Homework Assignment Number Nine Solutions
Assigned: Wednesday, March 24, 1999
Due: Wednesday, March 31, 1999 BEFORE LECTURE STARTS.

Problem 1. Geankoplis 4.5-1, page 320

We are asked to calculate the film transfer coefficient and heat flux for air flowing through a pipe.

1. calculate tube-side film temperature $T_{tube,f} = 0.5\left(\overline{T}_w + \overline{T}_{tube}\right)$
2. obtain tube-side fluid properties at tube-side film temperature C_p, k, μ at $T_{tube,f}$
3. obtain shell-side fluid properties at tube-side average temperature C_p, μ, ρ at $\overline{T}_{tube}$
4. obtain fluid viscosity at tube-side wall temperature, μ at $\overline{T}_w$
5. Calculate tube-side Prandtl Number $N_{Pr,tube} = \left(\frac{\mu C_p}{k}\right)_{T_{tube,f}} = 0.687$
6. Obtain tube-side velocity (this you were given in problem statement)
7. Calculate tube-side Reynolds Number $N_{Re,tube} = \frac{D_{tube}\overline{v}_{tube}\rho(\overline{T}_{tube})}{\mu(\overline{T}_{tube})} = 10900$
8. Calculate the Nusselt Number $N_{Nu} = 0.027 N_{Re}^{0.8} N_{Pr}^{1/3}\left(\frac{\mu_b}{\mu_w}\right)^{0.14} = 40.3$
9. Calculate the film heat transfer coefficient $N_{Nu} = \frac{hD}{k}$, $h = 39.4\frac{W}{m^2 \cdot K}$
10. Calculate heat flux $\frac{q}{A} = h\left(T_w - \overline{T}_{tube}\right) = 1090\frac{W}{m^2}$

Problem 2. Geankoplis 4.5-4, page 321

To do this problem, I used the code hxchger_v3.m given on the website. I made the following changes.

1) I fixed the tube outlet temperature (by setting the initial guess to be the given value and commenting out the two lines that change Ttubeout)
2) I fixed the overal heat transfer coefficient based on the outside area, Uo (by setting Uo=69.1) at a point in the code after the code's Uo had been calculated)
3) I calculated a new length at each iteration by solving

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L = abs(heattube/Uo/Ft/deltaTlm/(Aoutside/L));
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» p4_5_4_geankoplis
Shell-side contains the hot fluid & tube-side the cold.
initial guess:  Ttubeout = 360.800000 Tshellout = 573.000000
at j =    1, i =    2:  Ttubeout = 360.800000 Tshellout = 636.500000
at j =    2, i =    2:  Ttubeout = 360.800000 Tshellout = 604.750000
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…
at j = 23, i = 2: Ttubeout = 360.800000 Tshellout = 578.092728
at j = 24, i = 2: Ttubeout = 360.800000 Tshellout = 578.092720
Tube-side Temp (K) inlet: 327.500000, outlet 360.800000, avg 344.150000
Shell-side Temp (K) inlet: 700.000000, outlet 578.092720, avg 639.046364
Wall Temp (K): Tube-side = 348.093580, Shell-side = 635.796775, avg = 491.945178
Heat Transfer coefficients shell film, heat film, overall (W/m^2/K):
hshell = 6223.278426 htube = 7002.896910 Uo = 69.100000
Uo = 69.100000 Ui = 94.362366
Heat Transferred (W): q = -1934806.534499 q_tube = 72341294.239614 q_shell = 87790706.715896
Enthalpy Changes (W): tube = 1934806.590000 shell = -1934795.027278

L = 49.9569 m

Problem 3. Geankoplis 4.5-7, page 321

To do this problem, I used the algorithm given on the website. In fact, I used the same code but I made the shell temperature constant and I made the number of tubes 1. I set the fouling factors to a very high number so that they did not contribute to heat transfer resistance. I was given the velocity, so I calculated the mass flow. I added data for air instead of water in the physical properties table at the beginning of the code. The rest of the code was unchanged. It took about eight minutes to modify the code and solve this problem. A copy of the code is given at the end of this file.

» p4_5_7_geankoplis
initial guess: Ttubeout = 362.100000 Tshellout = 372.100000
at iteration 1: Ttubeout = 329.359595 Tshellout = 372.100000
at iteration 2: Ttubeout = 361.114267 Tshellout = 372.100000
at iteration 3: Ttubeout = 331.459570 Tshellout = 372.100000
…
at iteration 146: Ttubeout = 346.849931 Tshellout = 372.100000
at iteration 147: Ttubeout = 346.849716 Tshellout = 372.100000
at iteration 148: Ttubeout = 346.849914 Tshellout = 372.100000
Tube-side Temp (K) inlet: 288.800000, outlet 346.849914, avg 317.824858
Shell-side Temp (K) inlet: 372.100000, outlet 372.100000, avg 372.100000
Wall Temp (K): Tube-side = 365.582899, Shell-side = 371.637175, avg = 368.610037
hshell = 9100.000000 htube = 137.629431
Uo = 86.600551 Ui = 135.151412
Heat Transferred (W): q = -199.308126 q/Ai = -6572.912041

The problem asked for htube, which is given above, in SI units.

Problem 4. Geankoplis 4.6-2, page 321

For heat transfer over a horizontal plate:

$$N_{Re,L} = 14900$$
$$N_{Pr} = 0.723$$
$$A = 0.064516 m^2$$

Laminar flow, $N_{Re,L} < 3 \cdot 10^5$, $N_{Pr} > 0.7$

$$N_{Nu} = 0.664 N_{Re,L}{}^{0.5} N_{Pr}{}^{1/3} = 72.7$$

$$N_{Nu} = \frac{hD}{k}, \; h = 6.13 \frac{W}{m^2 \cdot K}$$