# MME9710a Assignment # 3

Date Given: October 27, 2015 Date Due: November 10, 2015

This assignment is intended to give you some exposure to convection/diffusion problems where the flow field is known. I will supply outlines for the additional subroutines that you are required to write. The subroutines are: *coefcn.f, masflx.f, hoconv.f* and *weight.f.*

**Programming Tasks:**

1. Expand *inital* to initialize values of `T, U, UHE` and `P` either from values set in *in.dat* or from the restart file, *rsi.bin*. Modify *save* to write out all variables needed for restart. `U` is the x–velocity at the nodal locations, and `UHE` is the velocity evaluated at the integration points on the east face of each control–volume; `UHE` is used to calculate the mass fluxes through the faces. `P` is not used in this assignment, but is included in preparation for solving the mass–momentum set in the next assignment.

2. Complete the subroutine *coefcn* to generate the coefficients for the conservation of mass equation $\dot{m}_e - \dot{m}_w = 0$, i.e.

   ```
   ACUE(I)*UHE(I) + ACUW(I)*UHE(I-1) + BC(I) = 0
   ```

   where: `ACUE(I)= RHO*AREP(I), ACUW(I)=-RHO*AREP(I-1)` and `BC(I)=0`.

3. Complete the subroutine *masflx* to calculate the mass fluxes, `ME(I)`, at all control-volume faces.

4. Complete the subroutine *weight*, which calculates the convective weights, `ALFAE(I)`. Be sure to fill in the values of `ALFAE` for the boundary faces.

5. Complete the subroutine *hoconv* so that either CDS or QUICK can be used for convection. Use the deferred correction approach discussed in class/notes to implement these schemes.

6. Update the *srct* routine to add the deferred corrections on convection to the source term coefficients `QT` and `RT`.

7. Modify *coeff* to pass `ME` and `ALFAE`, and modify the coefficients to include diffusion and convection effects, in addition to the transient terms.

8. Modify the main program so that the order of calls is:

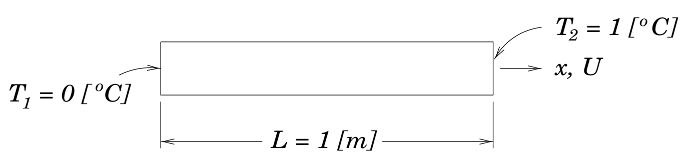
   ```
   CALL NULL( ... )
   CALL DIFPHI( ... )
   CALL MASFLX( ... )
   ```

```
CALL WEIGHT( ... )
CALL HOCONV( ... )
CALL SRCT( ... )
CALL COEFF( ...)
```

Be sure that you understand the sequence of calculations used to compute the active coefficients.

## Problems

1. Consider a convection/diffusion problem that has Dirichlet conditions on temperature imposed on both ends (see the figure below). As suggested in the lectures/notes, this is an unusual problem that would be difficult to reproduce in a laboratory, but it is an interesting problem by which to observe the performance of convection schemes. The exact solution to this problem is given by:




$$T(x) = T_1 + \frac{e^{xPe/L} - 1}{e^{Pe} - 1}(T_2 - T_1)$$

where $Pe$ is defined as $Pe = \rho u L/\Gamma$. We will solve this problem for $Pe = 50$ by imposing $L = 1.0$, $\rho = 1.0$, $u = 1.0$, $\Gamma = 0.02$ and $T_1 = 0$, $T_2 = 1.0$. Discretize the one–dimensional domain using 10 equal sized control–volumes. Initialize the field variables as `T0=0.0, U0=1.0`. Then, carry out the following:

   (a) Solve the problem using UDS, CDS and QUICK (use $\Delta t$= 1.0E+10). Make sure you set `ALFAE` correctly on the domain boundaries.

   (b) plot the results for `T(X)` for all cases along with the exact solution.

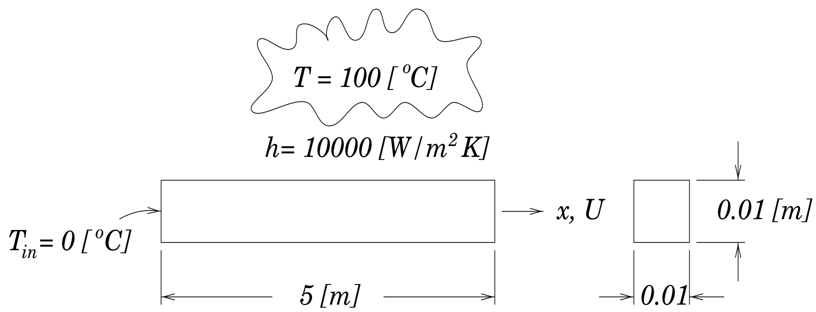
   (c) Discuss your results.

   (d) Re–run part (a) using 20, 40 and 80 uniformly spaced control volumes. Discuss your results.

2. Consider the problem of water flowing through a heated square duct: The properties of water are $\rho = 1000$ $[kg/m^3]$, $k = 0.590$ $[W/m \cdot K]$ and $C_p = 4189$ $[J/kg \cdot K]$. The exact solution for this problem is:

$$\frac{T_\infty - T(x)}{T_\infty - T_{in}} = e^{-\frac{hP_o x}{\dot{m}C_p}}$$

To solve this problem, start with 5 equal–length control–volumes, initialize the temperature and velocity fields as `T0= 0.0, U0= 1.5`, and use a time–step size of 1.0E+10. At the left boundary, set `ALFAE=1.0` to ensure that the correct value of `T` gets carried into the domain. Then, carry out the following:




(a) Solve the problem using UDS, CDS and QUICK and plot `T(I)` for all schemes along with $T_{exact}(I)$ vs. $x$. Discuss the results.

(b) Test the effect of `ALFAE` at the right boundary. That is, set `ALFAE= 1.0` at the right boundary, run the cases of (a) again and discuss the differences that occur. What physical effect does setting `ALFAE=`$\pm$`1.0` at the right boundary have? Which is realistic?

(c) Reverse the flow direction and the boundary conditions re–run parts (a) and (b). Show plots of `T(I)` vs. $x$. Make sure you use appropriate values for `ALFAE` on the boundaries. Your solutions should be the same as those from parts (a) and (b), except opposite.