ME 331 Homework Assignment #3
Due Tuesday April 18, by 5:30 pm in Bagley 260 (recitation)

1. Determine the steady-state power requirement of a soldering iron in which the tip is maintained at 400°C. The tip is a cylinder 3 mm in diameter and 10 mm long. The surrounding air temperature is 20°C, and the average convection heat transfer coefficient over the tip is 20 $W/(m^2\ K)$. The tip is highly polished initially, giving it a very low emittance. After aging, the soldering tip becomes oxidized, and its gray body emittance increases to 0.8. Assuming that the surroundings are at 20°C, determine the steady-state power requirement for the aged soldering iron.

2. Calculate and plot (using Excel or Matlab) the steady-state temperature distribution within the soldering iron cylinder, treating it as one-dimensional in the r direction. Consider both cases of a newly polished tip and an aged tip. For each case, determine the effective thermal generation rate in W/m^3. What is the maximum temperature in each of the two cases and where does it occur?

3. Consider both the highly polished and aged soldering iron tips described in problem #1. First, consider the highly polished tip (negligible emittance) with the same boundary condition as before. Use the steady state temperature(s) of the soldering iron calculated in problem #2 to predict the temperature within the soldering iron as a function of time, AFTER power to the tip is turned off at t = 0. Next, include radiative loss for the aged soldering iron and predict the temperature within the aged soldering iron as a function of time, after power to the tip is turned off at t = 0. Plot the temperature histories (as a function of time) for the new and aged soldering irons. Discuss your assumptions and results.

4. Estimate the minimum depth Z_{min} at which a water main can be positioned below the ground surface to avoid freezing. Assume an initial soil temperature of 20°C. Under the worst conditions, it is anticipated that the ground surface temperature could be as low as - 25°C for a winter period of up to 100 days.

5. A planar solid hardwood "fire" door can be considered as insulated on its interior surface (facing towards the interior of the building). The door thickness is 4.0 cm and its initial temperature is uniform throughout at 25°C. For fire safety testing purposes, the surface of the door opposing the insulated surface is exposed to a high ambient temperature of 925°C with an effective heat transfer coefficient of 80 $W/(m^2\ K)$. Predict and plot the temperature distribution within the door as a function of time. Choose at least several times for which the approximation of truncating to a single term of the infinite series is accurate. For what range of times is the single term approximation inaccurate? Plot the single term approximation to illustrate its inaccuracy for at least one time with $Fo < 0.2$. Can you show an improvement by including additional terms from the infinite series solution?