(Regular) HEAT TRANSFER OPERATIONS

CHE 2225 IV Semester April | May 2024

Type: DES

Q1. Air at a pressure of 1 atm and a temperature of 50°C is in parallel flow over the top surface of a flat plate that is heated to a uniform temperature of 100°C. The plate has a length of 0.20 m (in the flow direction) and a width of 0.10 m. The Reynolds number based on the plate length is 40,000. Evaluate the rate of heat transfer from the plate to the air? If the free stream velocity of the air is doubled and the pressure is increased to 10 atm, estimate the rate of heat transfer?

PROPERTIES: *Table A-4*, Air (T_f = 348K, 1 atm): k = 0.0299 W/m·K, Pr = 0.70.

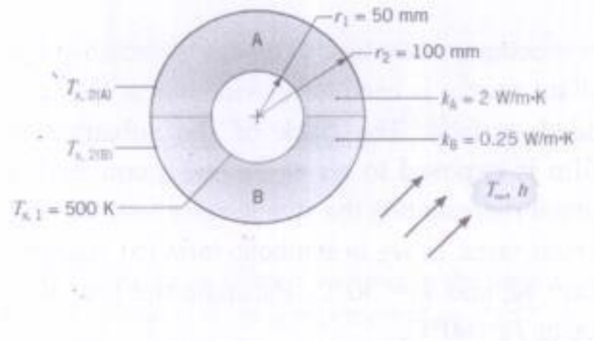
(4)

Q2. The heat flux through a wood slab 50 mm thick, whose inner and outer surface temperatures are 40 and 20°C, respectively, has been determined to be 40 W/m^2. Determine the thermal conductivity of the wood? Explain the importance of Biot number in validating lumped capacitance method. (3)

Q3. Develop an expression for the rate of heat transfer of a sphere for steady-state, one-dimensional conditions with no heat generation. (3)

Q4. A plane wall of thickness $2L$= 40 mm and thermal conductivity k= 5 W/m. K experiences uniform volumetric heat generation, while convection heat transfer occurs at both of its surfaces (x= - L,+ L), each of which is exposed to a fluid of temperature T= 20°C. Under steady-state conditions, the temperature distribution in the wall is of the form $T(x)= a+ bx+ cx^2$, where a= 82.0°C, b= -210°C/m, c=- 2X 10^4 °C/m^2, and x is in meters. The origin of the x-coordinate is at the midplane of the wall. a) estimate the volumetric rate of heat generation in the wall? (b) Determine the surface heat fluxes at -L and +L, how are these fluxes related to the heat generation rate? (c) Evaluate the convection coefficients for the surfaces at x=-L and x=+L? if T(-L) =78.2^{0}C and T (+L) =69.8^{0}C (d) Develop an expression for the heat flux distribution (e) If the source of the heat generation is suddenly deactivated, formulate the rate of change of energy stored in the wall at this instant? (4)

Q5. Steam flowing through a long, thin-walled pipe maintains the pipe wall at a uniform temperature of 500 K. The pipe is covered with an insulation blanket comprised of two different materials, A and B. The interface between the two materials may be assumed to have an infinite contact resistance, and the entire outer surface is exposed to air for which T_∞= 300 K and h = 25 W/m^2 K. (a) Sketch the thermal circuit of the system. (b) For the prescribed conditions, determine the total heat loss from the pipe? (C) evaluate the outer surface temperatures $T_{s,2(A)}$ and $T_{s,2(B)}$?



(3)

Q6. In a fire-tube boiler, hot products of combustion flowing through an array of thin-walled tubes are used to boil water flowing over the tubes. At the time of installation, the overall heat transfer coefficient ws 400W/m^2.K. After one year of use, the inner and outer tube surfaces are fouled with corresponding fouling factors of 0.0015 and 0.0005 m^2.k/W respectively. Should the boiler be scheduled for cleaning the tube surfaces? Justify your answer. (3)

Q7. With the help of a neat diagrams explain about various types of heat exchangers. Discuss the importance of baffles in HEs. (3)

Q8. A circular pipe of 25-mm outside diameter is placed in an airstream at 25°C and 1-atm pressure. The air moves in cross flow over the pipe at 15 m/s, while the outer surface of the pipe is maintained at 100°C. Estimate the rate of heat transfer from the pipe per unit length. Use Hilpert's and Zukauskas correlations to solve. C= 0.193 & m=0.618.

PROPERTIES: *Table A-4*, Air (T_f = 335 K, 1 atm): $\nu = 19.31 \times 10^{-6}$ m^2/s, $\rho = 1.048$ kg/m^3, k = 0.0288 W/m·K, Pr = 0.702.

Using the Zukauskas correlation and evaluating properties at T_∞ ($\nu = 15.71 \times 10^{-6}$ m^2/s, k = 0.0261 W/m·K, , Pr = 0.707), but with $Pr_s = 0.695$ at T_s.

TABLE 7.4 Constants of Equation 7.53 for the circular cylinder in cross flow [16]

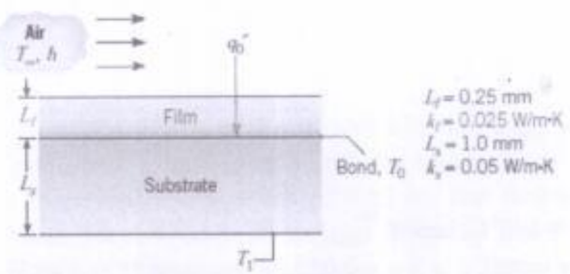
Re_D	C	m
1–40	0.75	0.4
40–1000	0.51	0.5
10^3–2×10^5	0.26	0.6
2×10^5–10^6	0.076	0.7

(5)

Q9. Describe about any two methods of feeding evaporators. (2)

Q10. Explain various modes of pool boiling with the help of a neat diagram. What is condensation? Distinguish between film and drop-wise condensation? (5)

Q11. In a manufacturing process, a transparent film is being bonded to a substrate as shown in the sketch. To cure the bond at a temperature T_0, a radiant source is used to provide a heat flux q_0'' (W/m^2), all of which is absorbed at the bonded surface. The back of the substrate is maintained at T_1 while the free surface of the film is exposed to air at T_∞ and a convection heat transfer coefficient h. (a) Show the thermal circuit representing the steady-state heat transfer situation. Be sure to label *all* elements, nodes, and heat rates. Leave in symbolic form.(b) Assume the following conditions: T_∞ = 20°C, h= 50 W/m^2. K, and T_1= 30°C. Estimate the heat flux q_0'' that is required to maintain the bonded surface at T_0= 60°C.

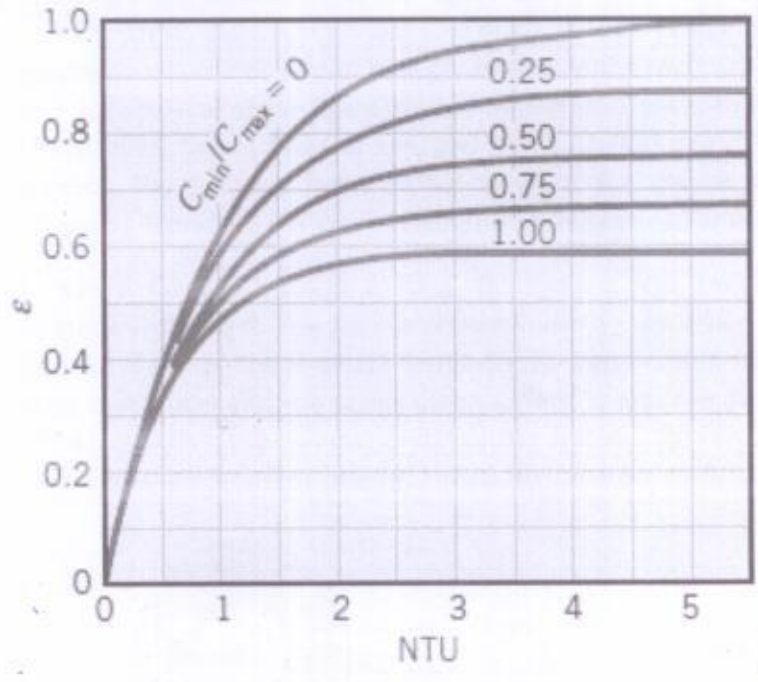


(3)

Q12. Explain Spectral intensity, total hemispherical emissive power, effectiveness of HEs and Evaporation. (2)

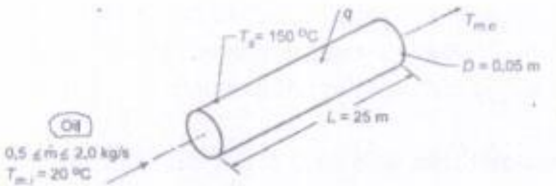
Q13. A shell-and-tube heat exchanger must be designed to heat 2.5 kg/s of water from 15 to 85°C. The heating is to be accomplished by passing hot engine oil, which is available at 160°C, through the shell side of the exchanger. The oil is known to provide an average convection coefficient of h_o=400 W/m^2.K on the outside of the tubes. Ten tubes pass the water through the shell. Each tube is thin walled, of diameter D= 25 mm, and makes eight passes through the shell. If the oil leaves the exchanger at 100°C, Estimate its flow rate? Predict the length of the tubes that needs to accomplish the desired heating? Solve using NTU method.

PROPERTIES: *Table A.5*, unused engine oil: ($\overline{T}_h$ = 130°C): c_p = 2350 J/kg·K. *Table A.6*, water ($\overline{T}_c$ = 50°C): c_p = 4181 J/kg·K, $\mu = 548 \times 10^{-6}$ N·s/m^2, k = 0.643 W/m·K, Pr = 3.56.



(4)

Q14. Engine oil is heated by flowing through a circular tube of diameter D= 50 mm and length L= 25 m and whose surface is maintained at 150°C. (a) If the flow rate and inlet temperature of the oil are 0.5 kg/s and 20°C, what is the outlet temperature $T_{m,o}$? Evaluate the total heat transfer rate q for the tube?



PROPERTIES: *Table A.5*, Engine oil (assume $T_{m,o} = 140°C$, hence $\bar{T}_m = 80°C = 353$ K): $\rho = 852$ kg/m^3, $\nu = 37.5 \times 10^{-6}$ m^2/s, $k = 138 \times 10^{-3}$ W/m·K, $Pr = 490$, $\mu = \rho \cdot \nu = 0.032$ kg/m·s, $c_p = 2131$ J/kg·K.

$$\overline{Nu_D} = 3.66 + \frac{0.0668(D/L)Re_D\,Pr}{1+0.04\left[(D/L)Re_D\,Pr\right]^{2/3}}.$$

(4)

Q15. An electric resistance heater is embedded in a long cylinder of diameter 30 mm. When water with a temperature of 25^{0}C and velocity of 1 m/s flows crosswise over the cylinder, the power per unit length required to maintain the surface at a uniform temperature of 90^{0}C is 28 kW/m. When air, also at 25^{0}C, but with a velocity of 10 m/s is flowing, the power per unit length required to maintain the same surface temperature is 400 W/m. Determine and compare the convection coefficients for the flows of water and air. **(2)**