Use Microsoft Word to submit your solutions to this assignment. Copy the required graphs from your numerical solution to the problems below in Excel into this Word document and answer the questions below in Problems 1, 2 and 3 (extra credit). Print out your Word document, in color if appropriate, and hand in at the assigned date in class.

1. Unsteady-State Heat Conduction; Numerical Solution using Schmidt Method (M=2) in Excel (50 pts)
Solve Example 5.4-2 of the Geankoplis text using the accompanying Excel spreadsheet. Plot temperature versus distance for several time points on a single graph; t = 0 s, 1,000 s, 2,000 s, 3,000 s, 4,000 s, 5,000 s, and 6,000 s. Label all graph axes correctly and clearly with symbols and units and create a legend for the graph identifying each of the seven temperature versus distance trace. Make sure that the graphs are readable when copied and pasted into Word. Describe the heat transfer process in your own words based on your solution and the temperature versus distance traces (limit to one paragraph). Do your own work in this problem. It would be easy to share spreadsheets and therefore answers, but you would only be cheating yourself of the skills-learning that will be valuable preparation in your future careers.

2. Unsteady-State Heat Conduction with Convective Resistance at one Boundary; Numerical Solution in Excel (50 pts)
Solve Example 5.4-3 of the Geankoplis text using the accompanying spreadsheet. Note the similarity between this problem and Example 5.4-2 from Problem 1 above. The only difference is the presence of a resistance to heat transfer at one boundary! Also, note the slight modification of the problem in the spreadsheet compared to the text; a smaller space step $\Delta x=0.05$ m, but this matches Problem 1. Plot temperature versus distance for several time points on a single graph; t = 0 s, 1,000 s, 2,000 s, 3,000 s, 4,000 s, 5,000 s, and 6,000 s. Label all graph axes correctly with symbols and units and create a legend for the graph identifying each of the seven temperature versus distance trace. Describe the heat transfer process in your own words based on your solution and the temperature versus distance traces. Also, compare and contrast these temperature traces to those from Problem 1 above. Explain why there are differences (limit descriptions to one or two paragraphs). Do your own work in this problem. It would be easy to share spreadsheets, but you would only be cheating yourself of the skills learning that would be valuable in your future career.
3. Extra Credit (10 pts)

Compare the numerical solution from Problem 1 above to the analytical solution at early times in the heat transfer process. You will derive the analytical solution here – it is a similar derivation as shown in class. Early times means before the temperature changes significantly at the insulated boundary of the solid. Make the comparison at $t = 1,000$ and $2,000$ s. We derived the analytical solution to heat conduction in a semi-infinite solid in class. But that solution assumed that the solid was cool initially and then the temperature at one boundary was raised to a higher level. The heat transfer occurring in Problem 1 above is just the opposite.

Repeat the Combination of Variable solution as presented in class, except use this definition for the dimensionless temperature; $\Phi = (T-T_1)/(T_0-T_1)$, where $T_0$ is the initial temperature of the semi-infinite solid (100°C) and $T_1$ is the lower temperature at the $x = 0$ boundary (0°C), and use this definition of the combined variable; $\eta = x/(4\alpha t)^{1/2}$ (note that $x$ replaces $y$ that’s all).

Show that the solution for the dimensionless temperature is; $\Phi = \text{erf}(\eta)$; the Error Function of the argument $\eta$. Solving for the temperature versus distance and time, show that;

$$T = T_1 + (T_0-T_1) \text{erf}(x/(4\alpha t)^{1/2}).$$

This expression for temperature versus distance and time can be compared to the numerical solution of Problem 1. How much deviation is there between the analytical (exact) solution and the numerical (approximate) solution? Select a few points along the $x$ axis at the two times for this comparison.