Gazi University
Department of Chemical Engineering
CHE321 Heat Transfer

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PROBLEM SET 2

Problem 1. (Forced convection)

Calculate the heat transfer coefficient for a fluid with the properties listed below flowing through a tube 6.1 m (20 ft) long and of 0.62’’ (0.016 m) inside diameter. The bulk fluid temperature is 212 °F (373 K) and the tube surface temperature is 122 °F. Calculate the heat transfer coefficient if the fluid is flowing at a rate of 2000 Ib/h (907.2 kg/h). Also calculate the heat transfer coefficient if the flow rate is reducud to 100 Ib/h (45.36 kg/h).

C_p = 0.65 Btu/Ib °F (2.72 kJ/kg K)

k = 0.085 Btu/ h ft °F (0.147 W/m K)

μ_w = 4.0 Ib/ft h (1.65 cP)

μ_b = 1.95 Ib/ft h (0.806 cP)

Problem 2. (Natural convection)

Calculate the heat transfer coefficient from a coil immersed in water with the physical properties listed below. The coil has a diameter of 1’’ (0.0254 m) and the temperature difference between the surface of the coil and the fluid is 10 °F (5.56 K). The properties of water: C_p= 4.19 kJ/kg K, ρ = 961.1 kg/m^3, k = 0.683 W/mK, μ= 0.298 cP, β = 0.00022 K^{-1}.

Problem 3. (Forced convection)

Benzene is cooled from 60.6 °C to 21.1 °C in the inner pipe of a double pipe exchanger. Cooling water flows countercurrently to the benzene entering to the jacket at 18.3 °C and leaving at 23.9 °C. The exchanger consists of an inner pipe of 7/8-in (22.2 mm) BWG copper tubing jacketed with 1 ½ -in (38.1 mm) Schedule 40 steel pipe. The linear velocity of the benzene is 1.52 m/s. Neglecting the resistance of the wall and scale films assuming L/D >60 for both pipes, compute the film coefficients of the benzene and water and the overall coefficient based on the outside area of the inner pipe.

	benzene	water
ρ, kg/m3	850.6	998
μ, cP	0.48	0.97
k, W/mK	0.154	0.599
Cp, J/kgK	182	4184

Problem 4. (Natural convection)

A vertical cylinder 76.2 mm in diameter and 121.9 mm high is maintained at 397.1 K at its surface. It loses heat by natural convection to air at 294.3 K. Heat is lost from the cylindirical side and the flat circular end at the top. Calculate the heat loss. Use the simplified equations of Table in Geankoplis and those equations for the lowest range of $N_{Gr}N_{Pr}$. The equivalent L to use for the top flat surface is 0.9 times the diameter.

Problem 5. (Heat exchanger)

The condenser of a large steam power plant is a heat exchanger in which steam is condensed to liquid water. Assume the condenser to be a shell and tube heat exchanger consisting of a single shell and 30000 tubes each executing two passes. The tubes are of thin wall construction with diameter 25 mm with convection coefficient of h_0 = 11000 W/m^{2}K. The heat transfer rate that must be effected by the exchanger is q= 2×10^9 W and this is accomplished by passing cooling water through the tubes at a rate of 3×10^4 kg/s (the flow rate per tube is therefore 1 kg/s). The water enters at 20 °C while steam condenses at 50 °C. What is temperature of the cooling water emerging from the condenser? What is the required tube length L per pass?

Problem 6. (Heat exchanger)

A counterflow heat exchenger is used to cool the lubricating oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube (D_i=25 mm) is 0.2 kg/s, while the flow rate of oil through the outer annulus (D_O=45 mm) is 0.1 kg/s. The oil and water enter at temperature of 100 and 30 °C respectively. How long must the tube be made if the outlet temperature of oil is to be 60 °C.

Problem 7. (Condensation)

What is the value of h for dry saturated steam (100 °C) condensing outside a bank of horizontal tubes, 16 tubes high. Average temperature of outer tube surface is 93.33 °C. (OD =0.0254 m).

Problem 8. (Shell and tube heat exchanger)

Toluene at the rate of 1290 kg/m^2 is to be heated from 298 K to 350 K in the tubes of an shell and tube heat exchanger. The exchanger 0.5 m ID contains 20 tubes, 7/8'' 16 BWG copper tubes. In the shell saturated steam at 380 K condenses as film (from tables average value h_{steam}= 13000 W/m^{2}K). Inside fouling factor is 5000 W/m^{2}K, outside fouling factor is 3500 W/m^{2}K. What is the length of the tubes for 2-1 shell and tube heat exchanger?

For toluen: ρ=860 kg/m^3, k=0.149 W/mK, μ=0.49 C_p=1900 J/kgK