Conduction and Radiation, Spring 2013
Homework Assignment #2

The first and third problems involve only symbolic derivations, and the second includes a small amount of calculation. These three will be due on Monday 4 February. The fourth problem could involve more lengthy computations – depending on how complicated you make the problem – and this will be due on Friday 8 February.

1. A plane wall of thickness $L$ is initially at temperature of $T_1$. At time $t = 0$ a uniform heat flux of strength $q''$ is applied to the surface at $x = L$. The surface at $x = 0$ is maintained at temperature $T_1$. Formulate the problem in appropriate nondimensional variables. Using separation of variables and the partial solutions procedure, determine the temperature distribution in the wall as a function of position and time.

2. Another plane wall, thickness $L$, is initially at $T_\infty$. At time $t = 0$ heat generation is applied within the wall. The heat generation is a function of $x$ and is given by
   \[ q''(x) = q'''_0 e^{-ax/L} \]
   where $q'''_0$ and $a$ are constants. The surface at $x = 0$ is adiabatic, and convection occurs at the $x = L$ surface, characterized by a heat transfer coefficient $h$ and an ambient temperature $T_\infty$. Non–dimensionalize the problem, and, using the SOV and partial solutions methods, find the solution for the nondimensional temperature field in the wall. Finally, prepare a plot of the nondimensional temperature at $x = 0$ and $x = L$ as a function of dimensionless time. Use values of $a = 2$ and $Bi = 10$ in calculating the numbers for this plot, and include at least the first two terms in the series expansion for the transient part of the temperature.

3. A pipe has an inner radius of $R_i$ and an outer radius of $R_0$. Initially the pipe is at a temperature of $T_1$. At $t = 0$ the inside temperature of the pipe is brought to the steady value of $T_2$. Convection occurs on the outer surface, characterized by $h$ and $T_\infty$. Formulate the problem in appropriate non–dimensional variables, and use SOV to determine the solution to the problem.

4. An egg has been sitting in a pan of boiling water for 12 minutes, at which point it can be considered hard–boiled. The egg is removed from the water and placed under the cold–water tap. Estimate the minimum amount of time the egg must remain under the flow of cold water so that, when the egg is removed from the flow and allowed to sit in air, the surface temperature of the egg will not exceed 50$^\circ$C. Make whatever assumptions are necessary and sensible to result in a simplified calculation. This is not, however, a lumped capacity problem.