ChE 306: HEAT TRANSFER
FALL 2010
Homework #3: Chapters 4 & 5
(70 points)
DUE: MONDAY, SEPTEMBER 13

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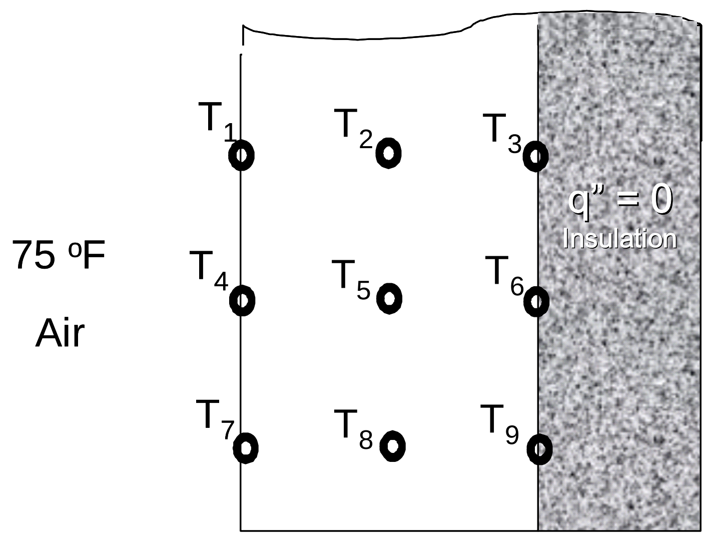
1. Work Incropera and DeWitt Problem 4.33
You may assume the material has a constant thermal conductivity, k.

2. A portion of a solid material is shown below. The material is a bar of gold that is fully insulated on its right side. The top and bottom of the section shown extend beyond the nodes shown in the picture, and the boundary on the left side of the gold is air at a temperature of 75 ^oF. You may assume there is no heat generation or consumption within the gold bar.

Nine nodes are shown on a square grid with $\Delta x = \Delta y = 0.025$ m
Given the following data, determine temperatures T_5 and T_6.



Properties of Gold
density = 19300 kg/m^3
heat capacity = 129 J/kg-K
thermal conductivity = 317 W/m-K
thermal diffusivity = 1.27 * 10^{-4} m^2/s

Known Node Temperatures
T_1 = 42.0 K ; T_2 = 58.0 K;
T_3 = 66.0 ^oC; T_4 = 40.0 K ,
T_7 = 39.0 K; T_8 = 47.0 K; T_9 = 59.0 K

Air Properties
convective heat transfer coefficient = 12.4 W/m^2-K
density = 1.08 kg/m^3
thermal conductivity = 0.0284 W/m-K

3. Work Incropera and DeWitt Problem 4.48
For part (b), recall that each node temperature represents the temperature for a unit square surrounding it in the solid; thus, the heat transfer rate will be the sum of convective heat loss from each surface segment of the grid.

4. Work Incropera & DeWitt Problem 5.5. Ignore cooling by radiation.

5. Work Incropera & DeWitt Problem 5.7.
(b) Using the h you determined from part (a), determine the Biot numbers for spheres made of stainless steel AISI 304 and soft vulcanized rubber. (Use appendices A.1 and A.3)
(c) What is the maximum diameter of each sphere (copper, stainless steel AISI 304, soft vulcanized rubber) that would allow the lumped capacitance model to be applied (i.e., Bi = 0.1)

6. A recently fabricated sheet of 5m-by-2m aluminum with thickness 2 mm comes out of the furnace at 400 ^oC. If the aluminum must reach 100 ^oC at its center (the midplane) prior to stacking, how long must the sheet be exposed to ambient air (25 ^oC, h = 10 W/m^2-K)?
k_{Al} = 237 W/m-K
ρ_{Al} = 2702 kg/m^3
$c_{p, Al}$ = 903 J/kg-K

7. For problem #6, if the sheet were made of cork, what would the Biot number be? (the air properties are the same as in #6).
Sketch (qualitatively) the temperature profile across the thickness of the sheets (T vs. x) for three different times during the cooling process. Draw three temperature profiles for (A) aluminum, and on a separate graph three temperature profiles for (B) cork. The three times you select should be: t = 0 (before cooling), and two times during the cooling (but not at infinite time).