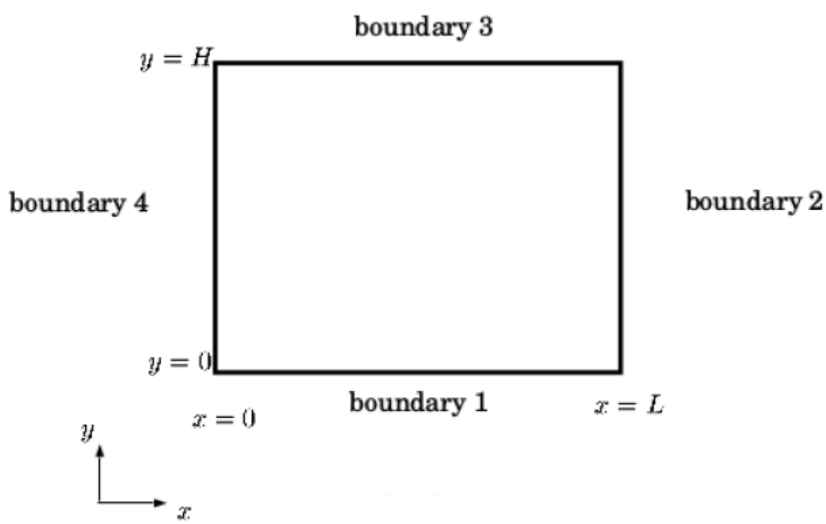
AM5630 Foundation of CFD
Assignment -2

AE25S051 MAYANK LONKAR

Heat conduction Equation -

$$0 = \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right) + S$$

Domain -



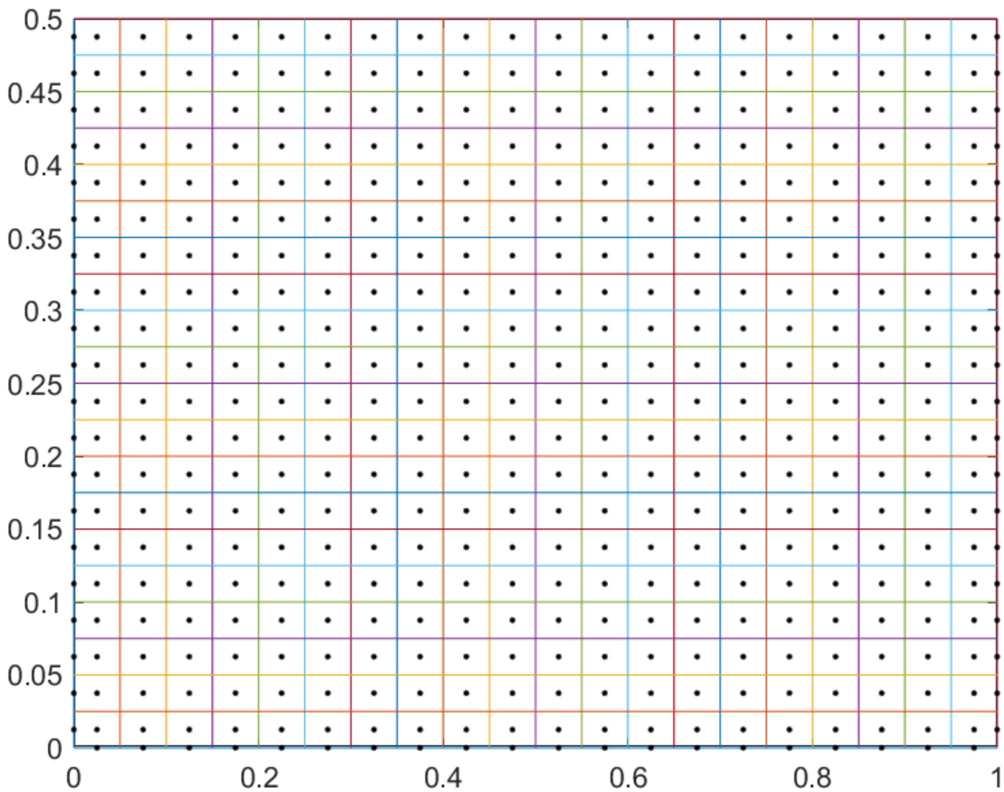
Boundary conditions -

T1	15
T2	5 x (1 − y/H) + 15 x sin(πy /H)
T3	10
T4	dT/dx = 0

Source Term = 500000 − 30000 ∗ T

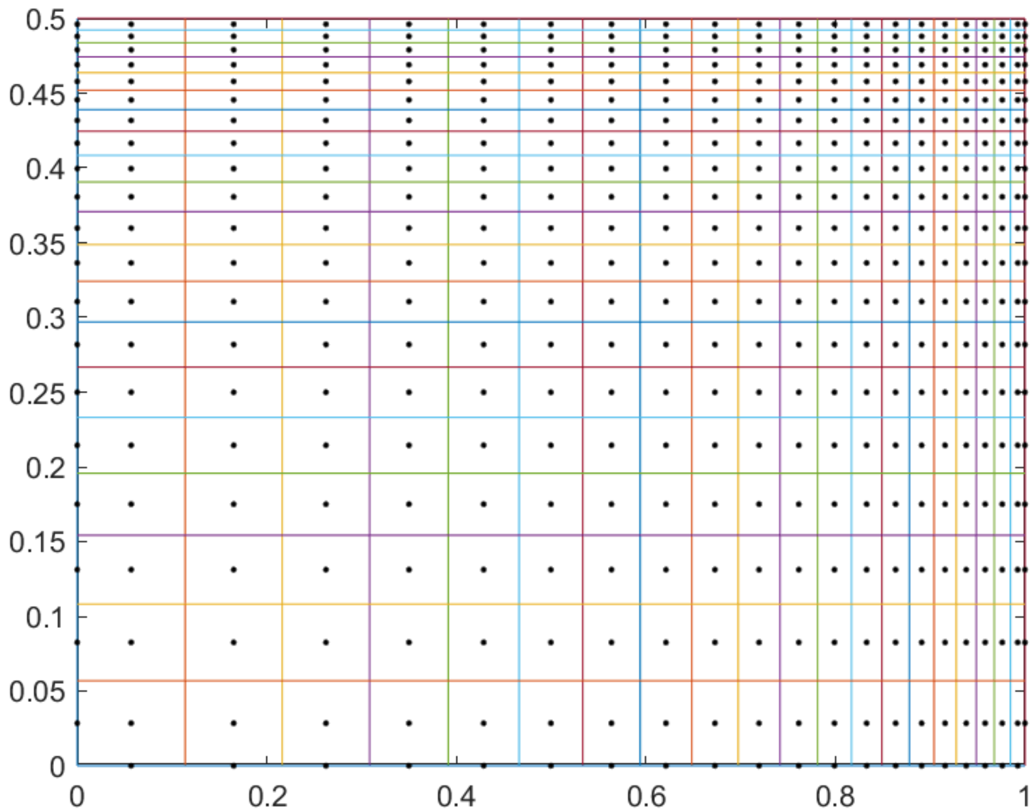
Meshing

1. **Uniform Mesh - (20 x 20)**



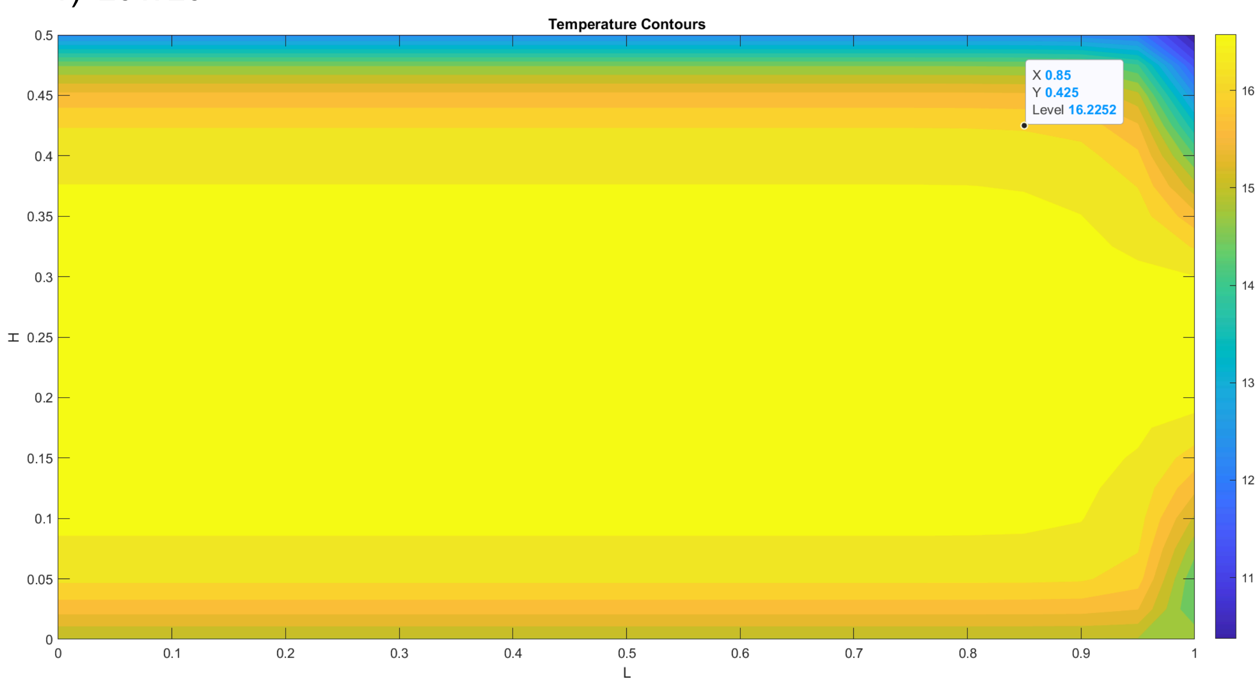
2. **Stretched and Refinement**

From the Temperature contour, it was observed that there is a variation in the values near the right and top boundaries. Thus the mess was stretched using a factor of 0.9 in both x and y direction as shown in the next figure.

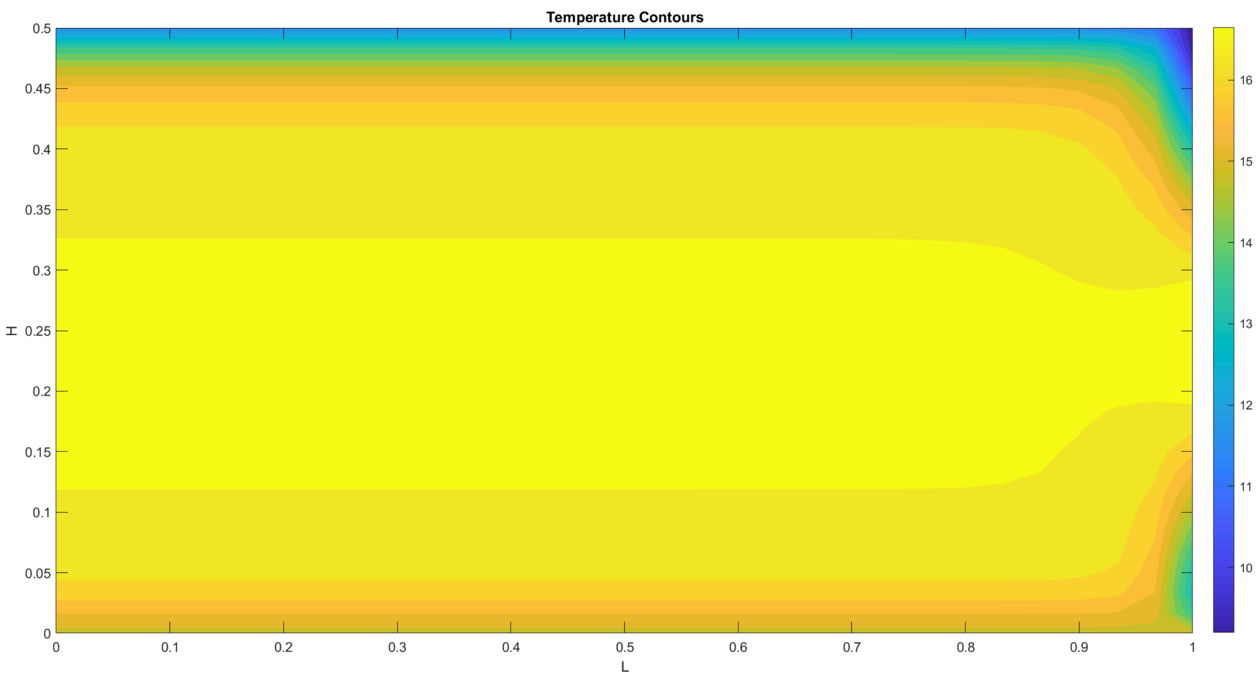


Equidistant Mesh Results

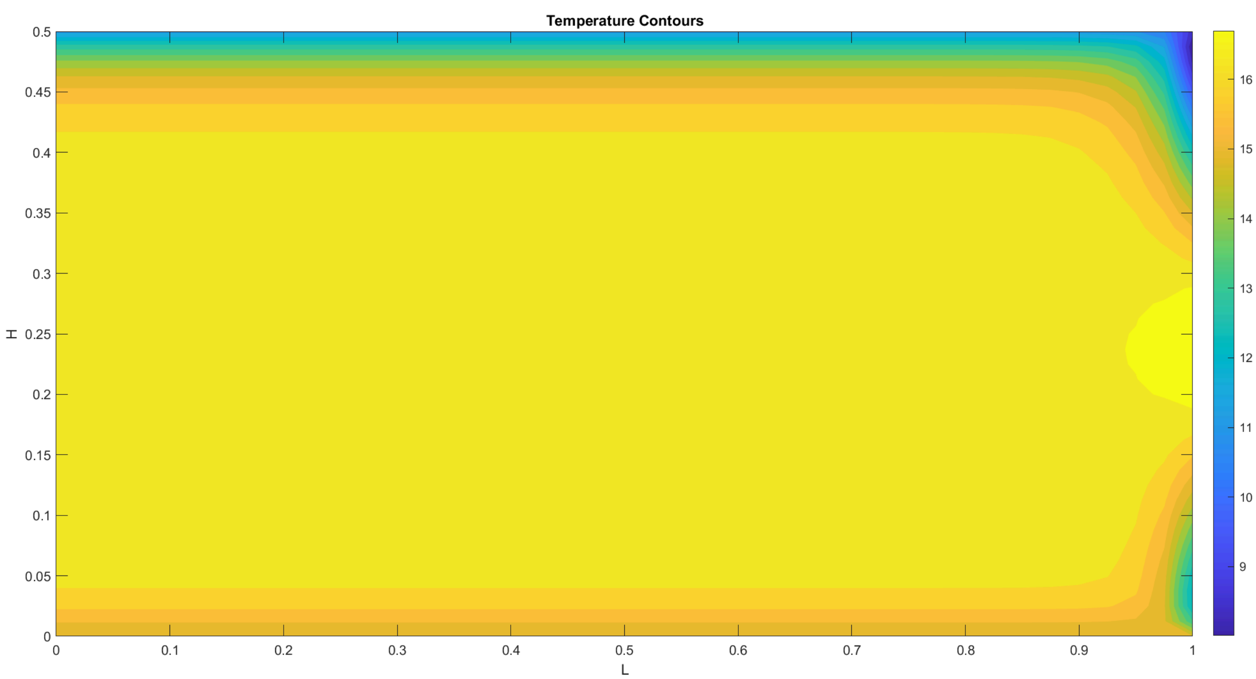
1) 20 x 20



2) 30 X 30

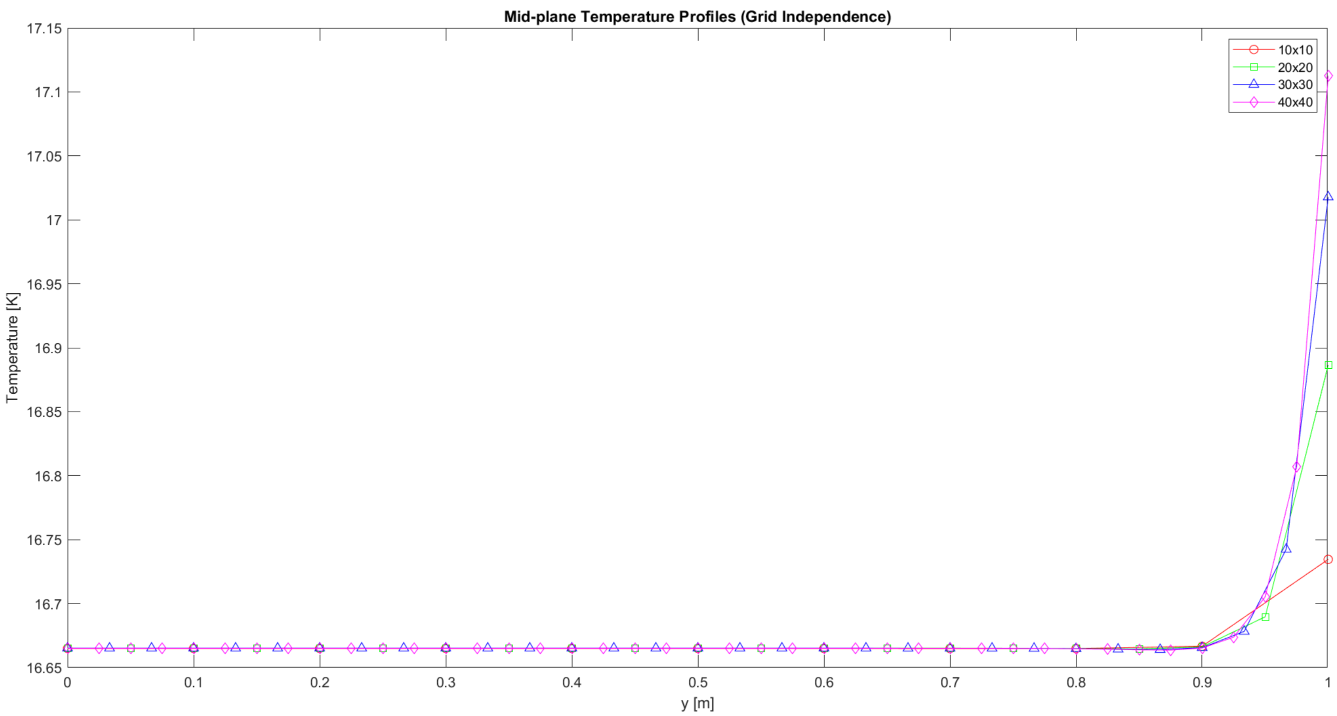


3) 40 x 40



Observations

- Mesh Independence was performed for the equidistant grid of 10x10 , 20x20, 30x30 and 40x40.
- Mid plane temperatures were plotted for different grid sizes.



- Temperatures for these mesh are mostly coincident till 0.9 m, and have a difference near the right boundary. Thus more finer grids are required in order to get mesh independence.
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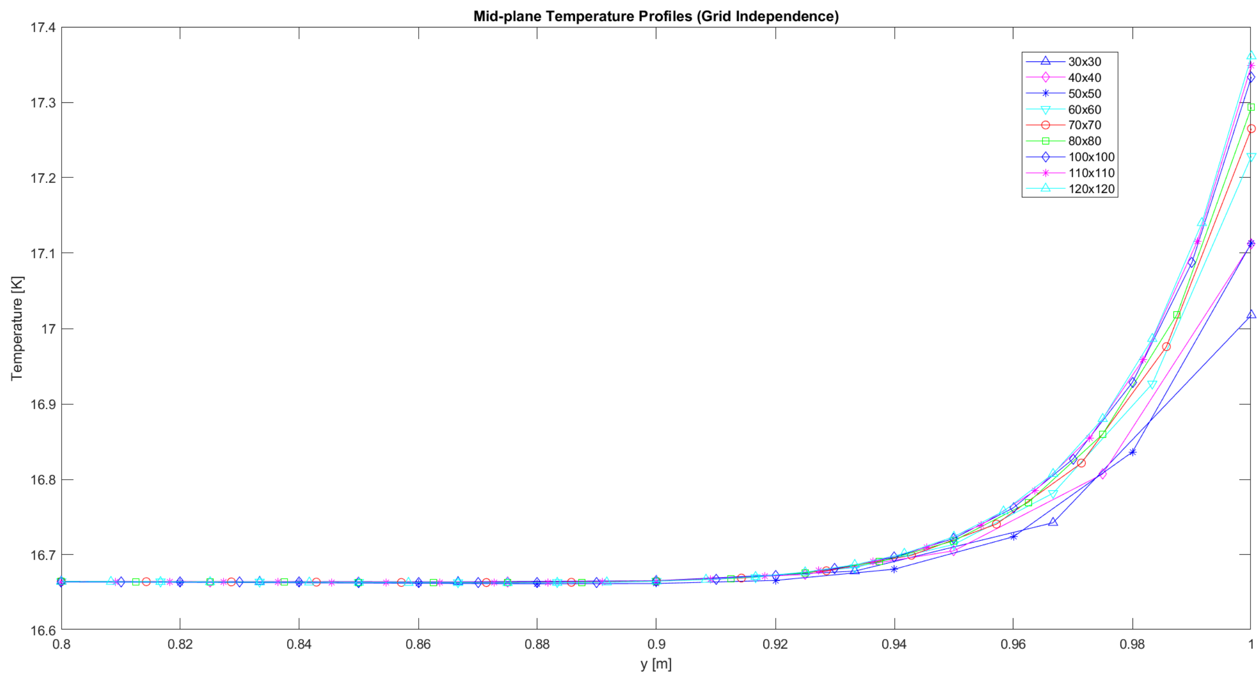
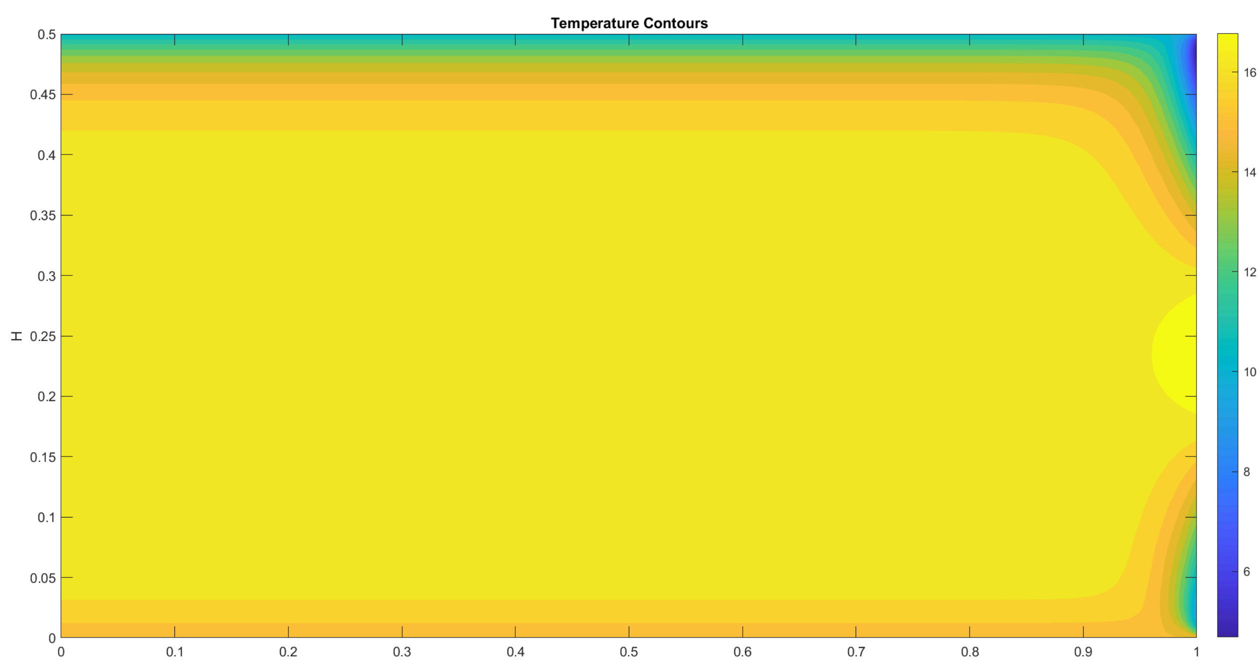
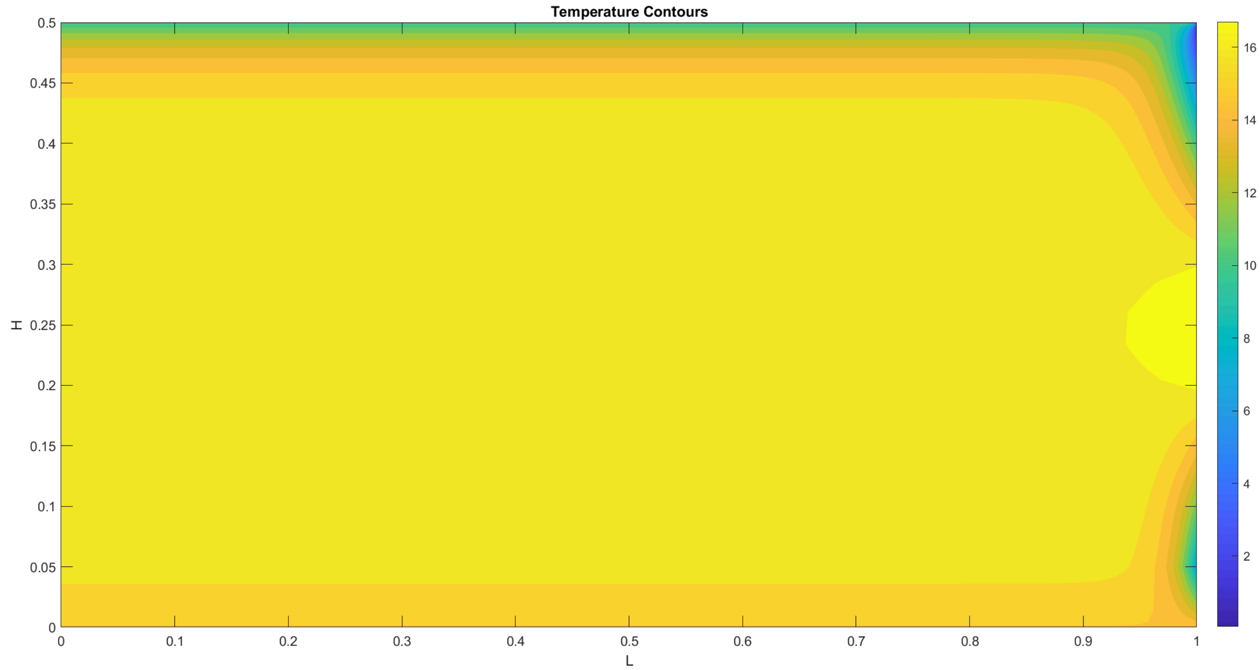
- Thus, finer mesh till 120 x 120 were also used and their results were plotted for mesh independence.



- 100 x 100 , 110 x 110 and 120 x 120 were overlaping showing convergence.



100 x 100 (Equidistant Mesh)



100 x 100 (with refinement near right and top boundaries)

With mesh refinements, we could get the temperature curve better in right boundary and also obtained better gradients in the top boundary.

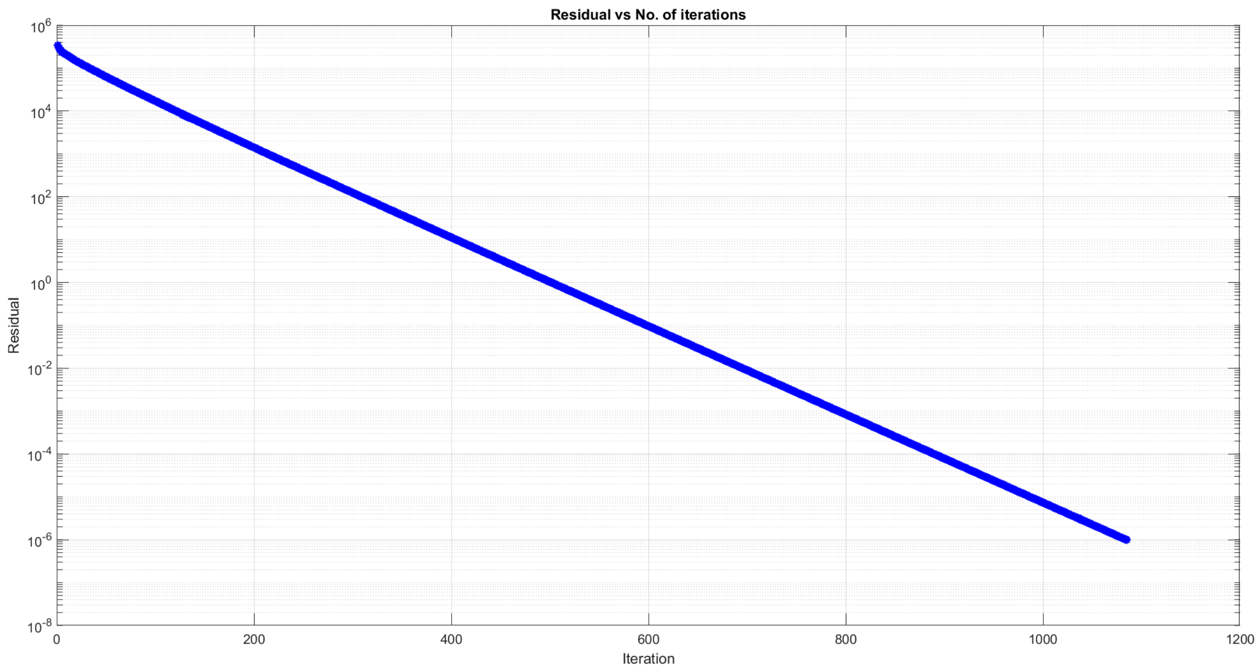
Temperature Contour Observations -

- For coarser mesh, the variation of temperature near the right boundary is not visible properly, while for mesh size greater than 40 x 40 temperature variation according to the boundary condition can be observed.
- We can observe the variation of temperature from 5℃ to 0℃ with a maximum value of approximately 17℃ at the centre. A high temperature curve can be observed in the centre.
- Source term 500000 is constant heat generation whereas 30000*T is a heat sink dependent on local temperature.
- Left boundary conditions allows the source term freely and the temperature is close to 16℃
- There is a gradient of temperature in all Dirichlet boundaries (T1, T2 and T3) from their boundary temperature to the source temperature (16.7℃) in the centre of the domain.

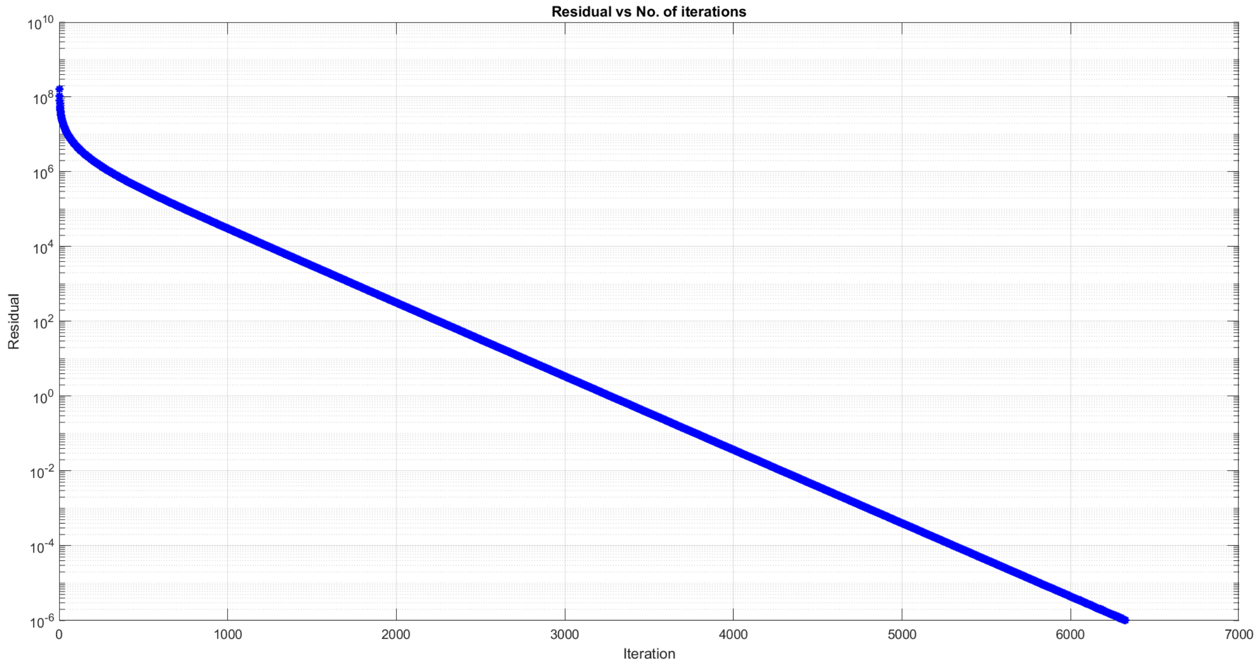
Residuals

Residuals vs No. of iterations results are plotted for 100 x 100 mesh size for 1e-6 and 1e-7 iterations.

1) Error tolerance - 1e-6

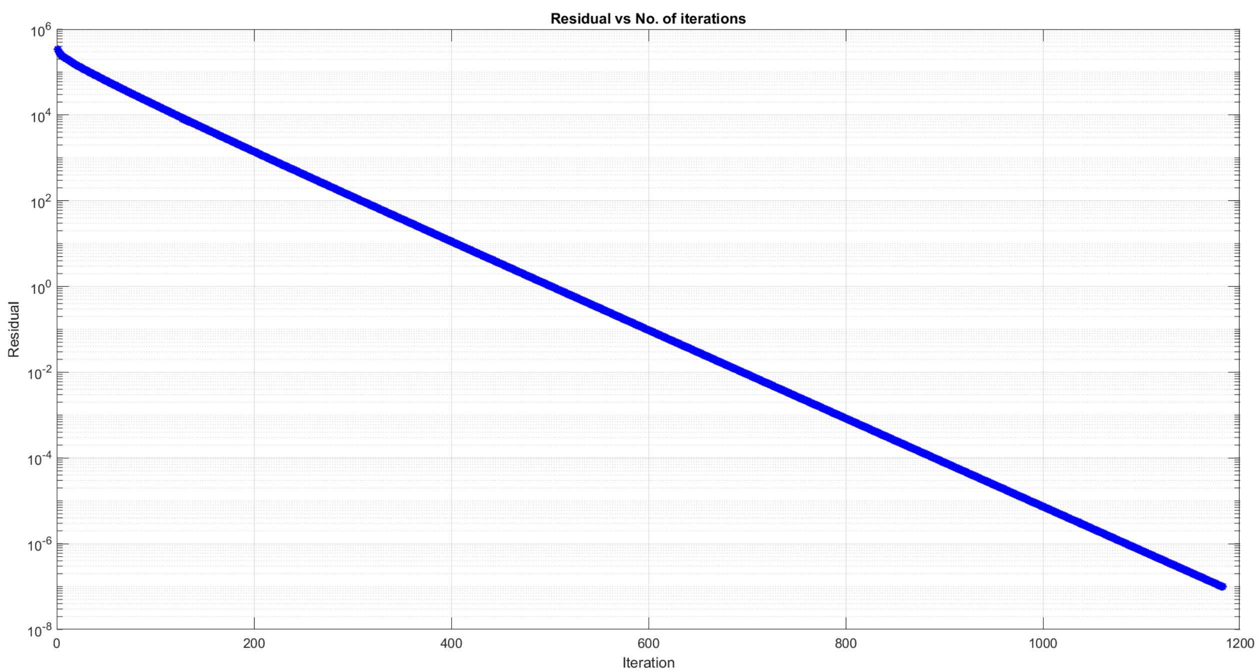


Equidistant mesh

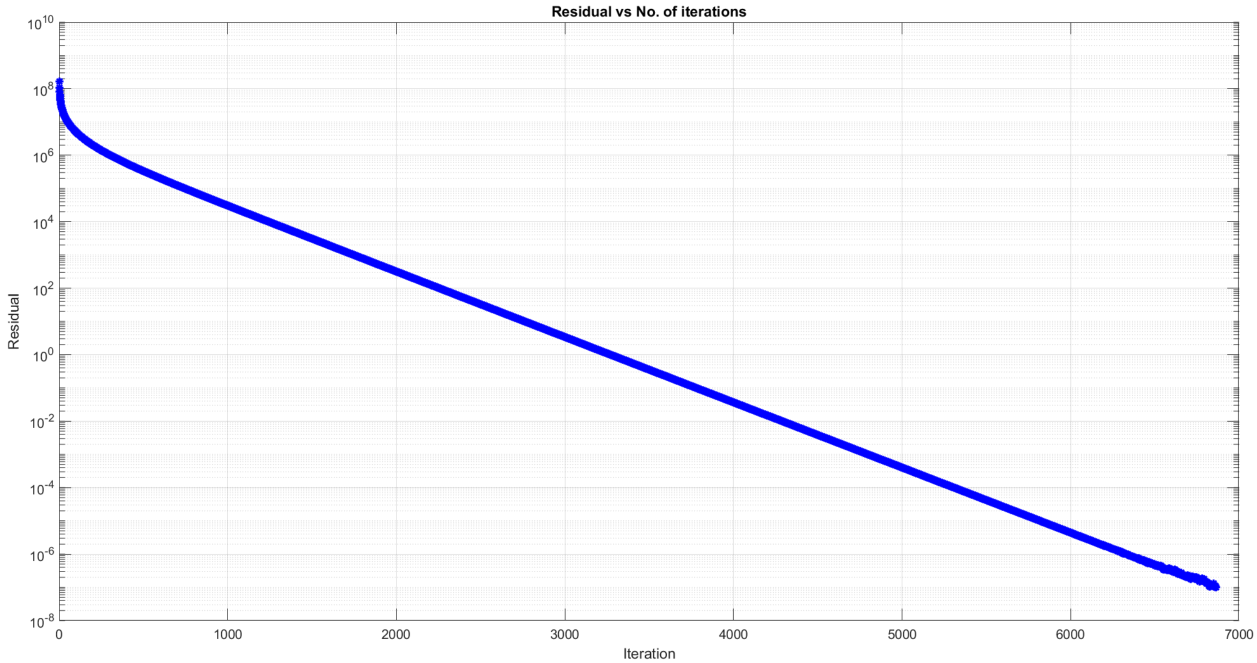


Refined Mesh

2) Error Tolerance - 1e-7



Equidistant mesh



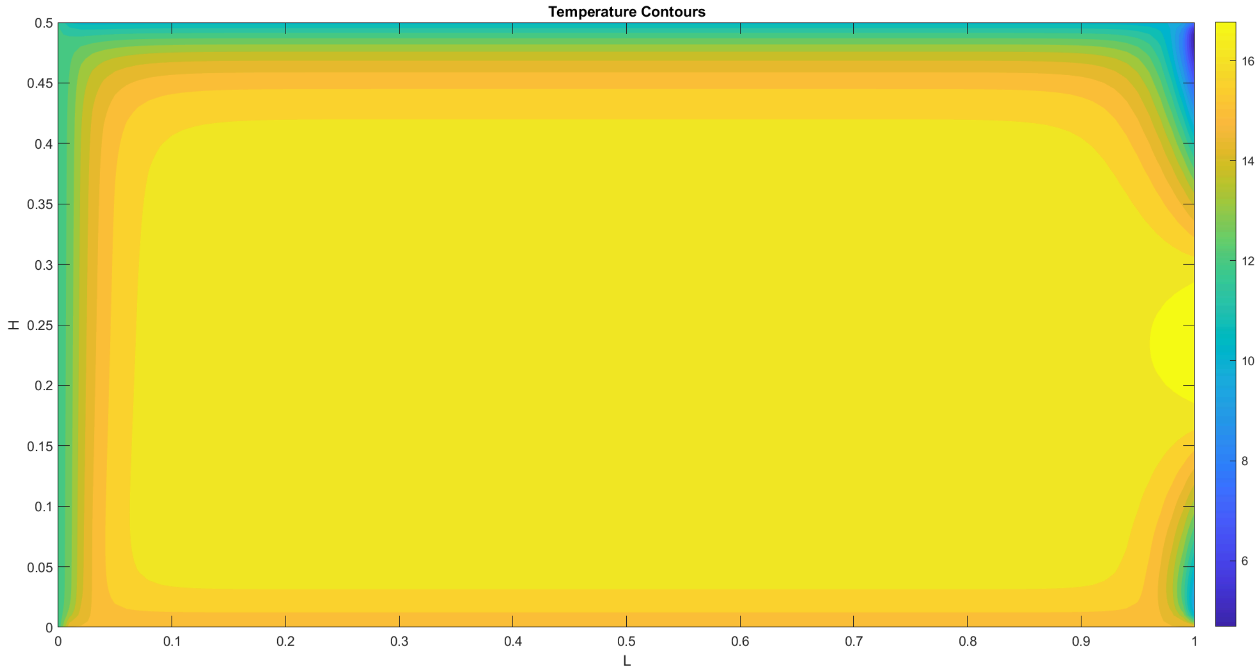
Refined Mesh

Error	**1e-6**	**1e-7**
Equidistant	1182	1085
Refined	6328	6862

As the tolerance is increased it takes more number of iterations to converge. Also refined mesh requires much higher iterations to converge as compared to the equidistant mesh.

Neumann to Dirichlet Boundary condition

The boundary 3 previously having dT/dx = 0 will be changed to neumann boundary condition where T4 = 12



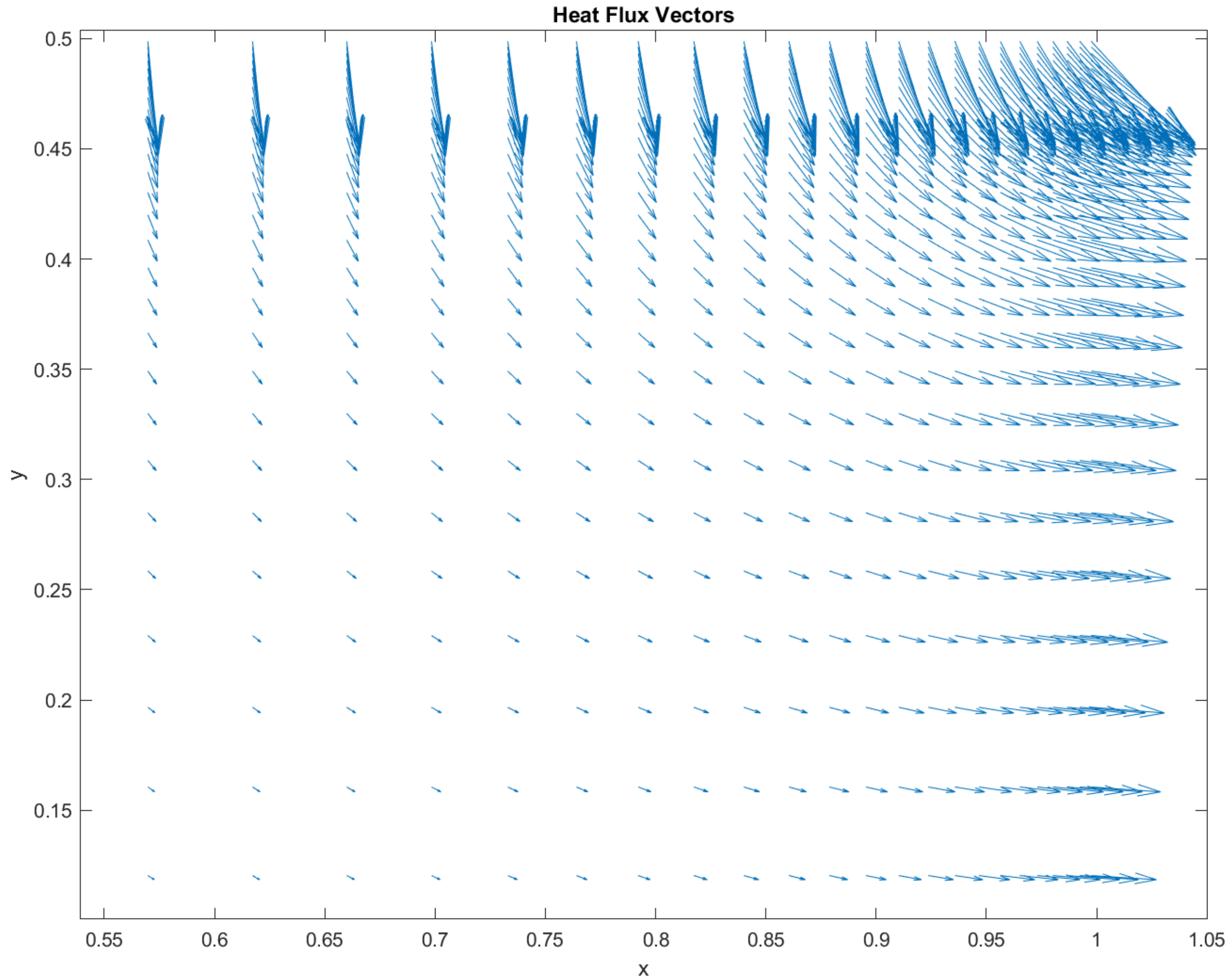
Temperature contour obtained shows that left boundary temperature is 12 and there gradient from 12 to 16.7 in the centre of the domain.

Vector Plots

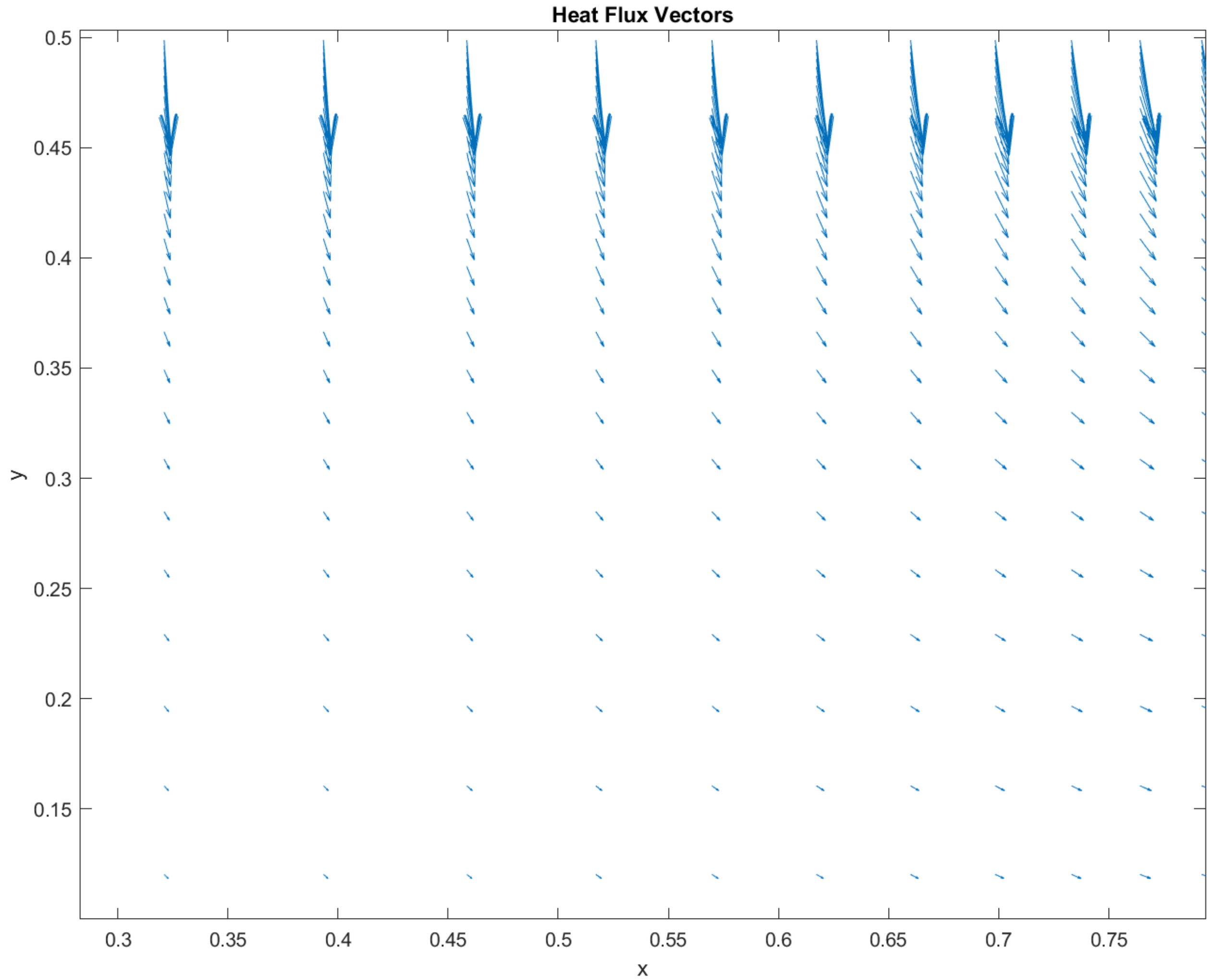
- Heat vector plots are also obtained by calculating the heat flux Q = k * (dT/dx) for each node.
- For better visualization, heat flux vector is plot for 30 x 30 (Refined mesh)

This is a snippet that shows top right corner, where we could the following

- Heat flux from the top and right corner towards the right boundary.
- The magnitude of heat flux is higher near the top boundary as there is a gradient of temperature .
- Also a significant heat flux is seen near the right corner in the figure



Heat Flux vector from x = 0.5 to 1.0



Heat Flux vector from x = 0.3 to 0.75

Heat flux vectors in the central portion also point downward and right. The heat magnitude is less in this region as there is not much variation in the temperature in this region.