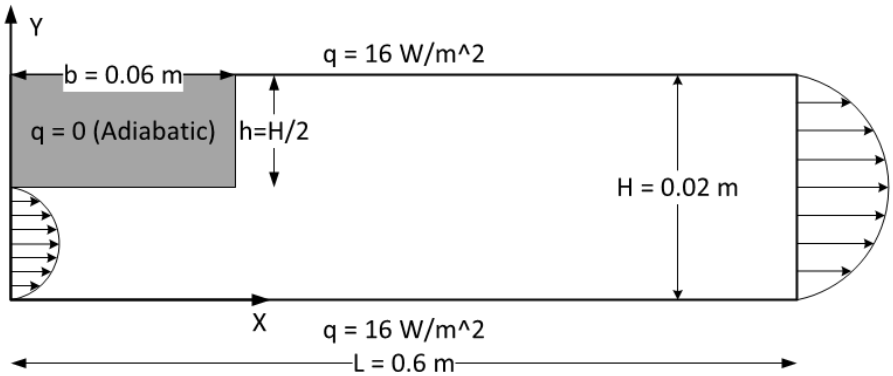
MEEN 644 **Final Take Home** **Spring 2019**

Instructor: N. K. Anand

Name _____

Due Date: 3:00 pm, May 3, 2019 **Maximum points: 100**



Flow Properties

$\rho = 998.3\ kg/m^3$

$k = 0.609\ W/m \cdot K$

$\mu = 1.002 \times 10^{-3} N \cdot s/m^2$

$C_P = 4183\ J/kg \cdot K$

Figure 1 Backward facing step flow

Consider an incompressible steady laminar flow over a backward facing step shown above. The properties of the fluid and geometric conditions are also given above. The bottom and top walls are maintained at constant heat flux boundary condition.

Boundary Condition:

Inlet velocity is defined as:

$$u(y) = u_{max} \cdot \left(\frac{4y}{H}\right) \cdot \left(2 - \frac{4y}{H}\right), \qquad where\ 0.01 > y > 0$$

Inlet temperature profile is defined as:

$$\frac{T(y) - T_w}{T_{max} - T_w} = \left(\frac{4y}{H}\right) \cdot \left(2 - \frac{4y}{H}\right), \quad where\ 0.01 > y > 0$$

Here, $T_w = 0$, $T_{max} = 1.5$, and Reynolds number is based on step height i.e. $Re = \rho u_{max} h/\mu$.

Write a finite volume code to predict flow and temperature fields. Represent the solution to 1-D Convection-Diffusion equation by the **Power Law**. Link velocity and pressure field using the **SIMPLE algorithm**. Declare convergence when $R_U, R_V, R_P \leq 10^{-6}$ and $R_T \leq 10^{-6}$ (Residual definitions are same as before).

In this exam, you will perform the following tasks.

1. Make calculations for ***Re =200*** using 160x30, 160x50, 160x70 and 160x90 CVs, respectively. Calculate reattachment length (X_r/h) for each grid size and print in a tabular form. **(30 points)**

- For 160x90 CVs Case, plot the following figures **(30 points):**

a) Plot the temperature profile at (X-b)/H = 6, 12 and 24.
b) Plot both upper and lower wall temperature along the channel length.
c) Plot Nusselt number (**Nu**) for both upper and lower wall along the channel length

2. Calculate reattachment length (X_r/h) for Re = 100, 300 and 400. Use 160x70 CVs. Compare your results with experimental data in reference. Print your comparison results in tabular form. For each Reynolds number, plot u and v velocity profile at (X-b)/H = 6, 12, and 24. **(40 points)**

Important Notes:

1. Reattachment length X_r is defined as the distance between reattachment point and the step. See Reference for more information.
2. Please include all results in one pdf file. Also, please explain how you treated the block in your code. If you used high viscosity method, explain your implementation for solid-fluid interface viscosity. If you used domain decomposition method, explain how you modified your line-by-line TDMA method.

References:

R. J. Goldstein, *"Laminar Separation, Reattachment, and Transition of the Flow Over a Downstream-Facing Step,"* Transaction of ASME, pp 732-741 December 1970