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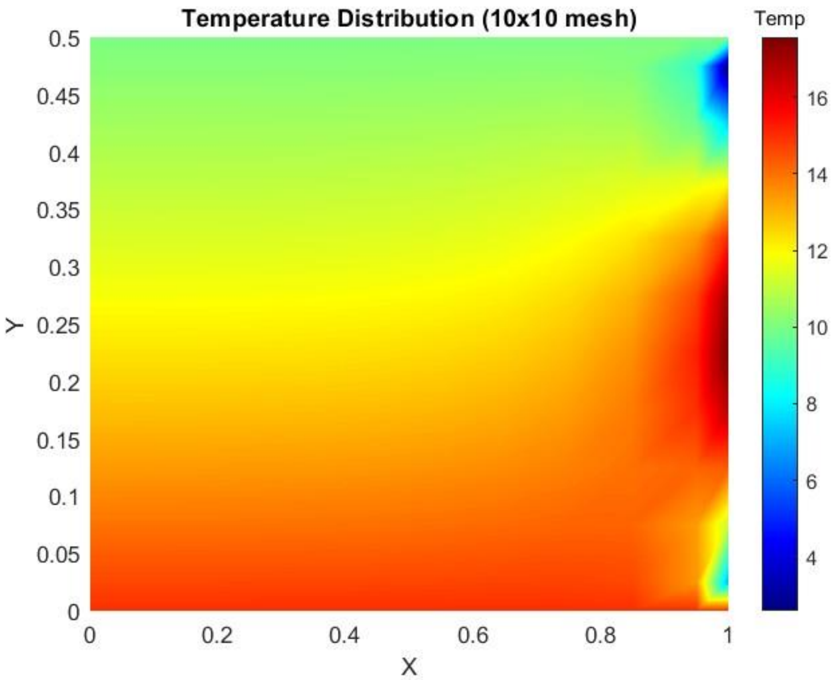
CH20B012

AM5630 Assignment 1

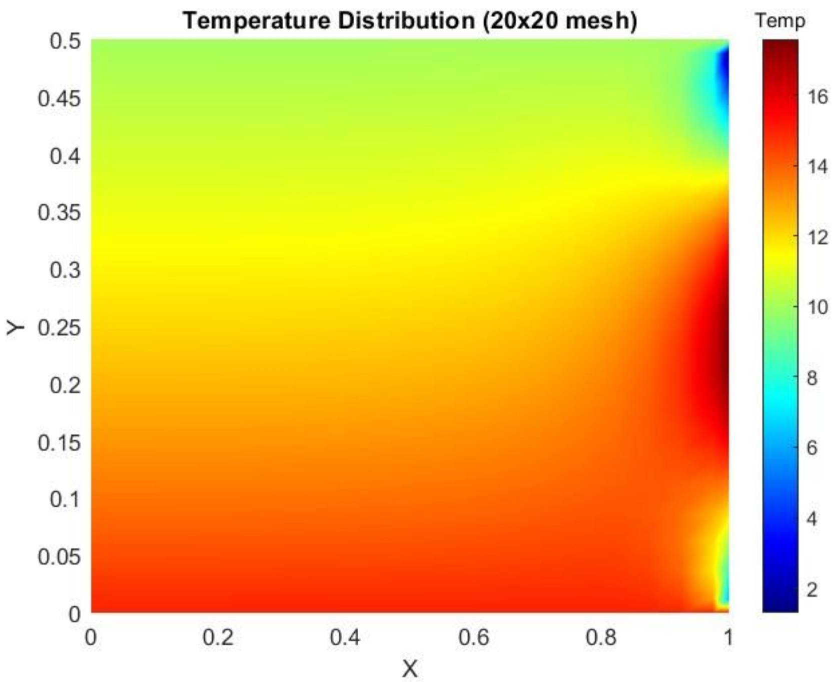
Q1) The plots below show the grid independence of the solution.

Temperature Distribution over the domain:

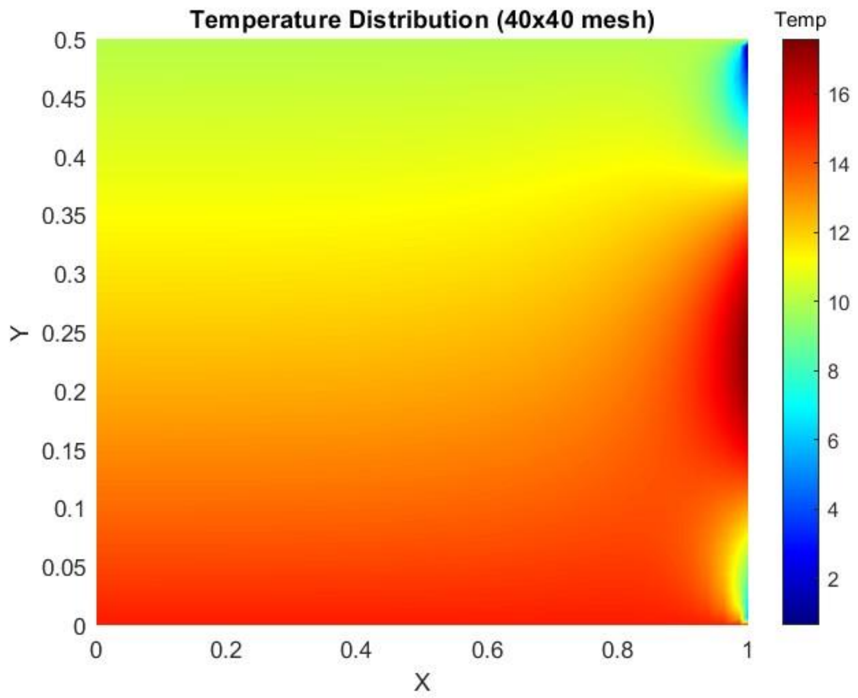
- 10x10 mesh:



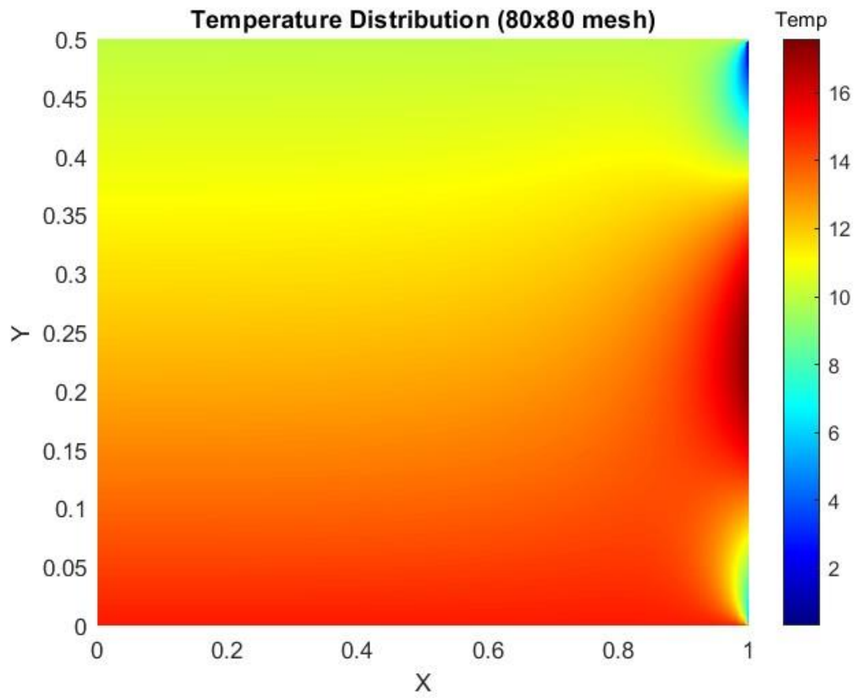
- 20x20 mesh:



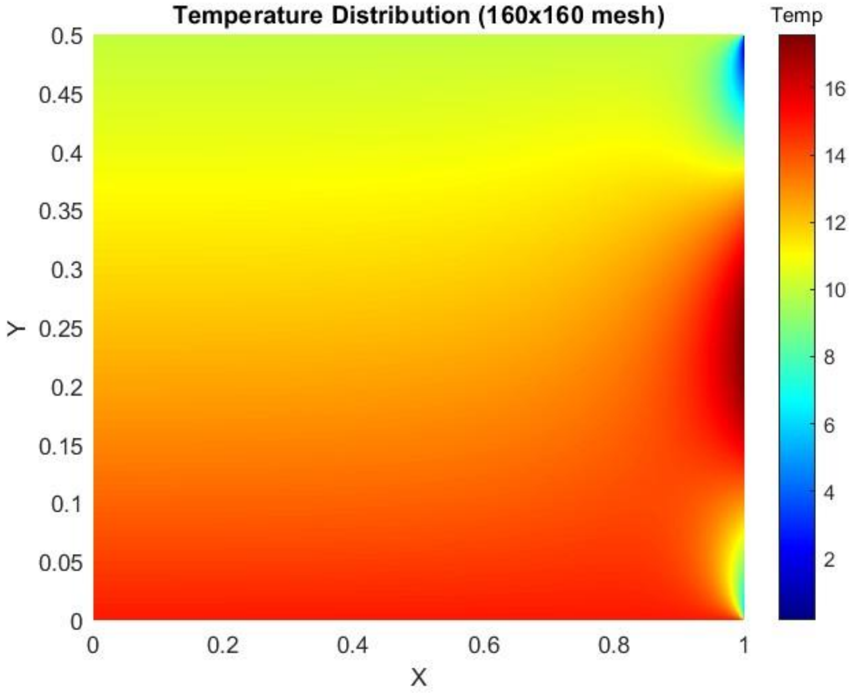
- 40x40 mesh:



- 80x80 mesh:

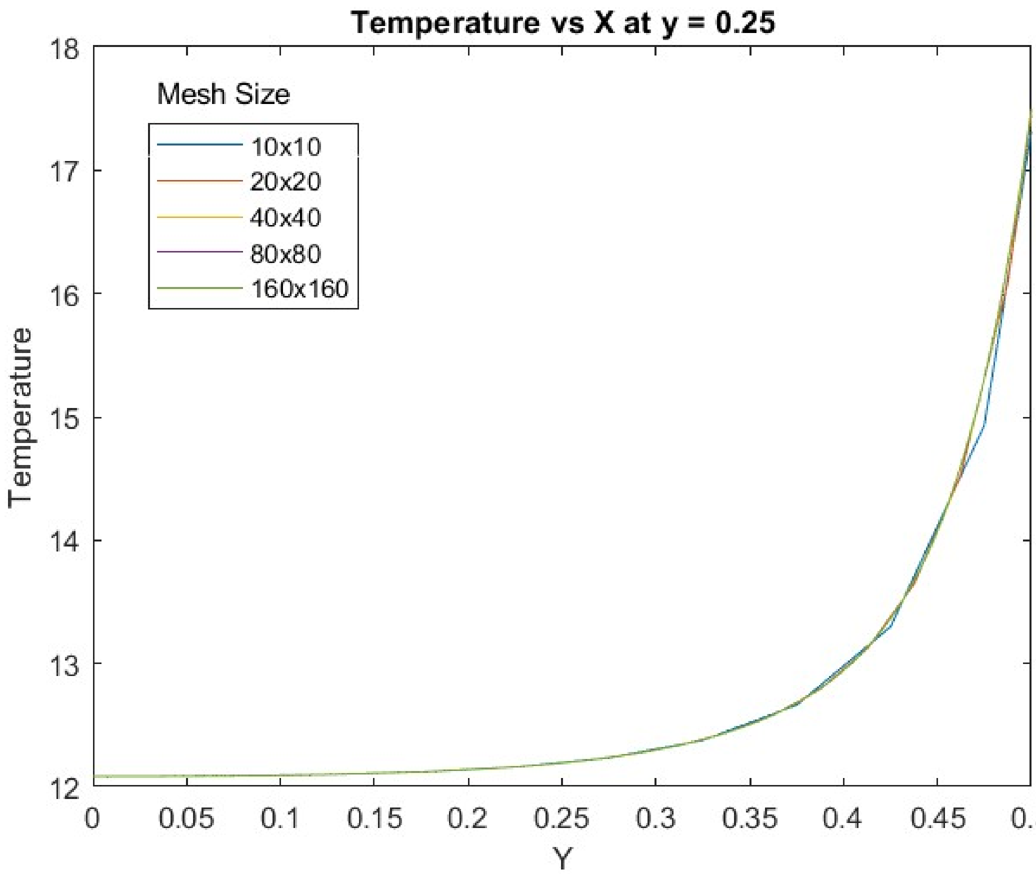


- 160x160 mesh:



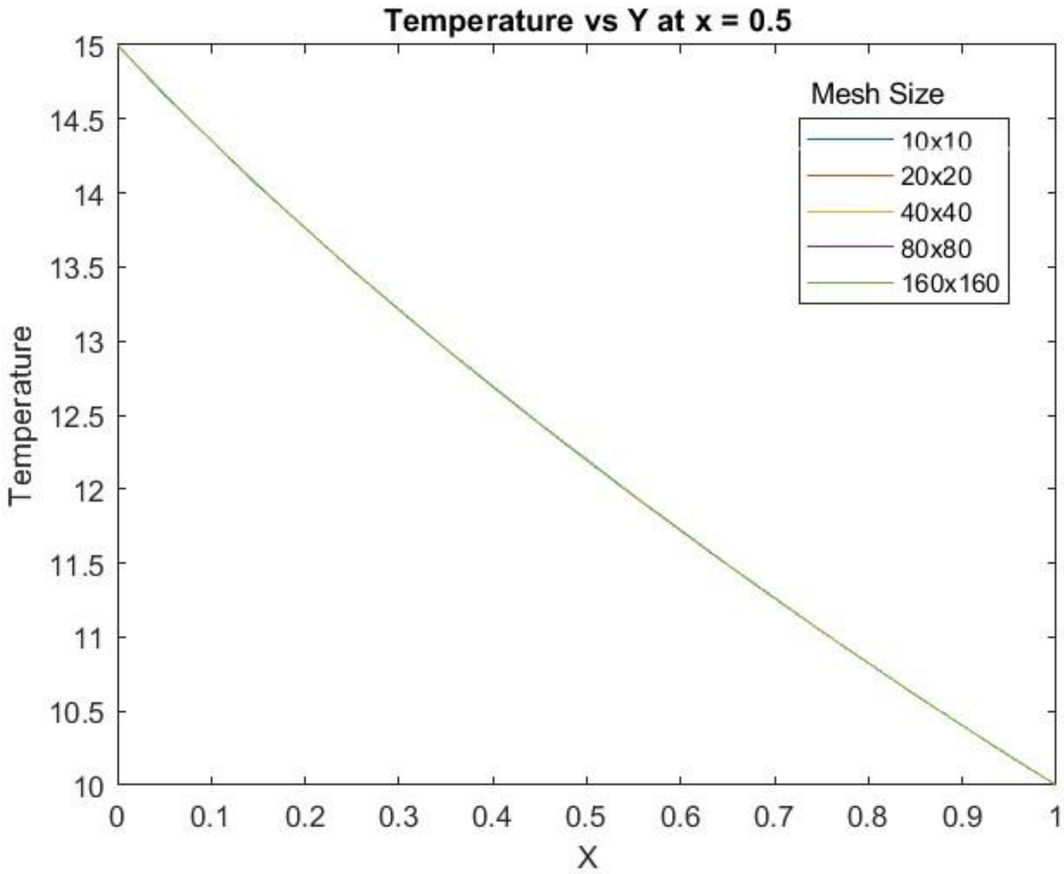
Temperature vs X at y = 0.25 plotted for different mesh sizes:

The temperatures are found by linear interpolation as there may not be nodes at y = 0.25



- Temperature profile towards x = 0 flattens out because of the insulated boundary condition.

Temperature vs Y at x = 0.5 plotted for different mesh sizes:
The temperatures are found by linear interpolation as there may not be nodes at x= 0.5



- The temperature at y = 0 and y = 0.5 is 15^0C and 10^0C according to the given boundary condition and the variation is almost linear between the boundaries.

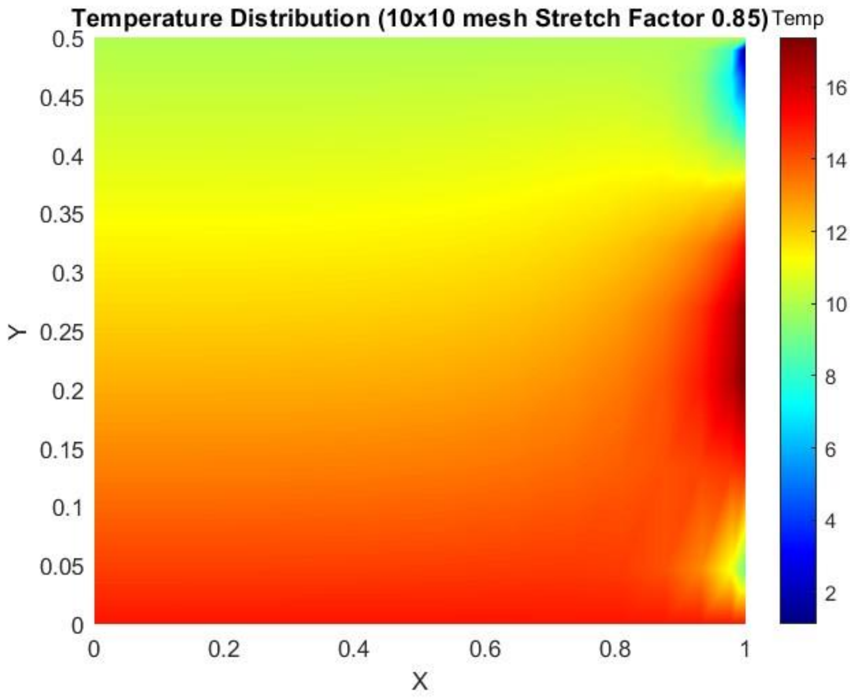
As the mesh becomes finer, the solution starts to become mesh independent which can be seen from all the 3 types of plots above.

From the solution, we can see that there are larger gradients towards the right side of the domain, gradient is uniform along Y direction.

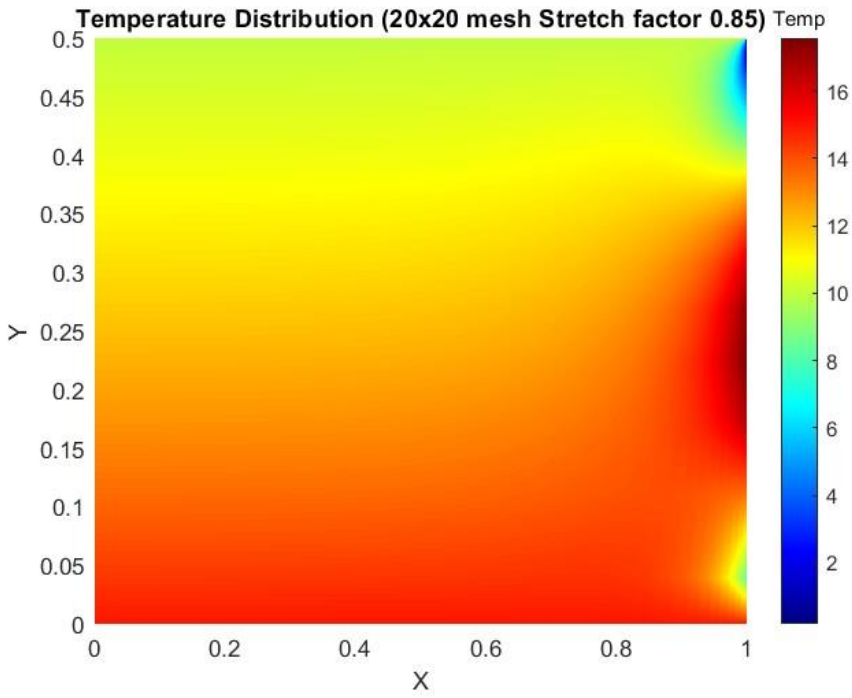
We can stretch the mesh such that the mesh becomes finer towards the right in X direction.

Temperature Distribution over the domain:

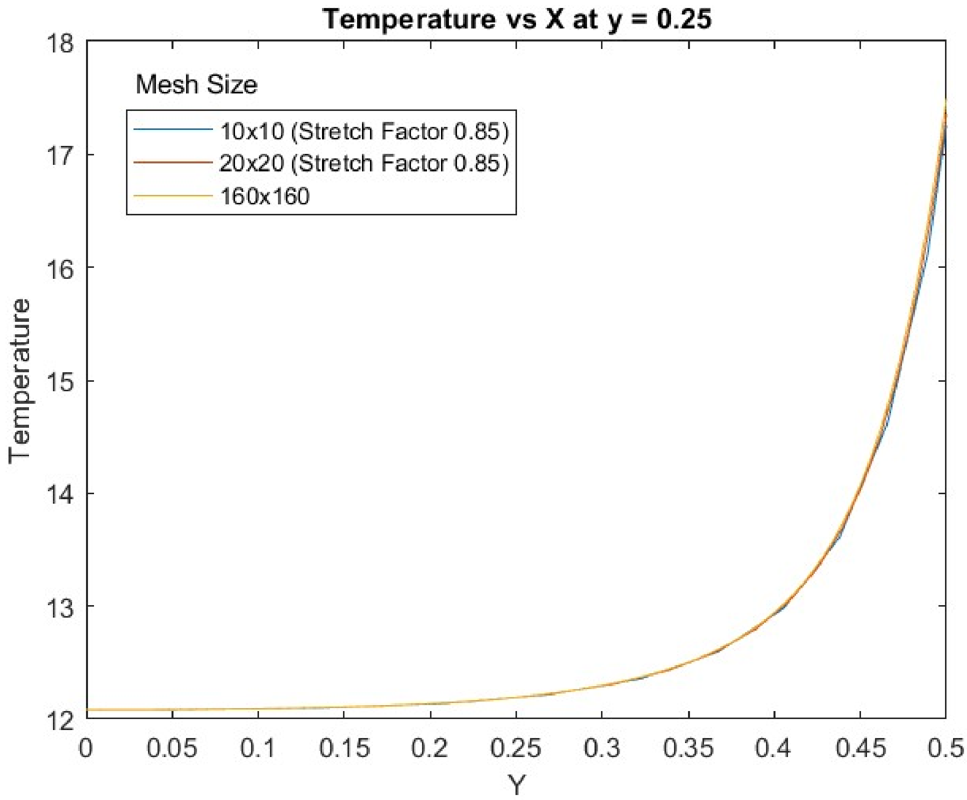
- 10x10 mesh with Stretch factor = 0.85 along X direction



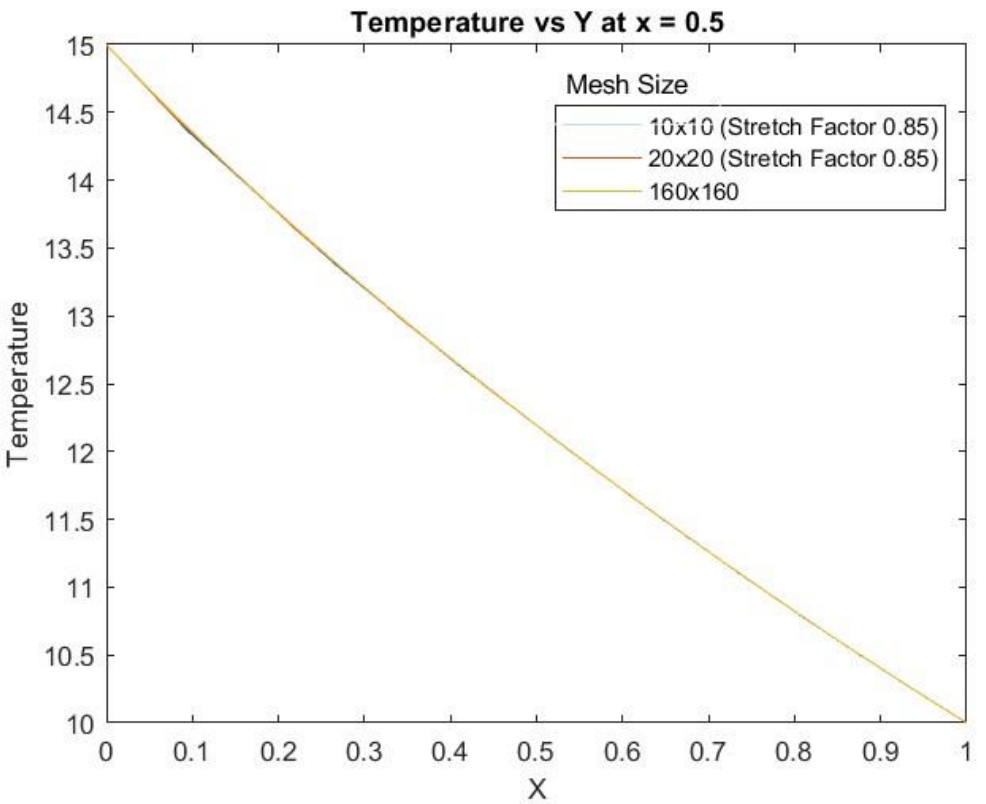
- 20x20 mesh with Stretch factor = 0.85 along X direction



Temperature vs X at y = 0.25:



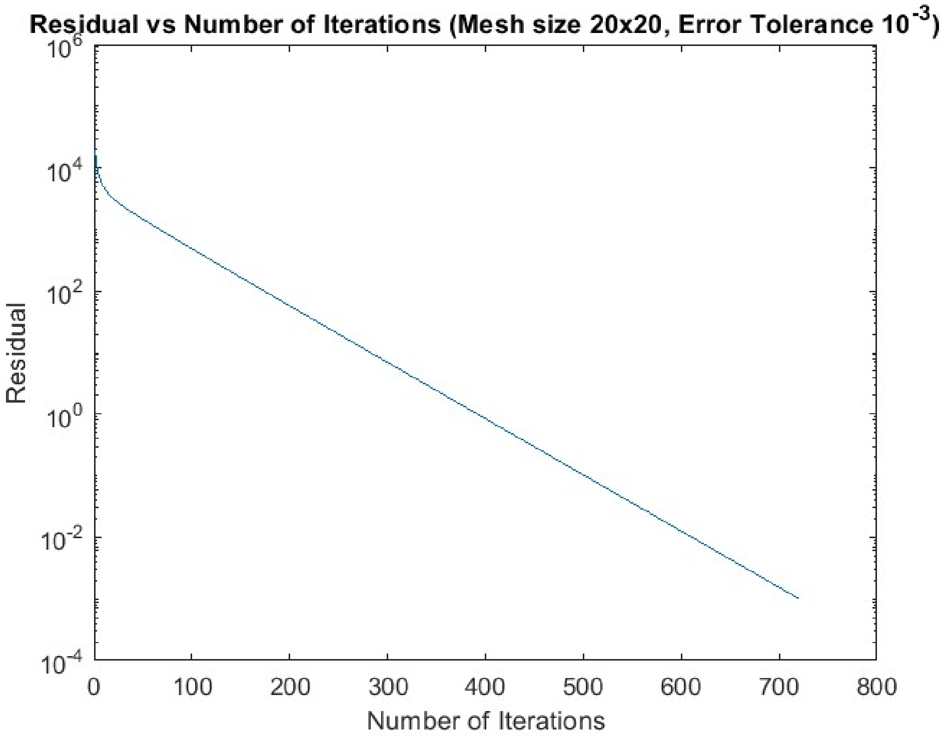
Temperature vs Y at x = 0.5



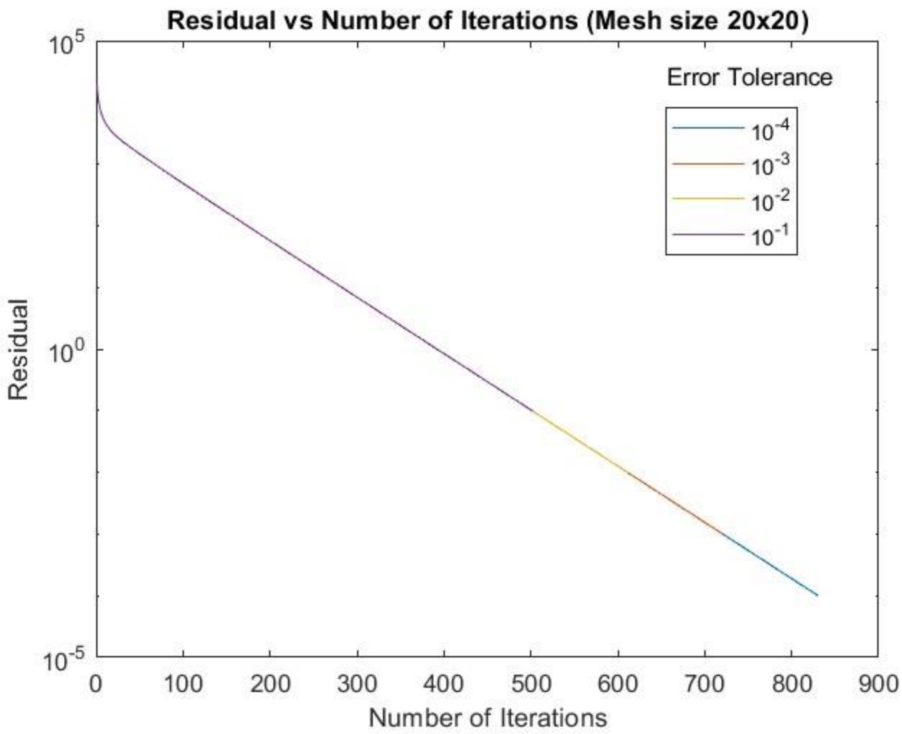
As seen from the plots above, by stretching the mesh appropriately, even from smaller grid sizes of 10x10 we get a better solution closer to the 160x160 mesh when compared to the equidistant 10x10 mesh.

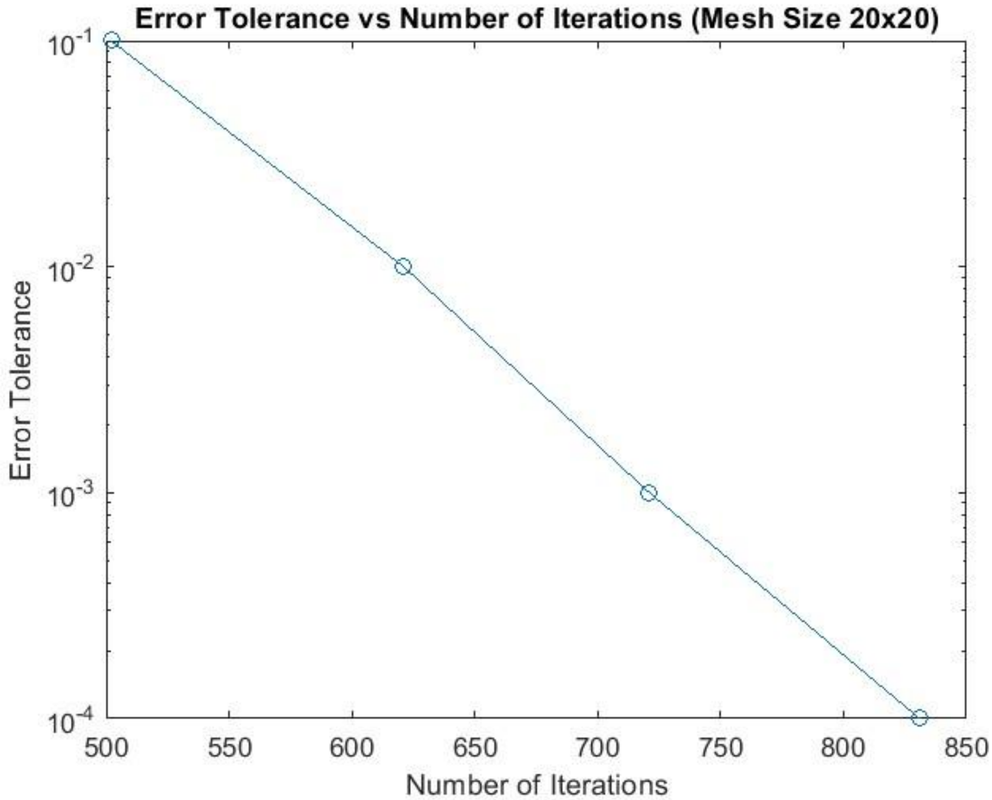
Q2) Residual vs Number of iterations:

Using a 20x20 mesh with an error tolerance of 10^{-3} we can plot the residual vs number of iterations in a semi log plot as below
The value off residual error decreases with each iteration till it reaches below the error tolerance, after which the iterations are stopped.



As the error tolerance is made smaller, the number of iterations increase as expected which is shown in the semi log plot below for a 20x20 mesh:

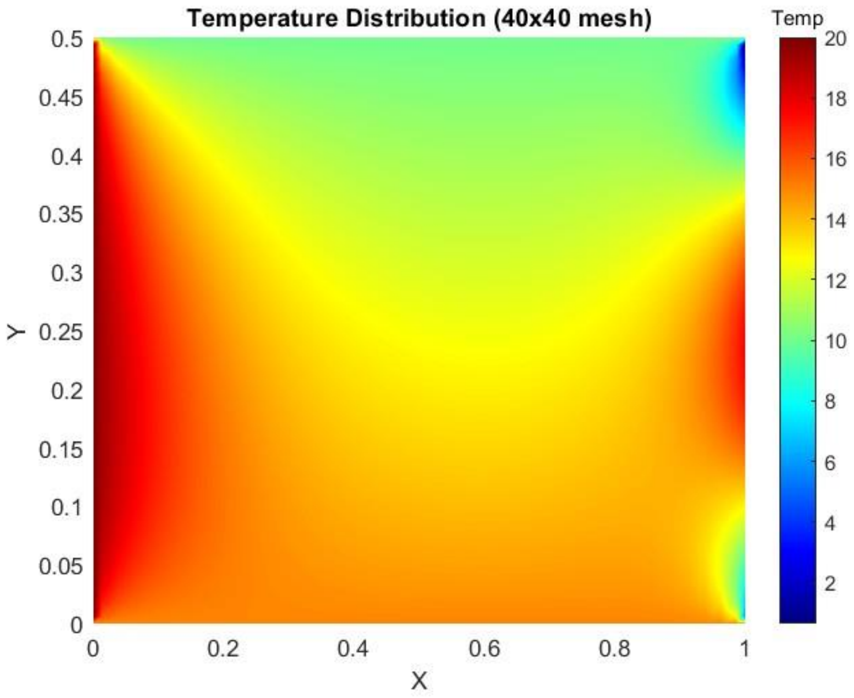



Error Tolerance vs Number of Iterations (Mesh Size 20x20)
Error Tolerance
10^{-1}
10^{-2}
10^{-3}
10^{-4}
500
550
600
650
700
750
800
850
Number of Iterations

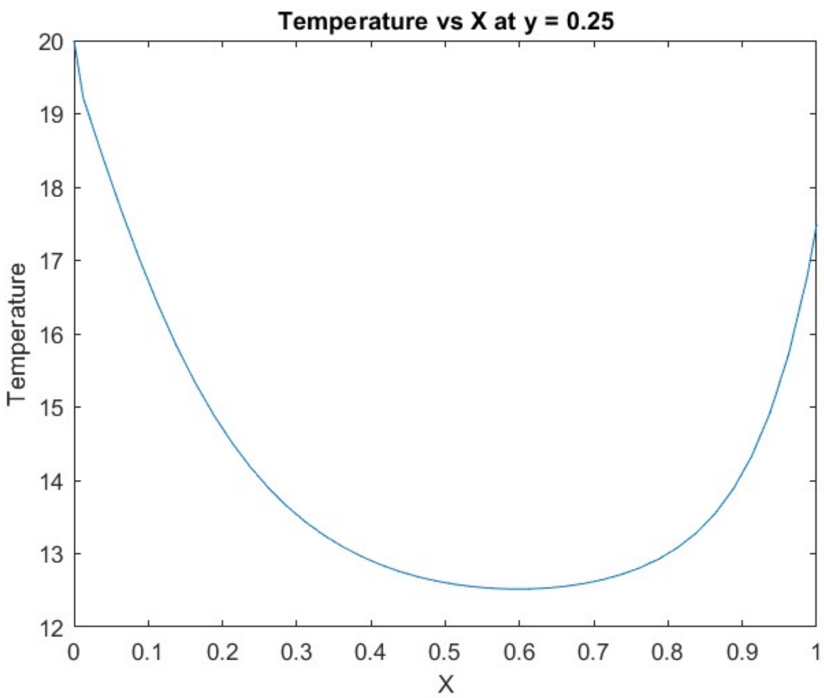
Q3)

- Changing the Neumann Boundary Condition (Insulated) on the left boundary to a Dirichlet Boundary Condition with T = 20^0C, we get the following results:

Temperature Distribution over the domain:

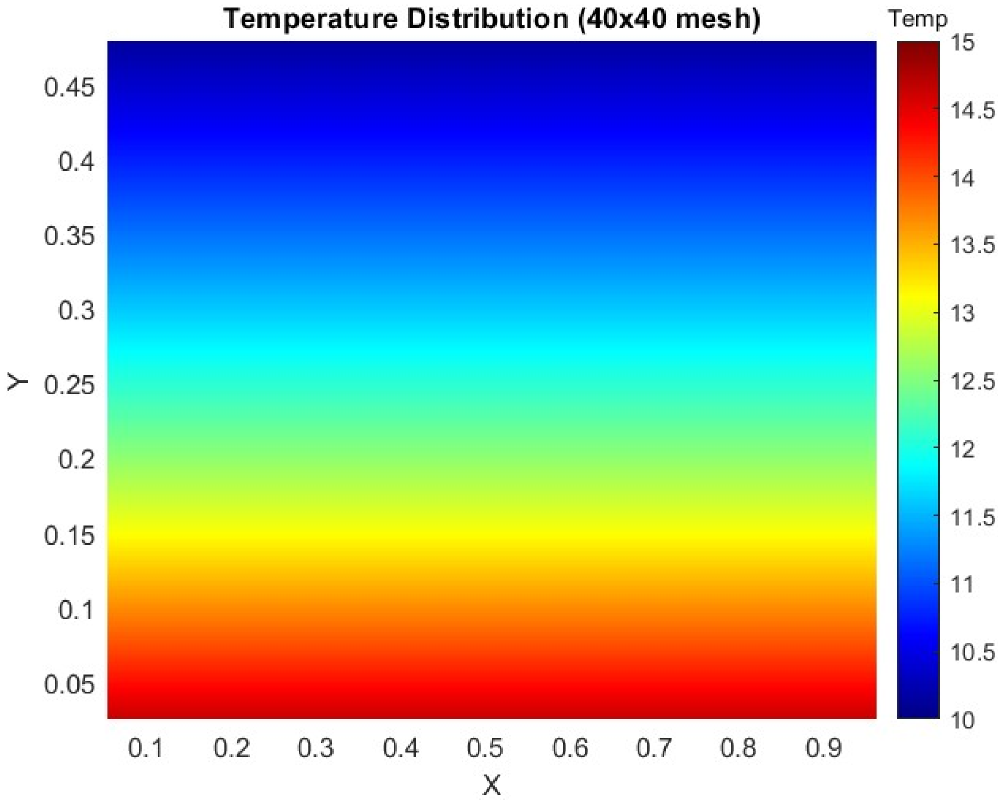


Temperature vs X at y = 0.25:



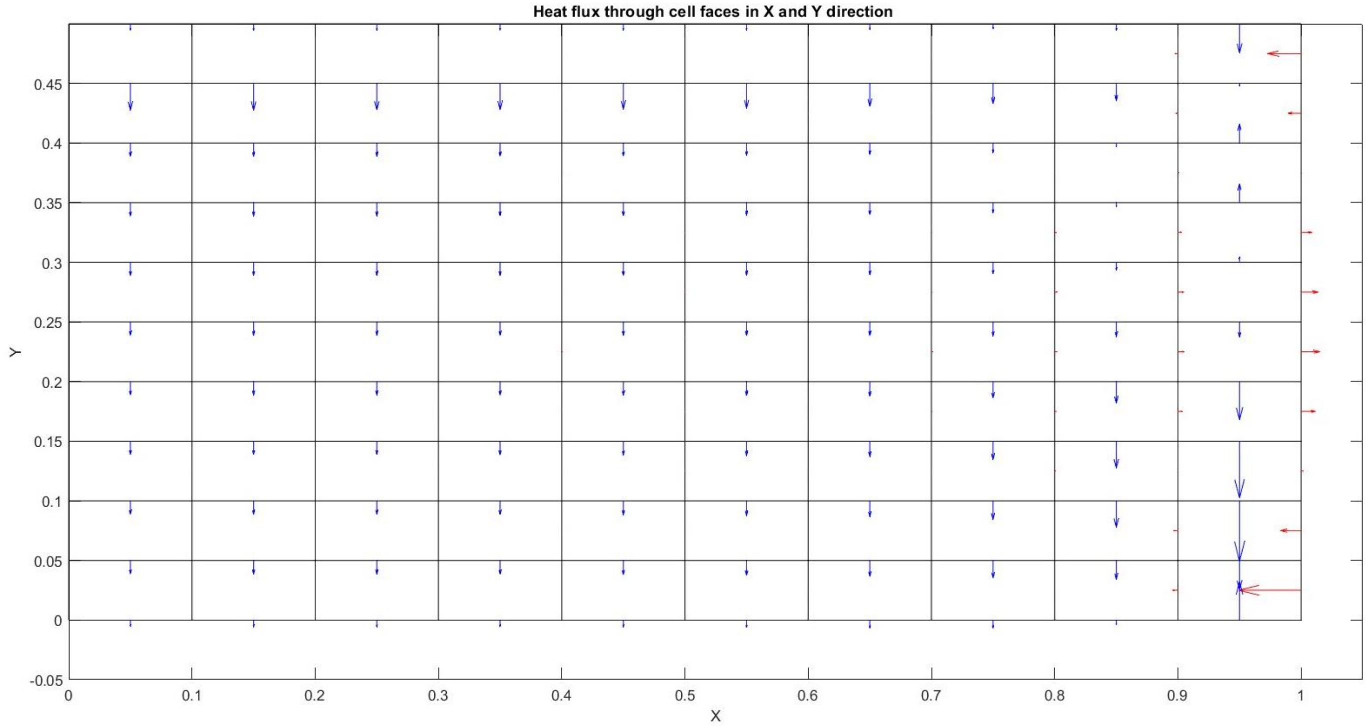
- As we change the left boundary condition to a Dirichlet BC with T_w = 20^0C, the temperature distribution changes as shown above.
- Instead of the temperature profile flattening out towards the left for the Neumann BC, now the temperature goes to the fixed value of 20^0C.

- Changing the Dirichlet Boundary Condition on the right boundary to a Neumann Boundary Condition (Insulated), we get the following results:



- As both the left and right boundary conditions are insulated, the problem now is similar to a 1D heat conduction in Y direction.
- There is almost no variation of temperature across X at a given Y, so there is not heat flux along X direction.
- The heat transfer is only in the Y direction from bottom (15^0C) to top (10^0C) and the temperature profile is almost linear which is similar to the original problem.

Q4) The heat flux along with the mesh is plotted in X and Y directions across the cell faces below:



- Along X direction, the heat flux is large near the right boundary as expected due to the varying temperature across the boundary and is close to zero elsewhere because of the Neumann Boundary condition on the left boundary. The flux vectors along the X faces are very small away from the right boundary and hence cannot be seen in the plot.

- Along the Y direction, the change in temperature is uniform and the variation is almost linear as seen before throughout the domain except for the right boundary. Hence the heat flux vectors are also of similar size and point in the direction of increasing temperature as shown in the plot.