MAE 423
Heat Transfer

Problem Set 3

Date: Fri, 11 Oct '19
Due: Fri, 18 Oct '19 Please turn in either in class or in the boxes outside my office, D302 EQ by 'midnight'

Important: Please read and follow the guidelines for problem set preparation as outlined in the introduction to the course (posted on BB in Course Materials). As a reminder: be sure to draw any relevant sketches, list any assumptions and/or simplifications, show all analyses, and be very sure to check dimensions/units of your final answer, along with ascertaining that the sign and rough order-of-magnitude of the answer appears reasonable (and if it doesn't, please comment accordingly).

This problem set has 4 problems.

1. Two parallel pipes, 5 cm and 10 cm in diameter, are entirely surrounded by loosely packed asbestos. The distance between centers for the pipes is 20 cm. One pipe carries steam at 110°C and the other carries chilled water at 3°C . Find the heat lost by the 'hot' pipe per unit length.

2. The total efficiency for a finned surface may be defined as the ratio of the total heat transfer of the combined area of the surface and fins to the heat that would be transferred if this total area were maintained at the base temperature T_0. Show that this efficiency can be calculated from

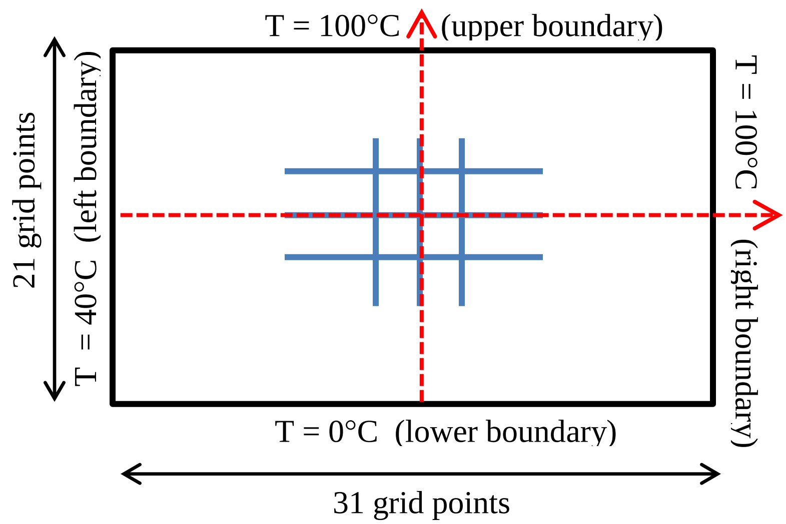
$$\eta_t = 1 - \frac{A_f}{A}\left(1 - \eta_f\right)$$

   where

   η_t = total efficiency
   η_f = fin efficiency
   A = total heat transfer area, including fins and exposed base area or other surfaces
   η_f = fin efficiency

3. A straight rectangular fin has a length of 3.5 cm and a thickness of 1.4 mm. The thermal conductivity is 55 W/m·K . The fin is exposed to a convection environment of 20°C with h = 500 W/m^2·K .
   a. Calculate the maximum possible heat loss for a base temperature of 150°C .
   b. What is the actual heat loss for this base temperature?

4. This problem is intended to be a ‘warm up’ exercise which involves developing a basic finite-difference code, as discussed in class. Solve the domain numerically for temperature, based on isothermal boundary conditions for a square grid. Use either point-Jacobi or Gauss-Seidel iteration. Develop and execute a program (e.g. MATLAB, C, Java, or similar code).



The domain should be divided into 31 grid points horizontally and 21 grid points vertically. The temperatures on each isothermal boundary are given in the diagram. Choose your convergence criteria, and determine if it is adequate, as discussed in class.

a. Plot the temperature distribution through the center of the domain in both the vertical and horizontal directions (i.e. along the paths shown above by the dashed red arrows). Note that to plot the temperature in the ‘center’ of the array we need an odd number of grid points in each direction, hence 21 x 31 grid points.

b. Plot the temperature distribution of the entire grid using color mapping for T (e.g. pure blue = lowest temp in grid; pure red = highest temperature in grid; intermediate temperatures are colored appropriately). Be sure to show your temperature scale mapping (i.e. what temperature ranges correspond to the colors).

   Please show your work (outline the algorithm you are using).

   Big Hint!: For this domain, your color plot for temperature and color map should look like the plot on the next page. This also shows how the four corned points were defined.

Example of computed temperatures in domain and an appropriate color map (note that this grid is very close to the dimensions given in Problem 4.