

MAE 598: Project 1

Jorge Moreno

10/17/2019

H.P Huang

Name of Collaborator: Juan Zavala	
Task(s), Specific Detail	Contribution to Collaborative Effort
Task 1	Worked with me on the geometry of the tank
Task 2	Worked with me on the helical curve
Task 3	Worked with me on the mesh setup and calculation settings
Task 4	Worked with me on the geometry of the tank

Task 1a:

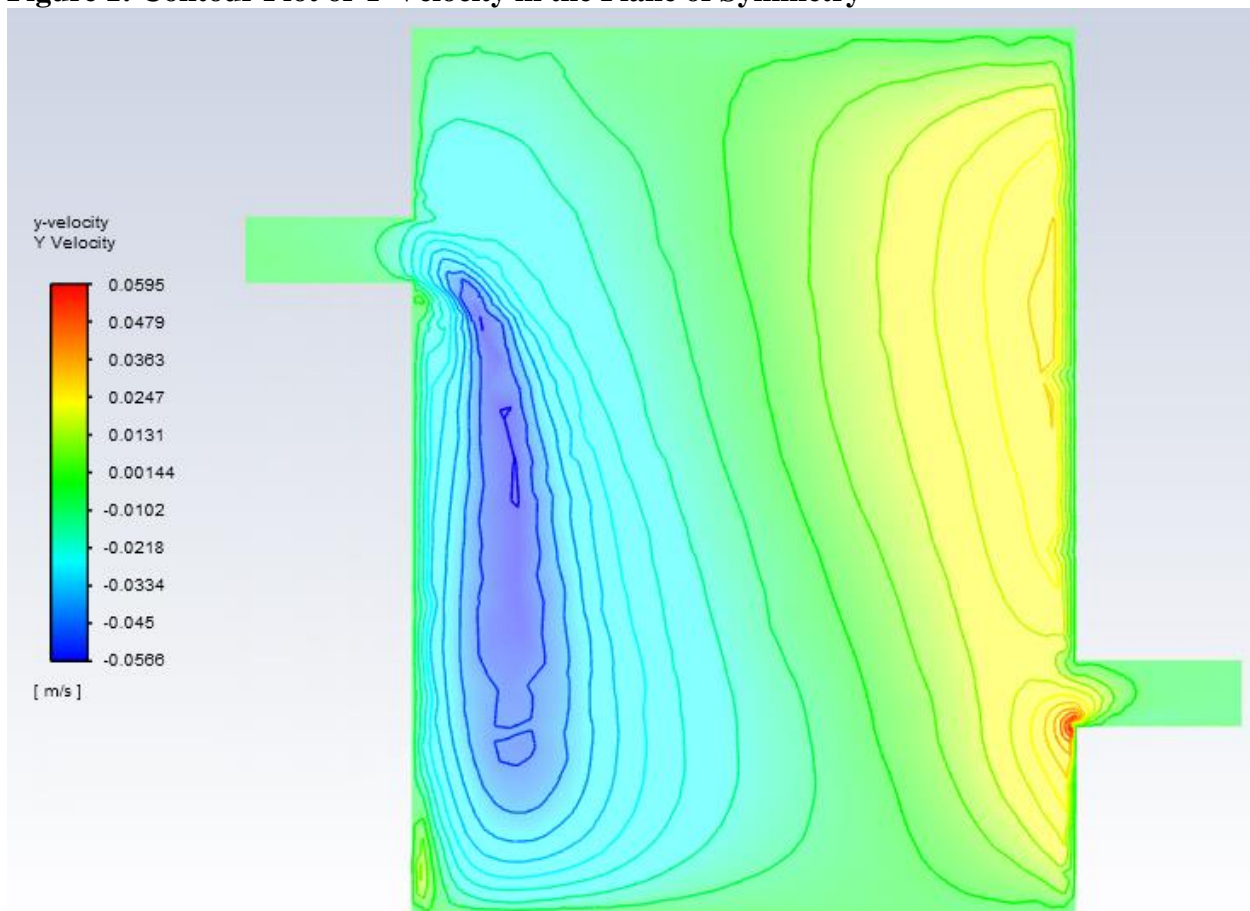
Background: For this task, I had to build a prototype of a water heater tank. Water was entering from a side pipe at 0.05 m/s at a temperature of 10 °C into a main cylindrical tank where the bottom plate was externally maintained at 55°C. One of the goals of this task was to determine the steady state temperature of the outflow. I set density to Boussinesq to allow variation of density with temperature. I followed the instructions on setup as provided by the professor in the task description including adjusting for earth gravitational effects (-9.8 m/s^2).

The mesh used for this part was A was a 2.5 cm element size. The inflation was set to program controlled and all the other settings were set to default.

Deliverables:

(i)

Figure 1: Contour Plot of Y-Velocity in the Plane of Symmetry



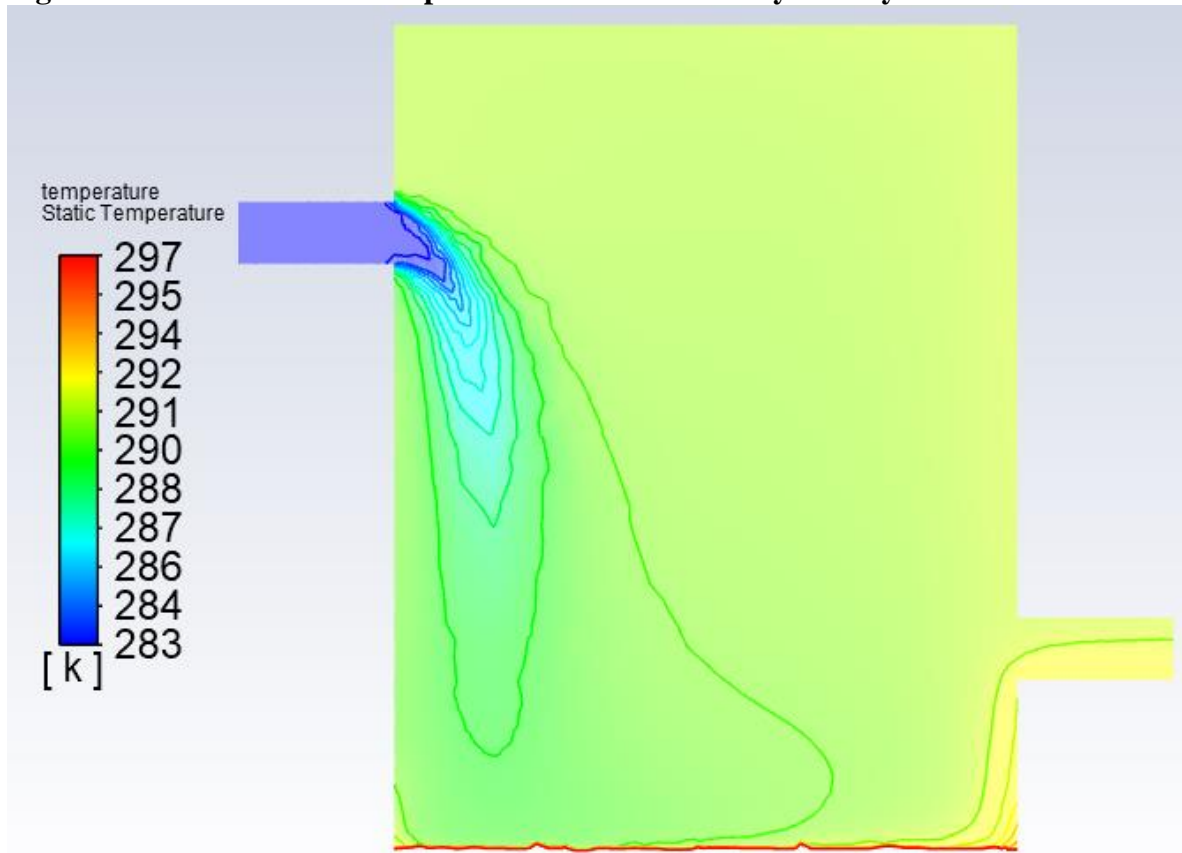
As you can see from the image above, the fluid enters from the inlet and then travels in the x direction slightly before falling downward with a negative y velocity. After hitting the bottom of the tank, the fluid travels in the x direction until it encounters the wall to the right, then proceeds to swing upward in the positive y-direction where some of the fluid escapes through the outlet.

Maximum y-velocity: 0.0595 m/s

Minimum y-velocity: -0.0566 m/s

(ii)

Figure 2: Contour Plot of Temperature in the Plane of Symmetry



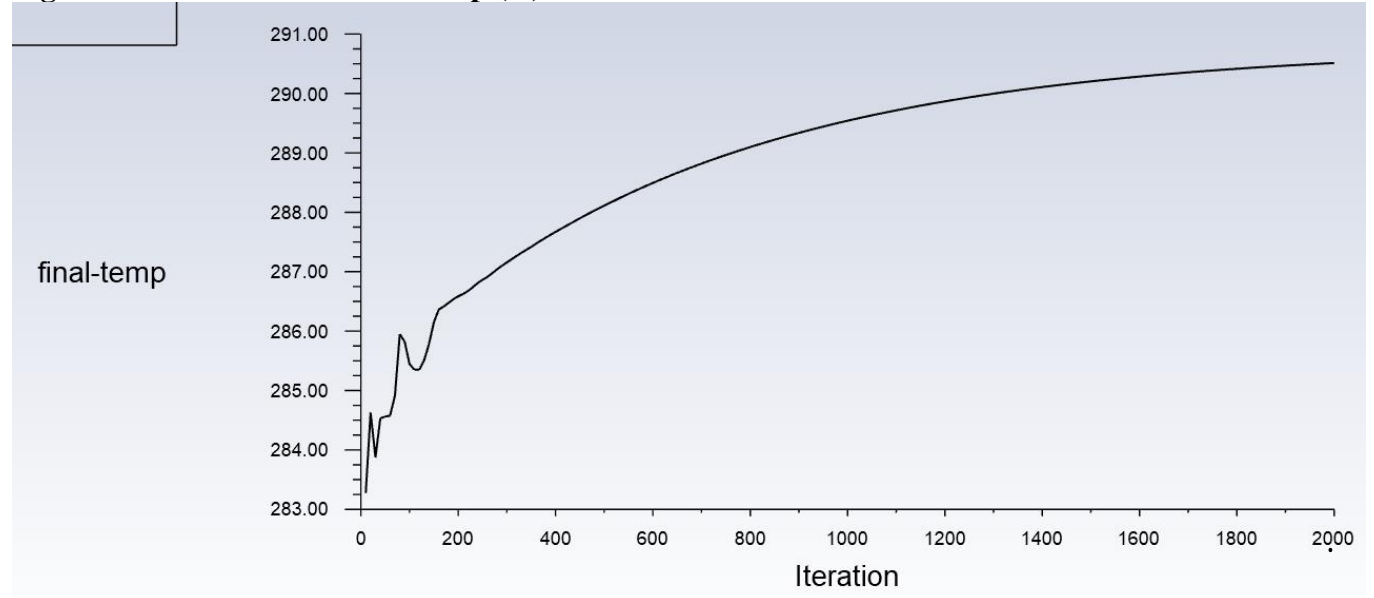
For Figure 2, I imposed manual ranges for the color bar. The reason I did this was to highlight the “waterfall” from the inlet into the main cylindrical tank. Otherwise, if I would have kept the default color bar range, the “waterfall” would not be very clear since most of the change in temperature would be highlighted by the temperature gradient produced by the hot plate at the bottom of the tank.

(iii)

Outlet Temperature at Steady-State:

Area-Weighted Average Static Temperature	(k)
outlet	290.51235

Figure 3: Line Plot of Outlet Temp (K) as a Function of Iterations



In order to satisfy the converge criterion that was demanded, I looked at the outlet temperature at 1900 iterations which was 290.47 K. I then looked at the outlet temperature at 2000 iterations which was 290.51 K. Since the difference between these two temperatures is 0.04, it is safe to say that I have met the convergence criterion (The calculation should be run until the variation of T_{out} is less than 0.05°C over the span of 100 iterations.)

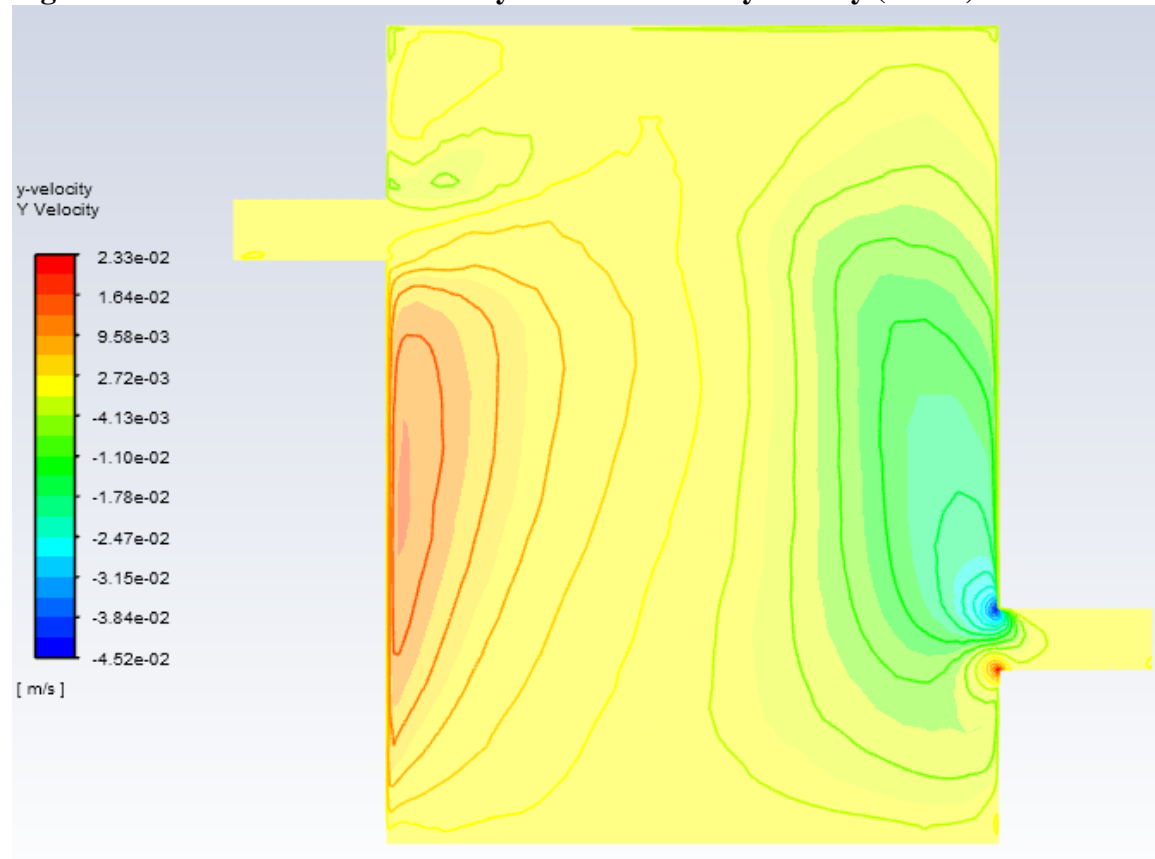
Task 1b:

Background: The background for this task was the exact same as that for task 1a except for the fact that the gravitational acceleration was now simulated as that on the moon (-1.62 m/s^2). Other than a different gravitational acceleration, the rest of the settings and conditions were treated the same as task 1a. The exact same mesh was used as task 1a (2.5 cm element size with inflation set to program controlled).

Deliverables:

(i)

Figure 4: Contour Plot of Y-Velocity in the Plane of Symmetry (Moon)



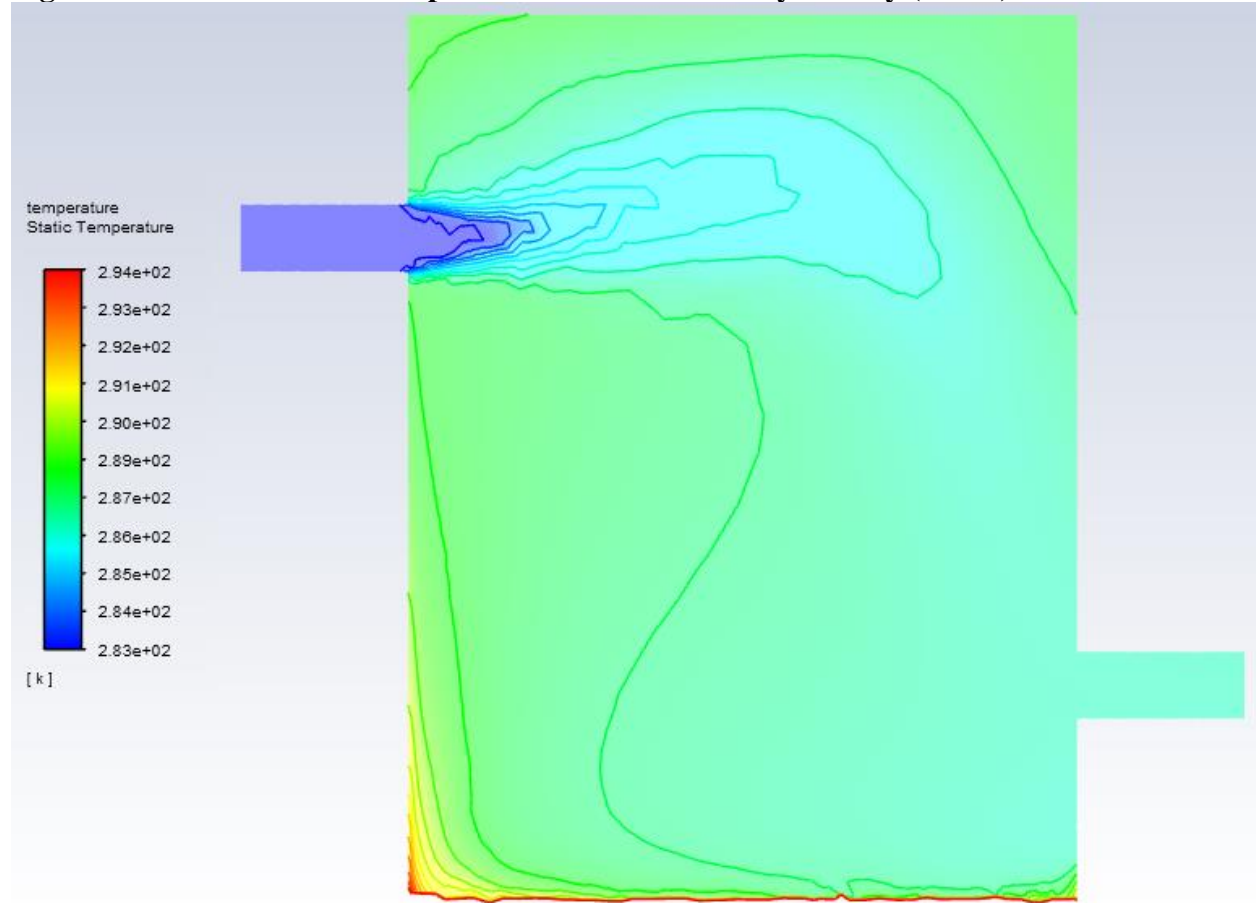
As you can see from the image above, the fluid enters the inlet and then travels in the x direction until it encounters the wall. When encountering the wall, the fluid then has a negative y velocity (moving downward) then proceeds to swing back around to the left wall where the fluid then travels upwards (positive y velocity).

Maximum y velocity: 0.0233 m/s

Minimum y velocity: -0.0452 m/s

(ii)

Figure 5: Contour Plot of Temperature in the Plane of Symmetry (Moon)



For Figure 5, I imposed manual ranges for the color bar. The reason I did this was to highlight the “waterfall” from the inlet into the main cylindrical tank. Notice how we see the “waterfall” travel further off to the right than compared to the earth gravity “waterfall”. This can be explained because since the moon has a lower gravitational acceleration, the inlet fluid will travel further in the x direction before falling.

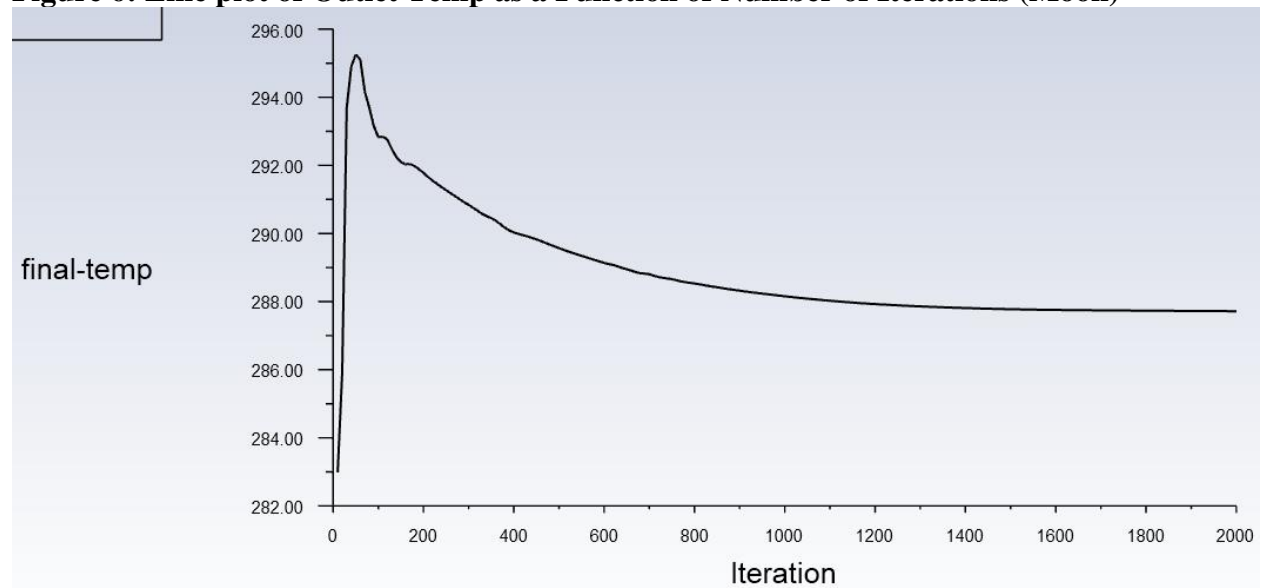
(iii)

Outlet Temperature at Steady State (Moon):

```
Calculation complete.
```

Area-Weighted Average Static Temperature	(k)
----- outlet	287.71726

Figure 6: Line plot of Outlet Temp as a Function of Number of Iterations (Moon)



After running 2000 iterations total, I needed to check to make sure that the convergence criterion was satisfied. Given that the temperature value at 1900 iterations was 287.7247 K and the value at 2000 was 287.7173 K, that means that the temperature difference between those 100 iterations was .0074 which was deemed acceptable. (Convergence criterion was a delta T lower than 0.05). I also noticed that the line plot began to flatten out after around 1600 iterations but kept it running a bit more for good measure.

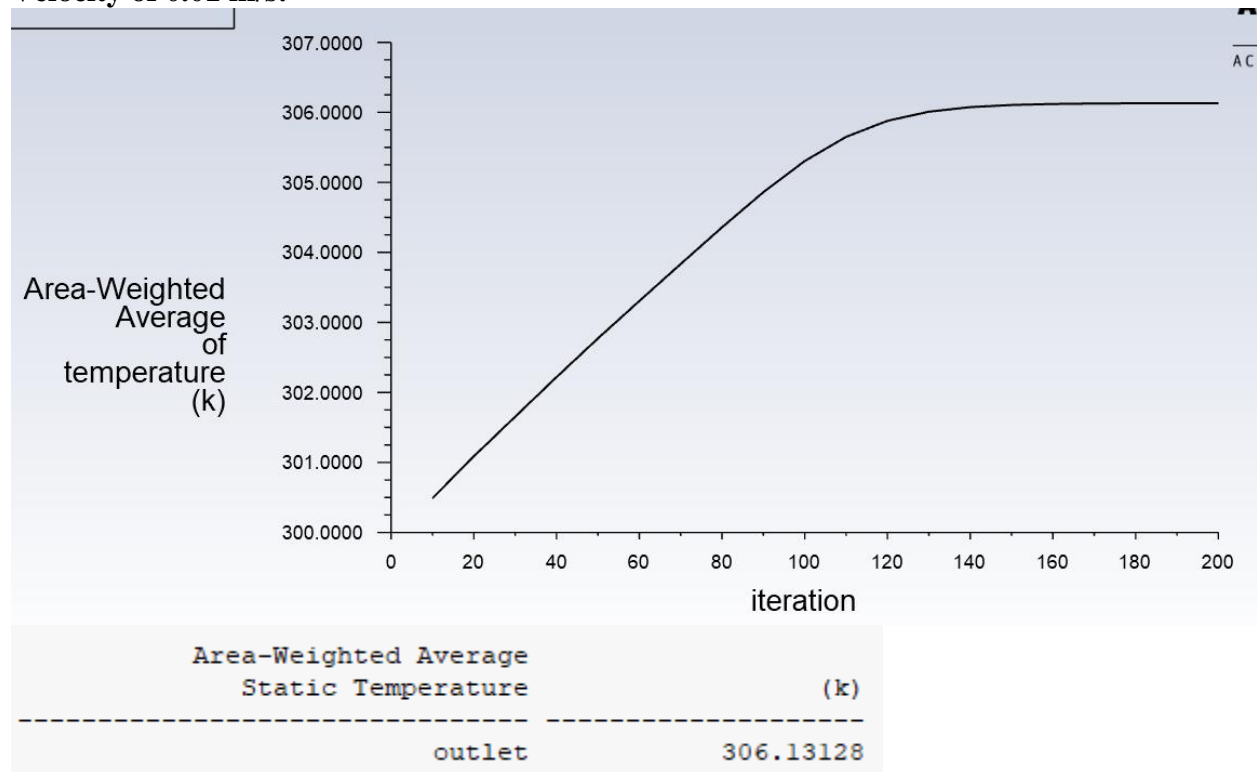
Task 2:

Background: The water heater used in Task 1 is very primitive and inefficient. In practice, the water heaters for household uses have very different designs. One design is to run water through a coiled pipe with heated wall. This allows water to heat up quickly within limited space. We will use Fluent to simulate a prototype of the coiled-pipe system filled with water. Unlike Task 1, to keep the physical processes simple we revert the setting to constant density and no gravity. The viscosity and heat conductivity of water are also set to constant, all using the default values in Fluent database.

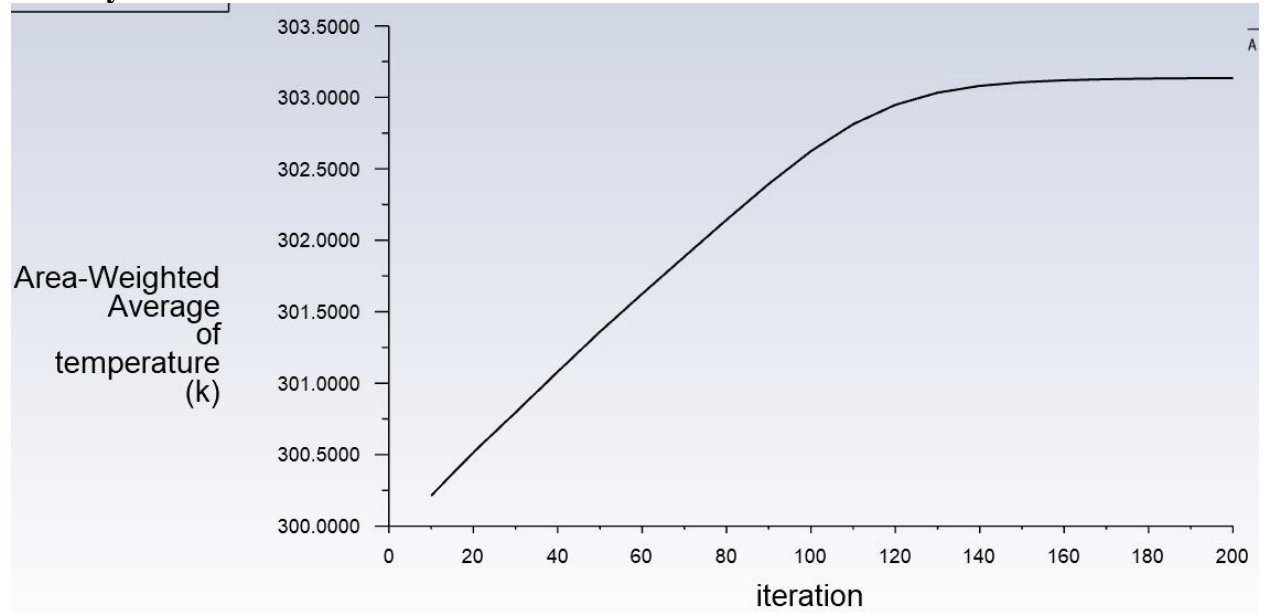
Approach: The approach taken for this task was to begin by building the geometry with the helical curve equations provided by the instructor. After building the geometry, I set the boundary conditions as follows: velocity inlet for the inlet and outflow for the outlet. Laminar viscous model was chosen for all runs to seek the steady solution. The wall also provided a uniform energy input of 500 W/m^2 . The inlet temperature was set to a constant 300°K .

This task was run 4 different times due to the changing inlet velocity varying from 0.01, 0.02, 0.04, and 0.08 in the direction normal to the opening of the inlet. This was done with a hybrid initialization. The findings are listed below.

Velocity of 0.01 m/s:



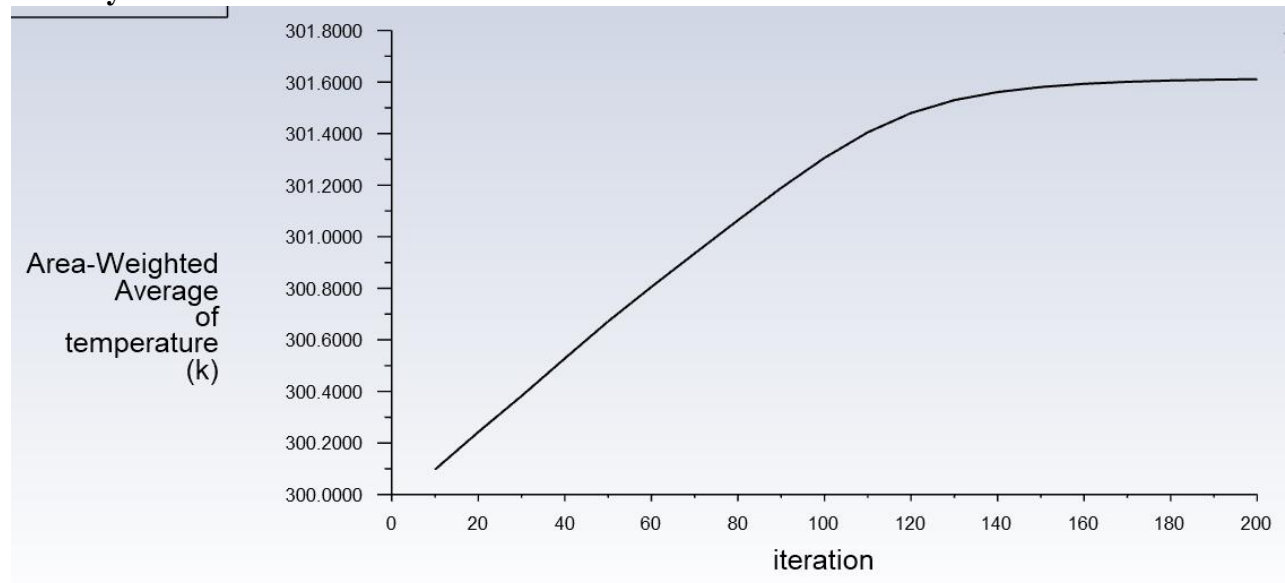
Velocity of 0.02 m/s:



Calculation complete.

Area-Weighted Average Static Temperature	(k)
----- outlet	303.13515

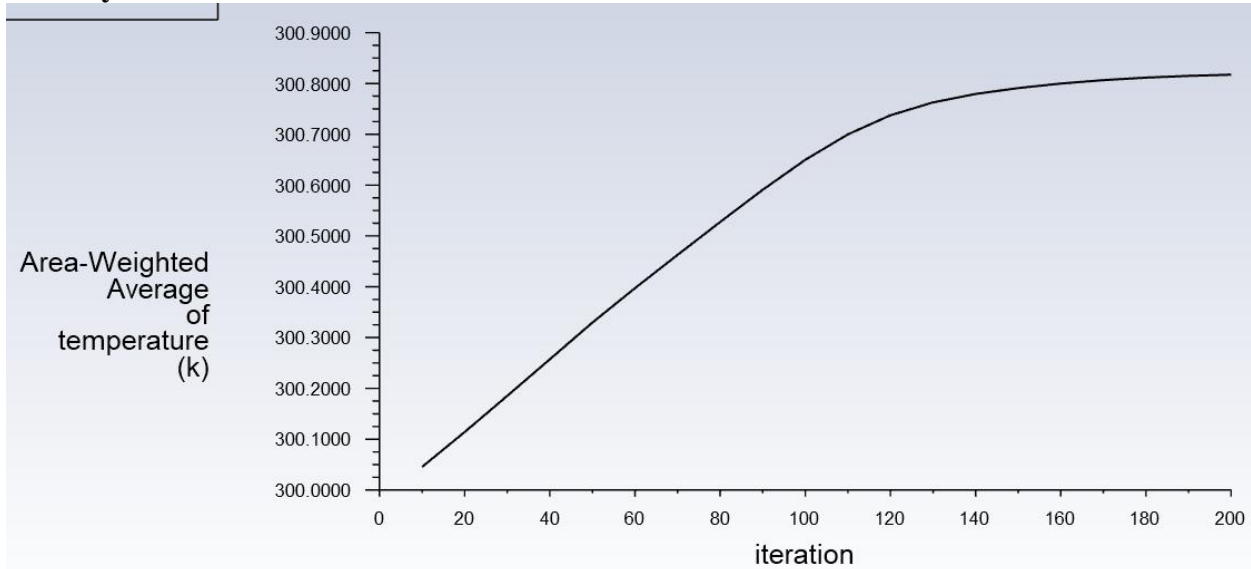
Velocity of 0.04 m/s:



Calculation complete.

Area-Weighted Average Static Temperature	(k)
outlet	301.61103

Velocity of 0.08 m/s:



Calculation complete.

Area-Weighted Average Static Temperature	(k)
outlet	300.81728

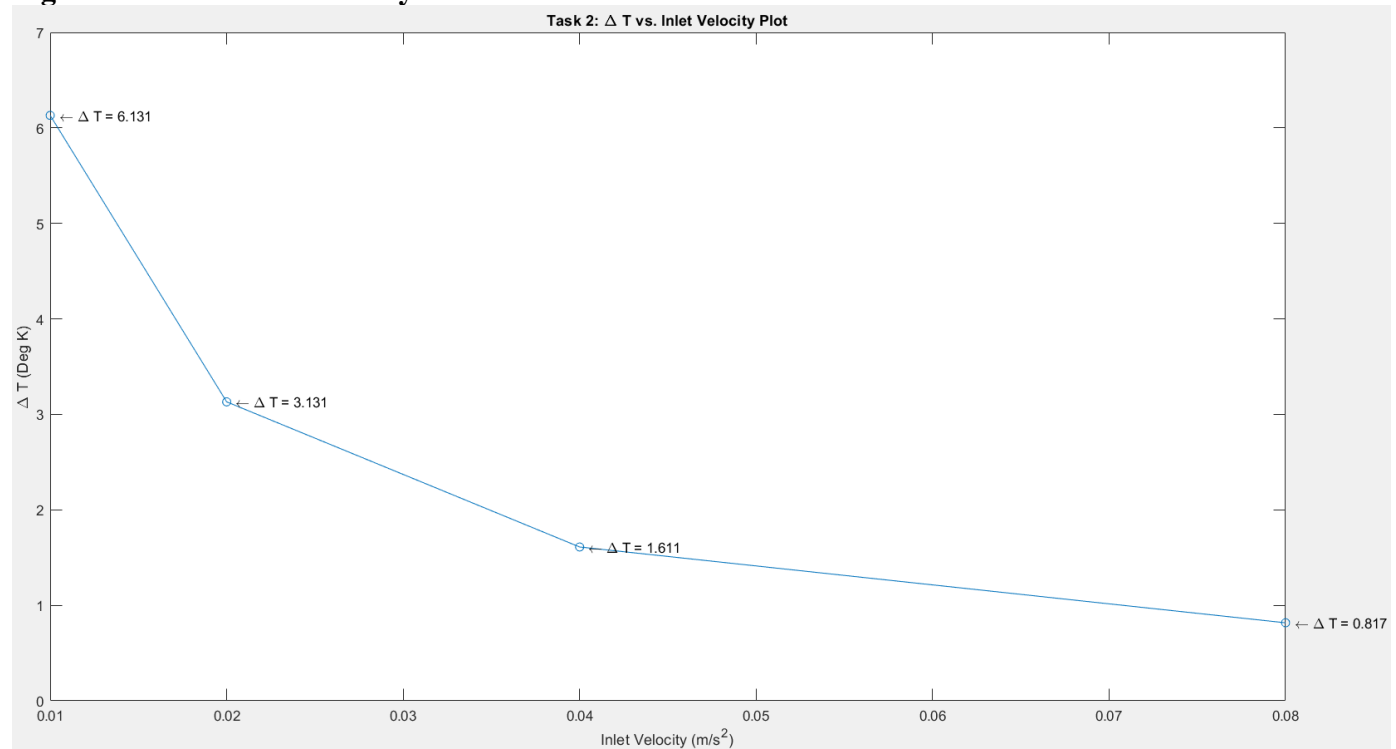
Deliverables:

(i)

Table 1: The values of ΔT for the 4 Cases

Inlet Velocity (m/s)	Outlet Temperature ($^{\circ}$ K)	Change in Temperature ($^{\circ}$ K)
0.01	306.13128	6.13128
0.02	303.13515	3.131515
0.04	301.61103	1.61103
0.08	300.81728	.81728

Figure 7: ΔT vs Inlet Velocity Plot



As shown in Figure 7, it can be seen that there is an inverse relationship between inlet velocity and change in temperature. This can best be explained because the change in temperature is proportional to a constant times one over the radius of the pipe times one over the inlet velocity (as discussed in class). This means that increasing the inlet velocity linearly will result in the temperature dropping by a factor of approximately $(1/x)$ as seen by the concave up decreasing plot above.

(ii)

Figure 8: Contour Plot of Temperature across Outlet (Inlet Velocity of 0.04 m/s)

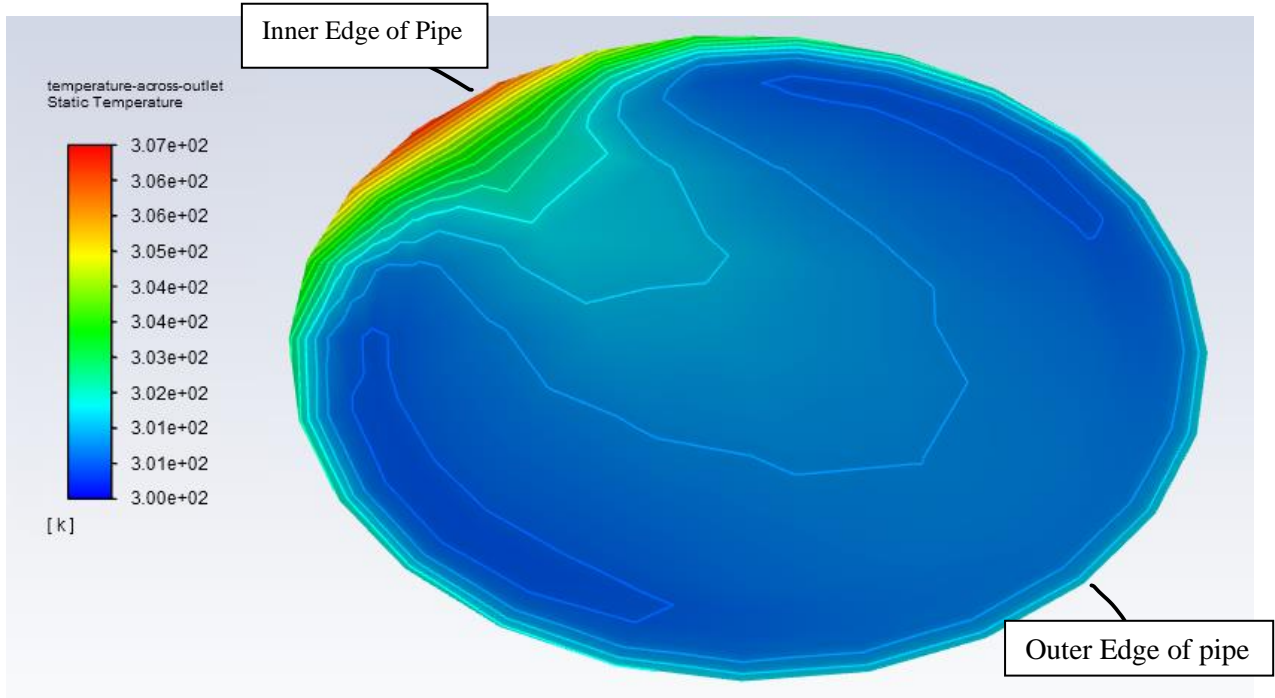
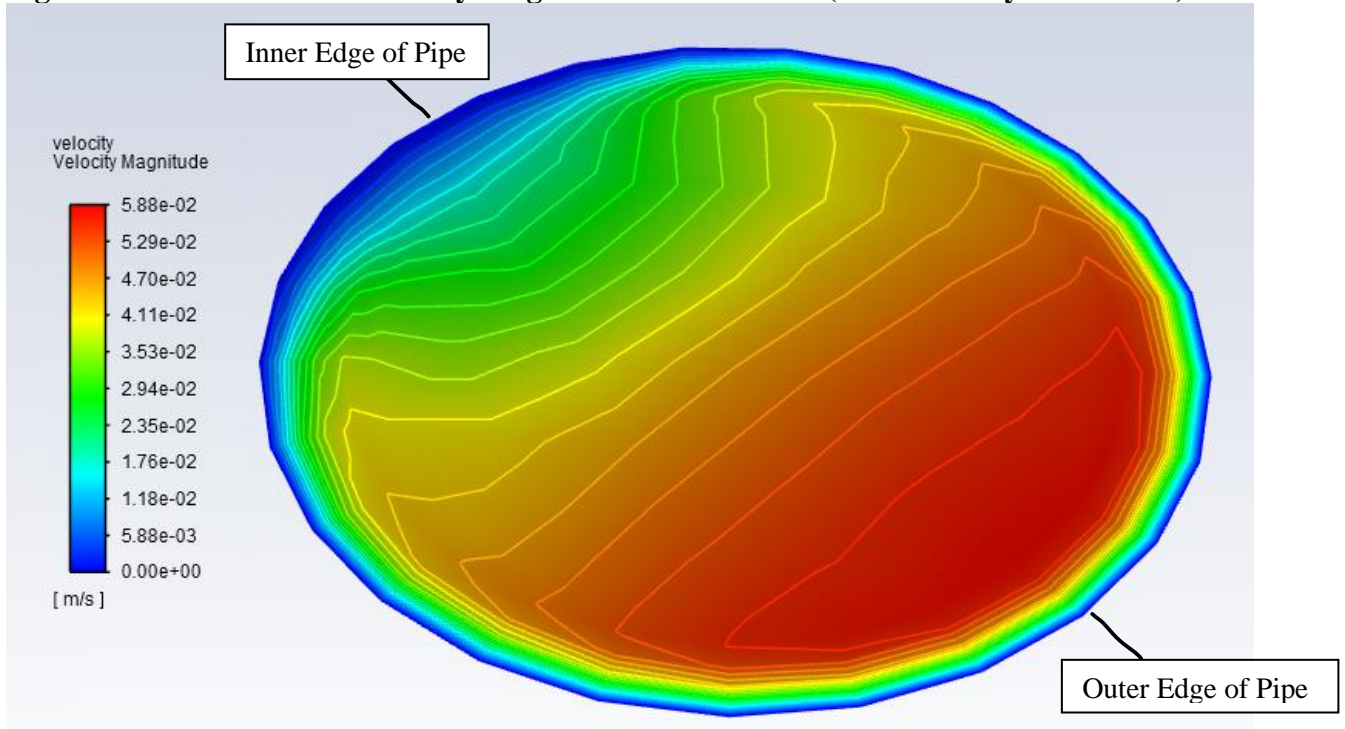
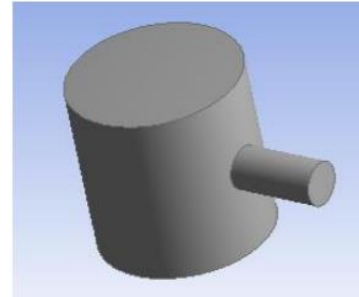


Figure 9: Contour Plot of Velocity Magnitude across Outlet (Inlet Velocity of 0.04 m/s)



Task 3:

Background: Considering a simple cylindrical chamber as shown to the right, there is only one opening at the end of the side pipe. The top and bottom plates of the main cylinder are heating panels, each supplying a uniform energy input of 10 W/m^2 . Starting from an initial state with zero velocity inside the chamber, as the air warms up, it expands and forces a flow out of the chamber. Density based solver is to be used and I have set the density of air to ideal gas. The solution to be run will be a transient one from $t=0\text{s}$ to 10s with the initial state (at $t = 0$) set to a uniform $T = 20^\circ\text{C}$, zero velocity, and zero gauge pressure inside the chamber. The initialization to be used will be standard initialization.

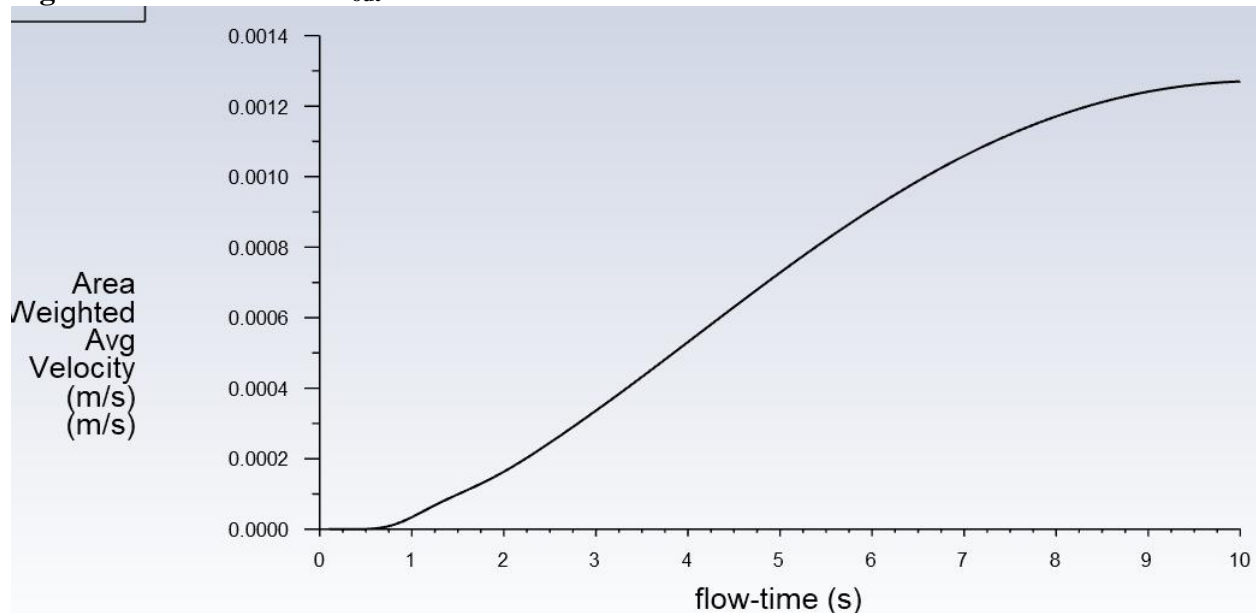


The mesh used had an element size of 1cm and the inflation was set to program controlled.

Deliverables:

(i)

Figure 10: Line Plot of V_{out} vs Time from 0s to 10s



Area-Weighted Average X Velocity (m/s)	
-----	-----
outlet	0.001269962

(ii)

Figure 11: Contour Plot of Pressure Along Vertical Plane of Symmetry

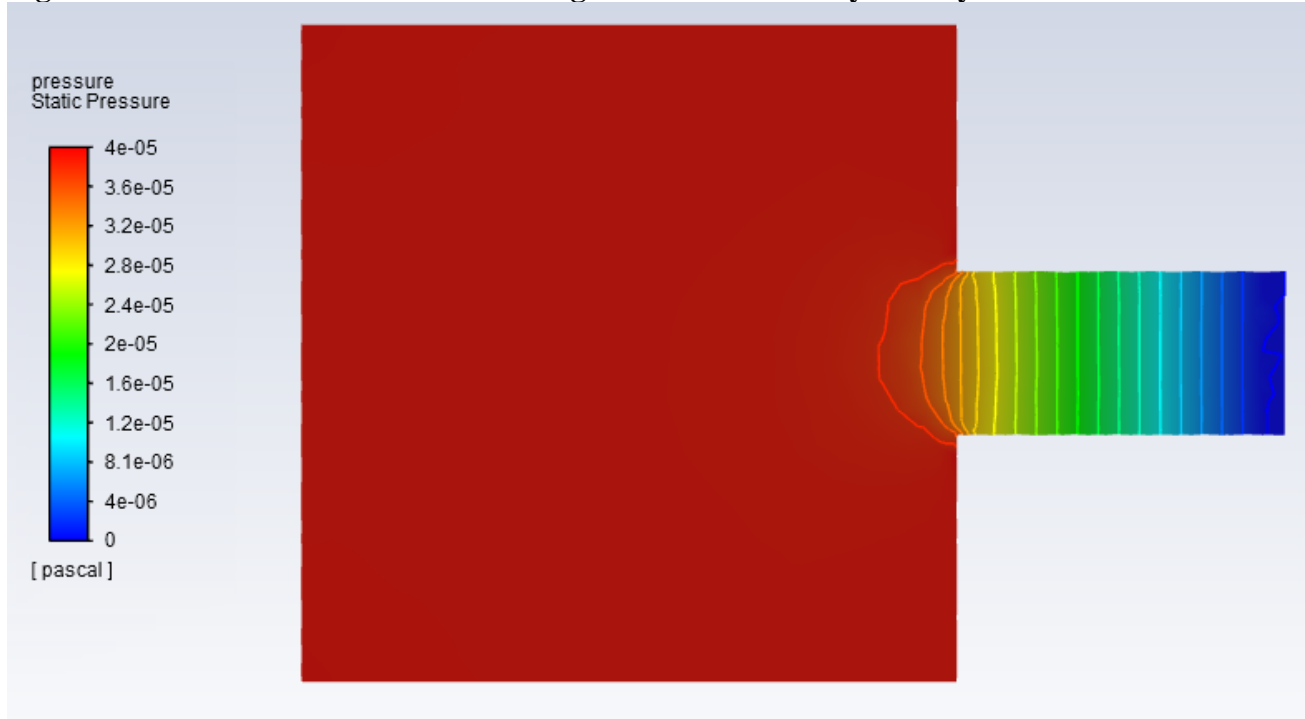


Figure 12: Contour Plot of Velocity Magnitude Along Vertical Plane of Symmetry

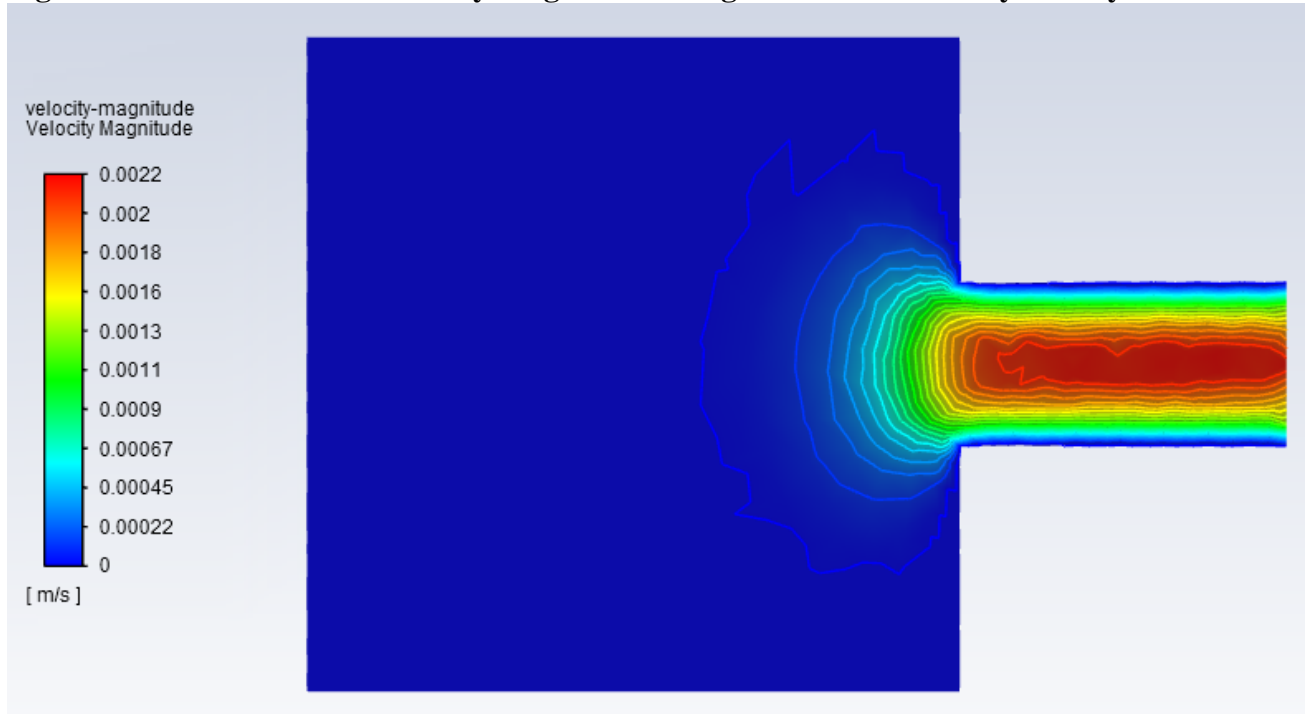
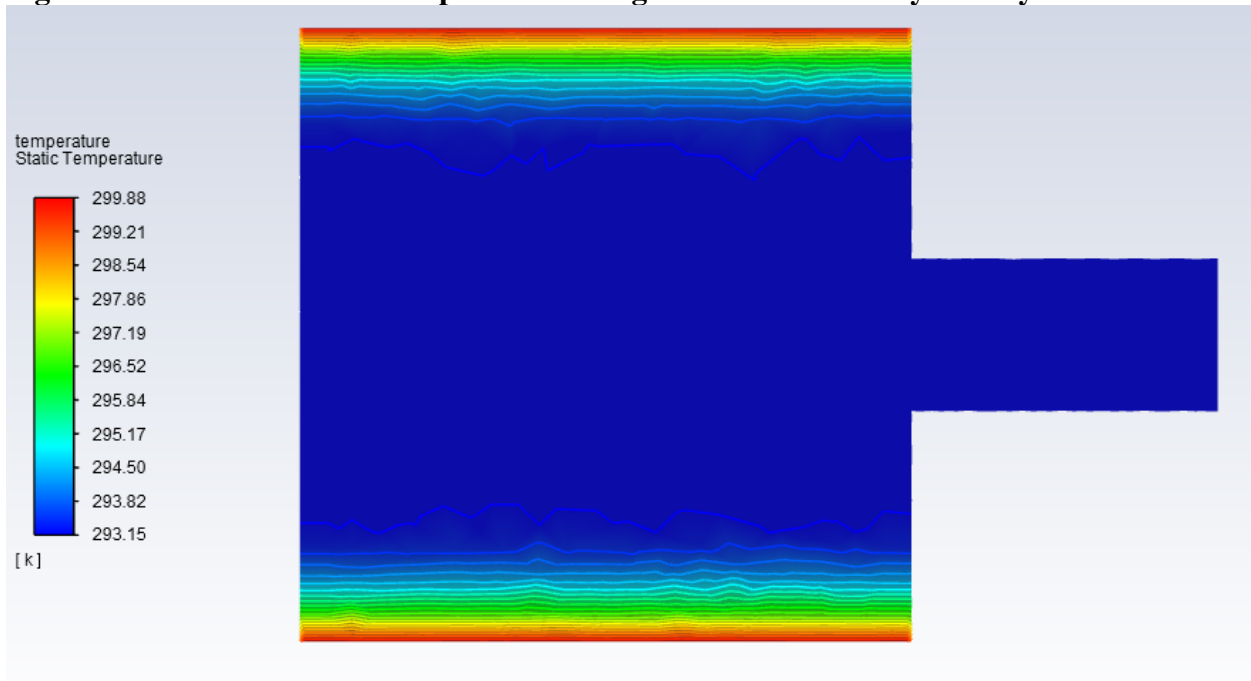


Figure 13: Contour Plot of Temperature Along Vertical Plane of Symmetry



Task 4:

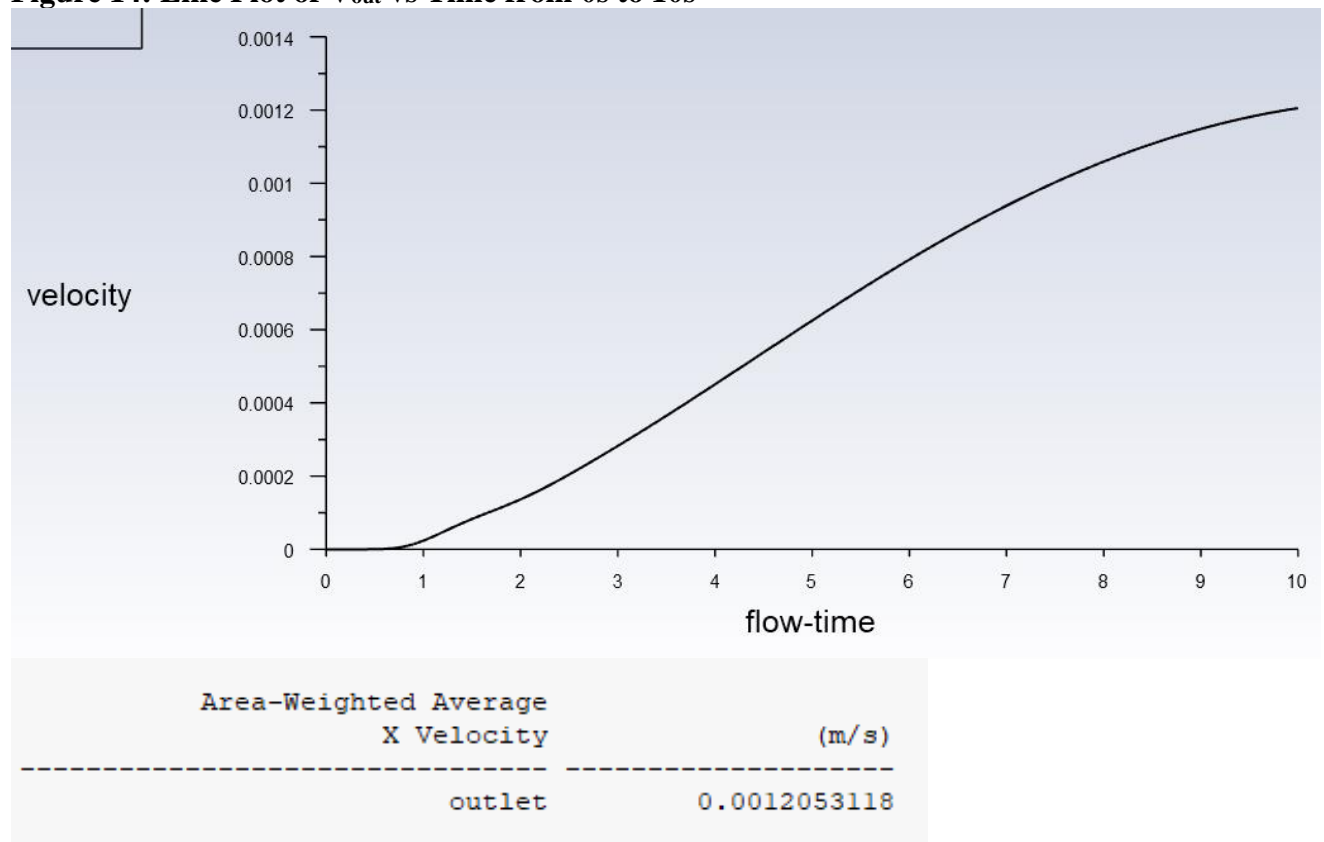
Background: The same analysis will be used in Task 4 that was used in task 3. The conditions, assumptions, and analyses are all the same. The only difference in task 4 is that the geometry used will now be a quarter of the original system. This is to be done by utilizing the two planes of symmetry found in the first geometry. The quarter of the system being used for this task is going to be the “top left” quarter.

The same meshing mechanism was used as in task 3. I implemented element size of 1 cm with inflation set to program controlled.

Deliverables: The deliverables will be the same as those demanded in Task 3 except for an additional one asking for the geometry and mesh of the modified system for the new simulation.

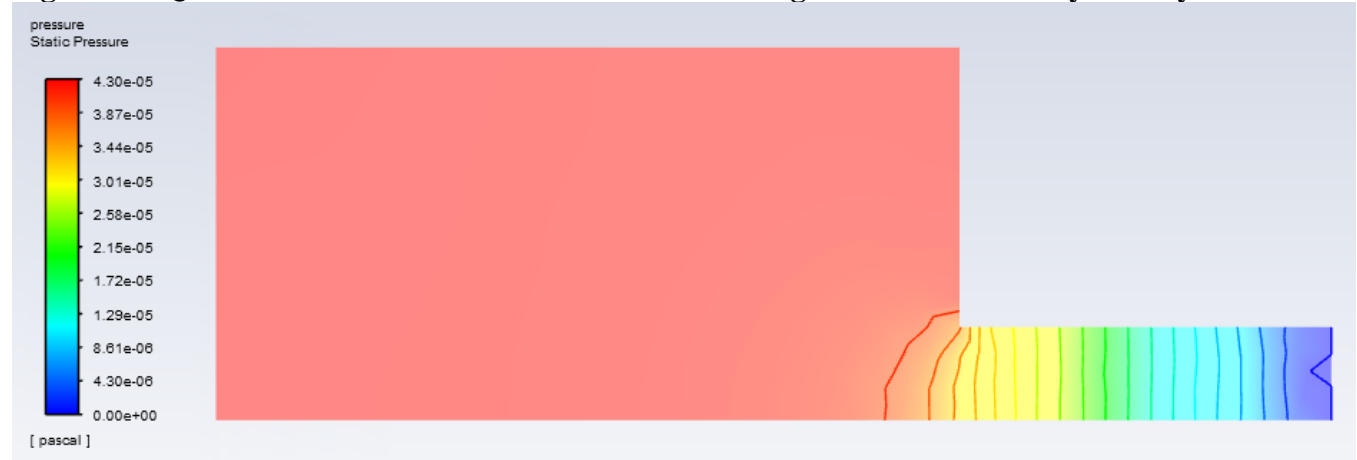
(i)

Figure 14: Line Plot of V_{out} vs Time from 0s to 10s



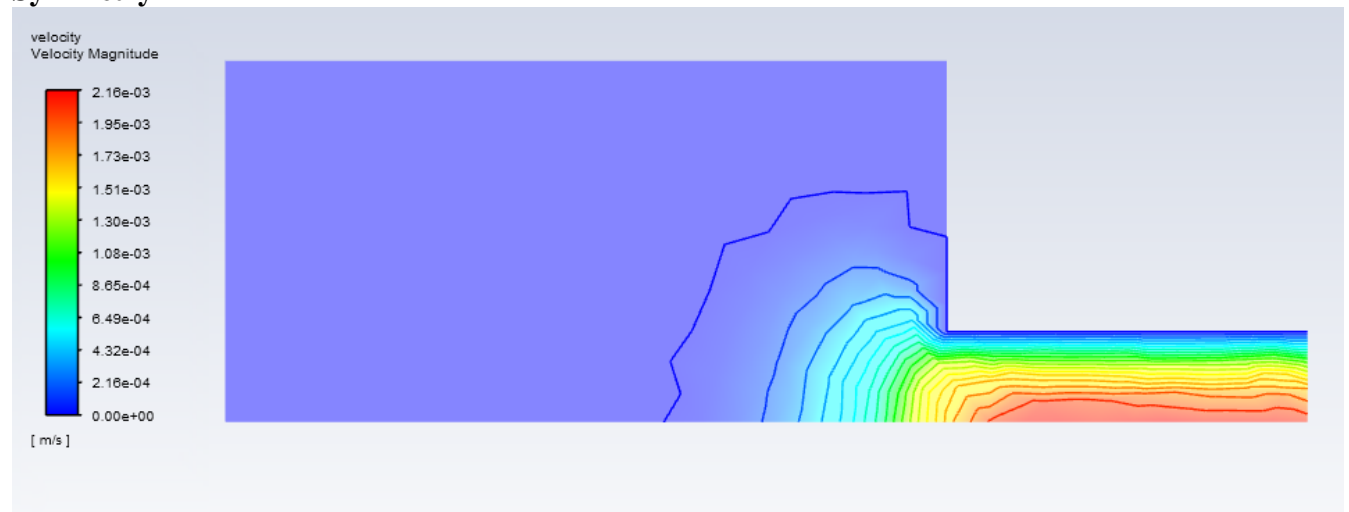
(ii)

Figure 15: Quarter Model Contour Plot of Pressure Along Vertical Plane of Symmetry



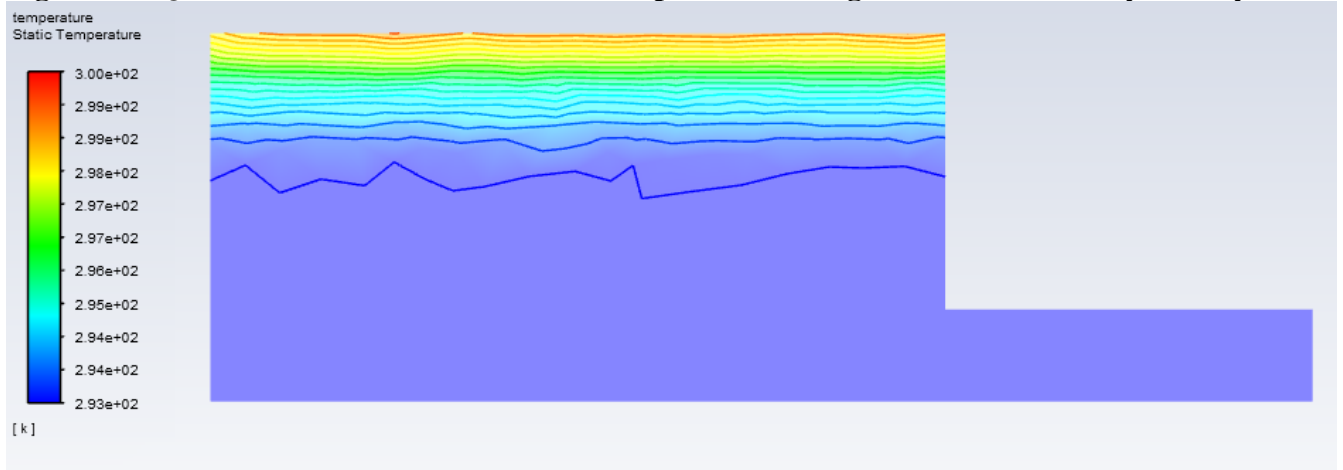
We see that the contour for pressure is almost the same contour as the one for the full model. The behavior is essentially the same with only a very slight difference for the pressure inside the main tank.

Figure 16: Quarter Model Contour Plot of Velocity Magnitude Along Vertical Plane of Symmetry



We see that for the velocity magnitude plot, the behavior shown is, again, essentially the same behavior as the full model. The contour color bar range is also pretty much consistent and the maximum velocity is approximately the same as well.

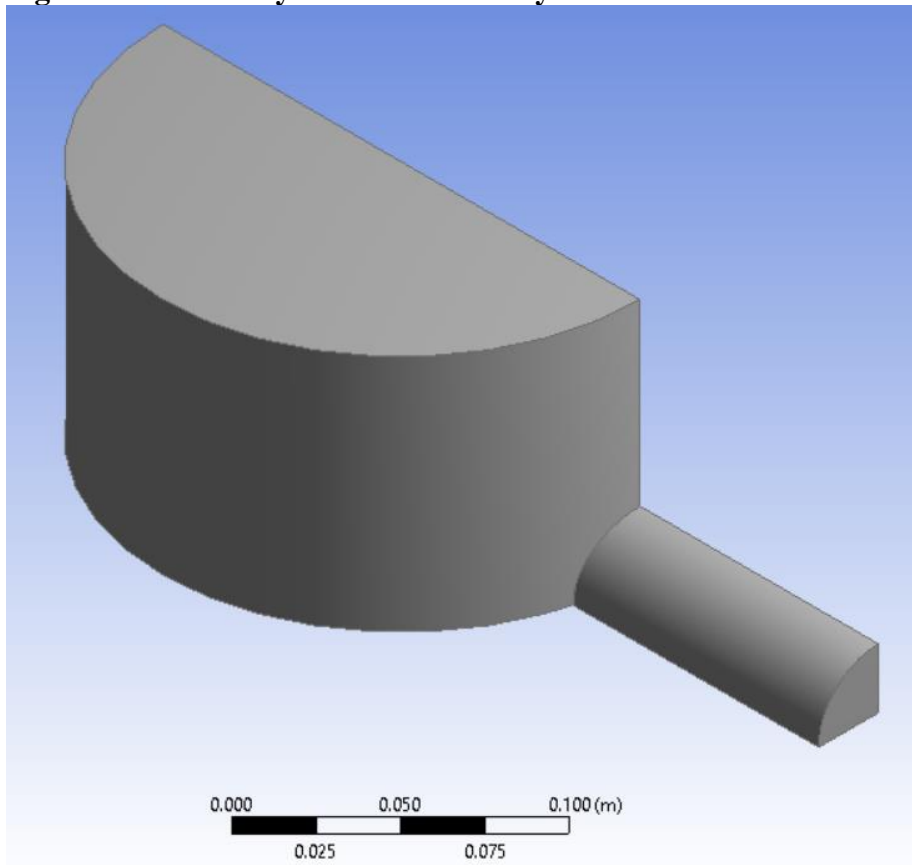
Figure 17: Quarter Model Contour Plot of Temperature Along Vertical Plane of Symmetry



We see that for the static temperature, the plot is again essentially the same as the one for the whole model. The color bar ranges are the same and the same general trend in terms of the temperature gradient when comparing this contour to the whole model one.

(iii)

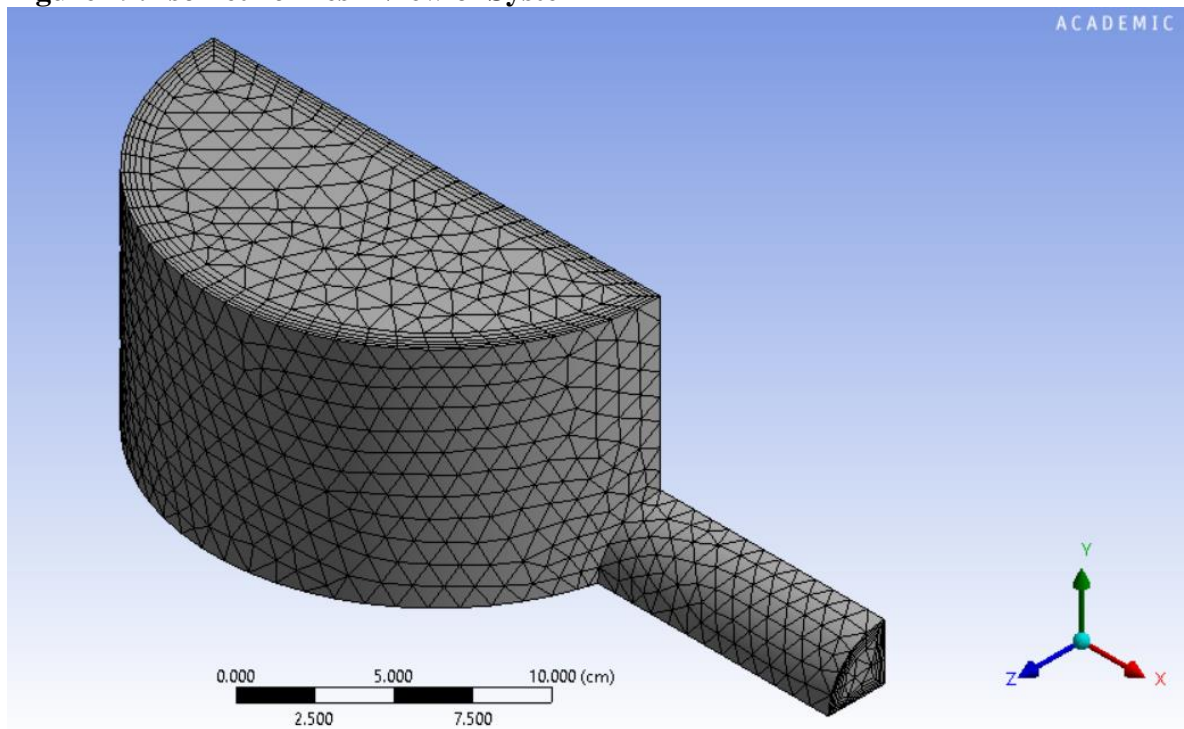
Figure 18: Geometry of the Modified System



The symmetry condition was made by using the symmetry feature in design modeler. I created named selections calling the surfaces “symmetry”. Starting with the overall model, I used

the symmetry conditions to “slice” the model in half along both planes of symmetry. I also manually named a new surface for the “wall” that is the exterior face of the quarter model.

Figure 19: Isometric Mesh View of System



The same element size (1cm) was used for this quarter circle model of the entire system in order to keep consistency with the meshing. The same general conditions were also kept (Inflation set to program controlled and no additional meshing techniques)