MME 9710A – Advanced CFD, Assignment # 1

Date Given: September 25, 2017 Date Due: October 16, 2017

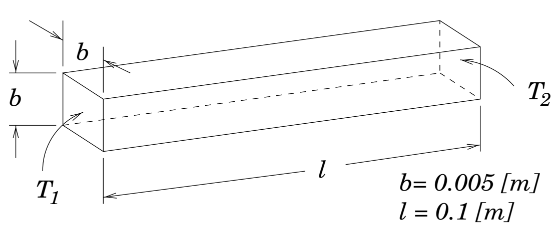
Install a Fortran compiler on your computer (Mac, PC, and Linux are all fine). The files for this assignment are posted along with this assignment description in the *Assignments* section of the course OWL site. The files are listed in the table below. In the *Status* column, the files that have *outline provided* require some programming work to be done; the files that have *complete* require no additional programming, but must be understood. The files and a brief description are as follows:

File	Description	Status
main.f:	mainline program	outline provided
bndct.f:	subroutine for applying boundary conditions	outline provided
coeff.f:	subroutine for computing active coefficients	outline provided
difphi.f:	subroutine for computing diffusivities	outline provided
srct.f:	subroutine to compute source terms	outline provided
grdgeo.f:	subroutine used in grid generation	complete
makgrd.f:	subroutine used in grid generation	complete
inital.f:	subroutine to initialize solution field	complete
input.f:	subroutine to read input information	complete
null.f:	subroutine to null a vector	complete
out1d.f:	subroutine to print out 1D fields	complete
tdma.f:	tri-diagonal matrix solver	complete
makefile:	compilation file	complete
in.dat:	input file for program main	

Make sure that you understand all of the details related to the analysis of steady, one–dimensional heat conduction using the finite–volume method. Then, complete the necessary subroutines and the mainline program. Finally, solve the problems given below to verify your code.

Code verification:

1. Linear heat conduction problem. Solve for the one–dimensional temperature distribution in a square bar of mild steel as given below. The properties of mild steel are $k = 60$ $[W/m \cdot K]$, $\rho = 7800$ $[kg/m^3]$ and $C_p = 430$ $[J/kg \cdot K]$. Assume the convection coefficient, $h = 0$ $[W/m^2 \cdot K]$ on the exposed surfaces, and fixed end temperatures of $T_1 = 100$ $[^oC]$ and $T_2 = 0$ $[^oC]$. Explore the capabilities of your code and explain your results.



2. Convection problem. Consider the same geometry and properties as in question 1, except use $h = 12$ $[W/m^2 \cdot K]$ for the exposed surfaces of the bar, and end temperatures of $T_1 = T_2 = 100$ $[^oC]$. Assume the surrounding air to be at $T_\infty = 25$ $[^oC]$. Obtain the solution for this problem and compare your solution to the analytical solution. Explain your results.

3. Internal heat generation problem. A plane wall $L = 0.1$ $[m]$ thick with a thermal conductivity of $k = 26$ $[W/m \cdot K]$ is exposed to an environment at an ambient temperature of 50 $[^oC]$ on one side and an environment of 40 $[^oC]$ on the other side. The convection coefficient at the exposed surfaces is estimated to be $h = 280$ $[W/m^2 \cdot K]$. If heat is generated uniformly within the wall at a rate $50,000$ $[W/m^3]$, determine the surface temperatures of the walls, and the location and value of the maximum temperature inside the wall. Compare your result to the analytical result, which can be obtained from a textbook. Explain your results.

4. Nonlinear problems. Solve the following problems using the square fin geometry given in question 1. Assume that the convection coefficient is $h = 0$ $[W/m^2 \cdot K]$, the emmisivity is $\epsilon = 1.0$, the end temperatures are $T_1 = 400$ $[K]$ and $T_2 = 0$ $[K]$, and use the following linearizations for the radiation component:

   (a) Linearization one: Use: $q_o'' = \epsilon\sigma((T^{m-1})^4 - T_\infty^4)$.

   (b) Linearization two: Use: $q_o'' = \epsilon\sigma((T^{m-1})^3 T^m - T_\infty^4)$.

   (c) Linearization three: Use Newton–Raphson.

   Solve parts a), b), c) assuming the material is steel for which: $k = 60$ $[W/m \cdot K]$, $C_p = 430$ $[J/kg \cdot K]$, and assuming the material is wood for which: $k = 0.1$ $[W/m \cdot K]$, $C_p = 1.3$ $[J/kg \cdot K]$. Explain yor results.

Note: For all problems, ensure that the solution is grid–independent to within 2%.