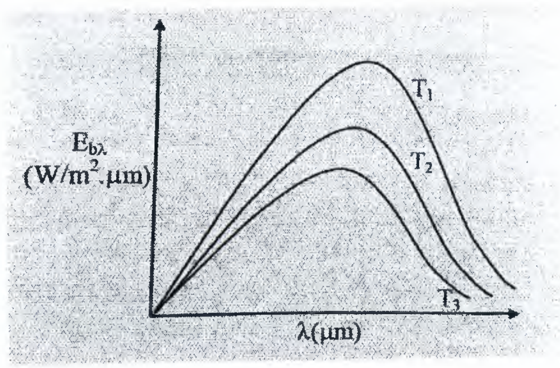
[ ] liquid region [ ] vapor region

[ ] liquid-vapor interface [ ] both liquid and vapor region

17. In a parallel-flow, liquid-to-liquid heat exchanger, the inlet and outlet temperatures of the hot fluid are 150°C and 90°C while that of the cold fluid are 30°C and 70°C, respectively. For the same overall heat transfer coefficient and heat transfer, the percentage decrease in the surface area of the heat exchanger if counter-flow arrangement is used is

[ ] 9.7% [ ] 14.5% [ ] 19.7% [ ] 24.6%

18. The following figure was generated from experimental data relating spectral black body emissive power to wave length at three temperatures T_1, T_2 and T_3 ($T_1 > T_2 > T_3$).



The conclusion is that the measurements are

[ ] Correct because the maxima in $E_{b\lambda}$ show the correct trend

[ ] Correct because Planck's law is satisfied

[ ] Wrong because Stephen Boltzmann's law is not satisfied

[ ] Wrong because Wien's displacement law is not satisfied

19. The wavelength at which the blackbody emissive power reaches its maximum value at 300 K is

[ ] 5.1 μm [ ] 9.7 μm [ ] 13.8 μm [ ] 14.6 μm

20. A hollow enclosure is formed between two infinitely long concentric cylinders of radii 1m and 2m, respectively. Radiative heat exchange takes place between the inner surface of the larger cylinder (surface-2) and the outer surface of the smaller cylinder (surface-1). The radiating surfaces are diffuse, and the medium in the enclosure is non-participating. The fraction of the thermal radiation leaving the larger surface and striking itself is …………