CASE WESTERN RESERVE UNIVERSITY
Case School of Engineering

ECHE 225: Fall 2024

Homework #12: Fins, transient heat transfer, forced convection

Due: December 5

1. [Chapter 17] 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. 25°C) The width and thickness of the fin are 5 cm and 1 mm, respectively, and its thermal conductivity is 230 W/m·K. The temperature at the base of the fin is 50°C and the heat transfer coefficient is 30 W/m^2·K. Estimate the fin temperature at a distance of 5 cm from the base and the rate of heat loss from the entire fin.

2. [Chapter 17] A 10 mm diameter and 50 cm long aluminum fin (k=237 W/m·K) is attached to a surface. If the heat transfer coefficient is 15 W/m^2·K, determine the percent error in the rate of heat transfer from the fin when the infinitely long assumption is used instead of the adiabatic fin tip assumption.

3. [Chapter 18] Obtain a relation for the time required for a lumped system to reach the average temperature ($\frac{T_i+T_\infty}{2}$) where T_i is the initial temperature and T_∞ is the temperature of the surroundings.

4. [Chapter 18] Metal plates (k=200 W/m·K, ρ=3000 kg/m^3, c$_p$=900 J/kg·K) with a thickness of 1 cm are being heated in an oven for 2 minutes. Air in the oven is maintained at 800°C with a convection heat transfer coefficient of 200 W/m^2·K. If the initial temperature of the plate is 20°C, determine the temperature of the plates when they are removed from the oven.

5. [Chapter 18] Carbon steel balls (ρ=8000 kg/m^3, k=60 W/m·K, c$_p$=0.5 kJ/kg·K) 10 mm in diameter are annealed by heating them first to 900°C in a furnace and then allowing them to cool slowly to 100°C in ambient air at 35°C. If the average heat transfer coefficient is 75 W/m^2·K, determine how long the annealing process will take. If 2000 balls are to be annealed per hour, determine the total rate of heat transfer from the balls to the ambient air.

6. [Chapter 19] Hot carbon dioxide exhaust gas at 1 atm is being cooled by flat plates. The gas at 220°C flows in parallel over the upper and lower surfaces of a 1-m long flat plate at a velocity of 5 m/s. If the flat plate surface temperature is maintained at 80°C, determine:

   (a) the local convection heat transfer coefficient at 0.5 m from the leading edge

   (b) the average convection heat transfer coefficient over the entire plate

   (c) the total heat flux to the plate.

7. An array of power transistors, dissipating 6 W of power each, are to be cooled by mounting them on a 50 cm x 50 cm square aluminum plate and blowing air at 35°C over the plate with a fan at a velocity of 2 m/s. The average temperature of the plate is not to exceed 65°C. Assuming the heat transfer from the back side of the plate to be negligible and disregarding radiation, determine the maximum number of transistors that can be placed on this plate.

8. [Chapter 19] Combustion gases (calculate properties based on air) passing through a 5-cm internal diameter circular tube are used to vaporize waste water at atmospheric pressure. Hot gases enter the tube at 115 kPa and 250°C at a mean velocity of 3 m/s and leave at 150°C. If the average heat transfer coefficient is 120 W/m^2·K and the inner surface temperature of the tube is 110°C determine (a) the tube length and (b) the rate of evaporation of the water.

9. [Chapter 19] Consider a 12-m-long smooth rectangular tube (with sides $a = 50$ mm and $b = 25$ mm) that is maintained at a constant surface temperature. Liquid water enters the tube at 20°C with a mass flow rate of 0.01 kg/s. Determine the tube surface temperature necessary to heat the water to the desired outlet temperature of 80°C.

Answers

1. 36°C, 4.7 W
2. 1.3%
3. 0.693/b
4. 668°C
5. 3.8 minutes, 931 W
6. (a) 6.25 W/m^2·K, (b) 8.85 W/m^2·K, (c) 1238 W/m^2
7. 9
8. 30.7 cm, 0.736 kg/hr
9. 83.8°C