

Applied CFD Project 1

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Task 1

The hot water tank shown in Fig 1 is used for analysis of cool water flow with the heat from a hot plate at the bottom. For all tasks, the temperature of the water entering the inlet is 30°C. This task shows an analysis of how the steady-state temperature of the outflow is affected by the setup with gravity in the negative z-direction.

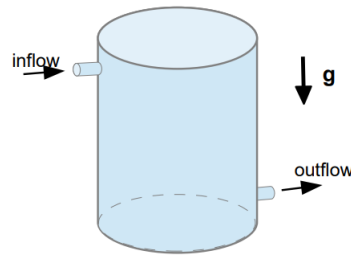


Figure 1: Tank geometry with gravity in the negative z-direction

To calculate the value of the output temperature, a user-defined field function must be created to calculate the surface integral at the outflow. This is defined by an averaged temperature:

$$T_{out} = \frac{\iint v_n T dA}{\iint v_n dA} \quad (1)$$

The outlet temperature is calculated from the output of Fluent's surface integrals of the numerator and denominator of this equation.

Integral	
custom-function-0	

outflow	0.0096265952
Integral	
Y Velocity	(m/s) (m2)

outflow	3.0739888e-05

Figure 2: ANSYS Fluent surface integral output for Task 1

$$T_{out} = 313.1630K$$

The following figures show the mesh refinement done in the analysis of the water tank, contour plots of the temperature and velocity magnitude on the plane of symmetry, and a plot of the stream lines.

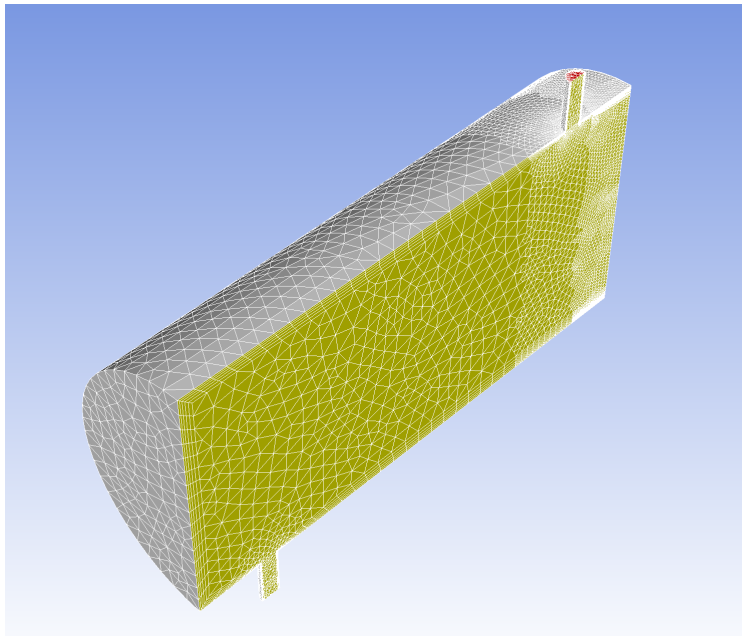


Figure 3: Mesh refinement for the bottom surface of the water tank

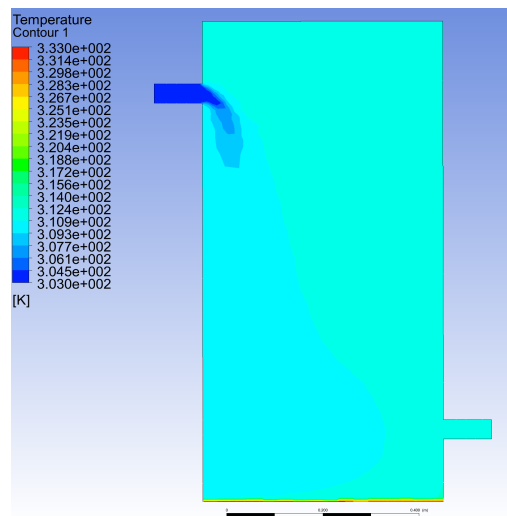


Figure 4: Contour plot of temperature in the plane of symmetry Task 1

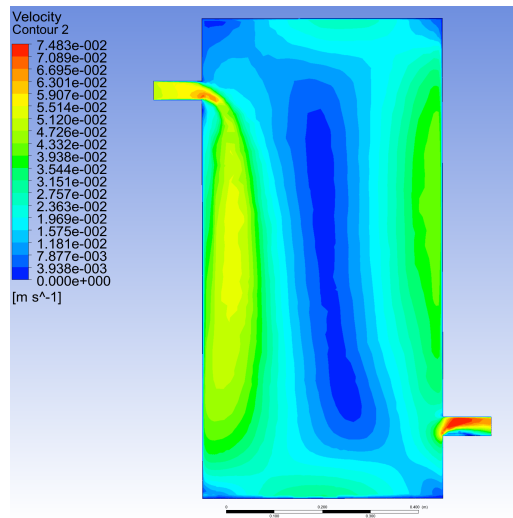


Figure 5: Contour plot of velocity magnitude in the plane of symmetry Task 1

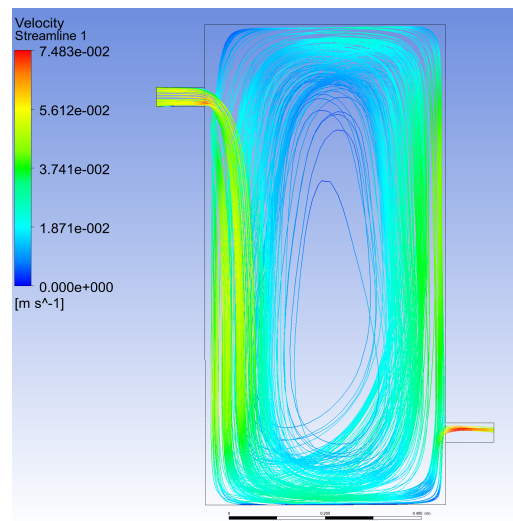


Figure 6: Plot of stream lines Task 1

Task 2

Task 2 repeats the analysis of Task 1 with gravity oriented so that gravity is pointed in the same direction normal to the surface of the outflow. In the contour plots, this geometry is flipped upside down, so that the outflow is on top and gravity points in the positive y-direction. This follows with the orientation of the original geometry created, so the directions are properly set up.

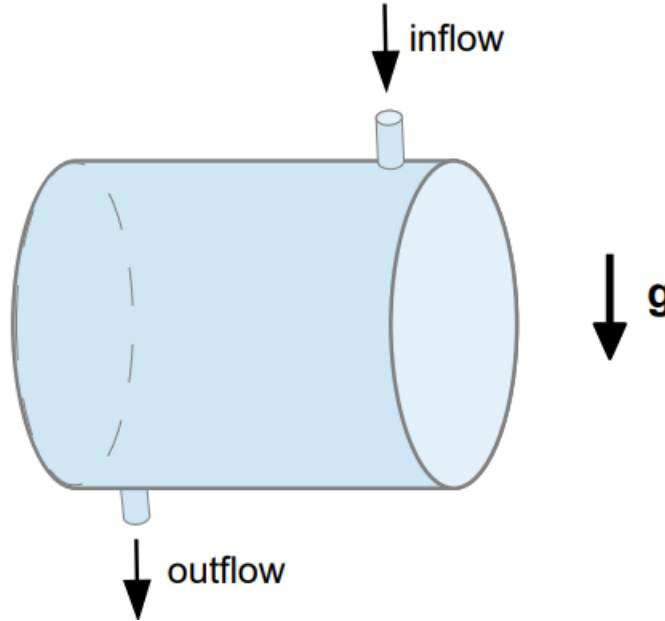


Figure 7: Geometry of water tank with gravity in the positive-y direction

Similarly to Task 1, the value of outlet temperature is calculated with the same definition of T_{out} , and the contour plots of temperature and velocity and plot of stream lines are also shown in the following figures

Integral	
custom-function-0	

outflow	0.0096990018
Integral	
Y Velocity (m/s) (m2)	

outflow	3.1220622e-05

Figure 8: ANSYS Fluent surface integral output for Task 1

$$T_{out} = 310.6601K$$

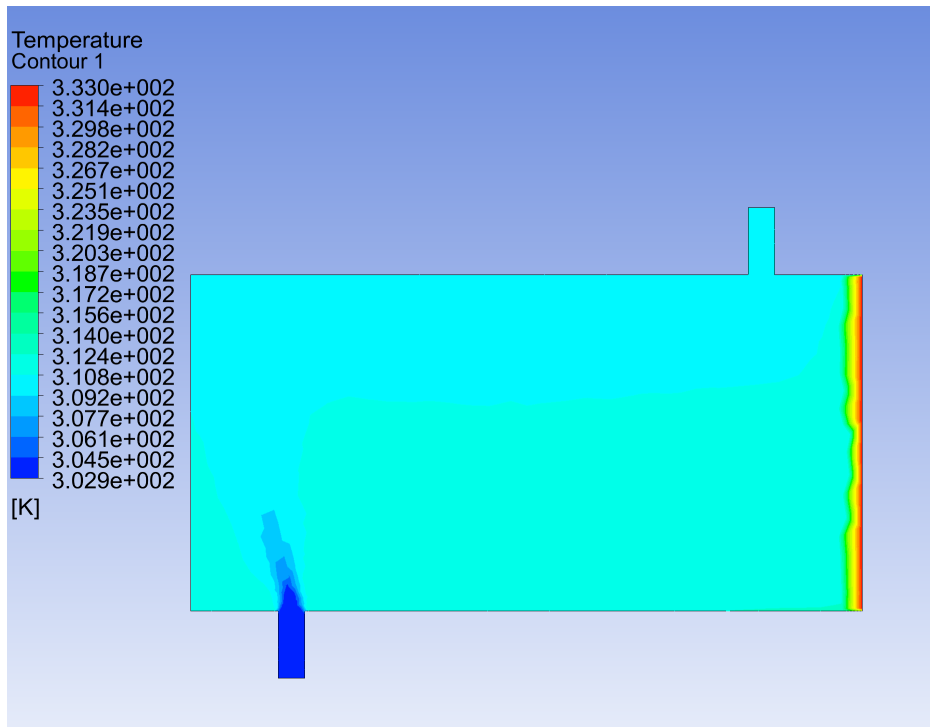


Figure 9: Contour plot of temperature in the plane of symmetry Task 2

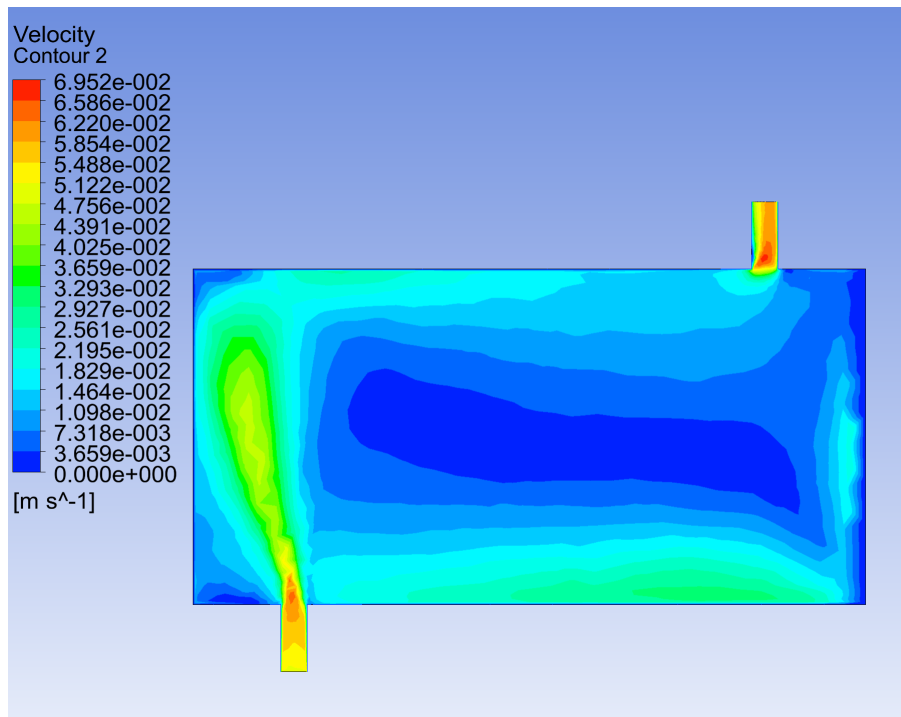


Figure 10: Contour plot of velocity magnitude in the plane of symmetry Task 2

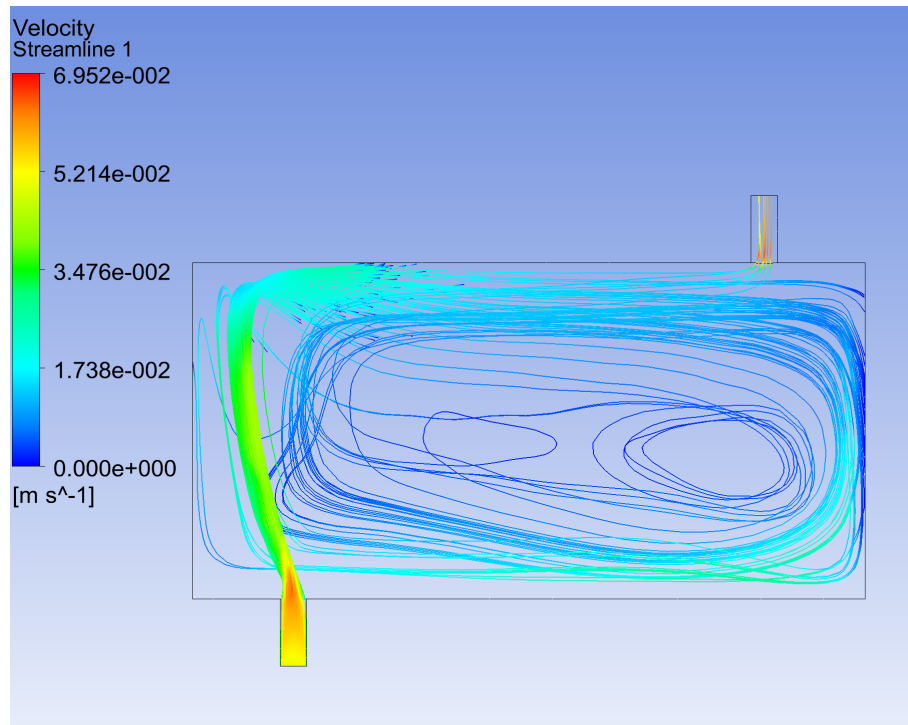


Figure 11: Plot of stream lines Task 2

Task 3

Task 3 repeats the analysis of Task 1 with gravity entirely removed from the calculations. The value of outlet temperature is calculated with the same definition of T_{out} , and the contour plots of temperature and velocity and plot of stream lines are also shown in the following figures

Integral	
custom-function-0	

outflow	0.0093575943
Integral	
Y Velocity	(m/s) (m2)

outflow	3.0715844e-05

Figure 12: ANSYS Fluent surface integral output for Task 1

$$T_{out} = 304.6504K$$

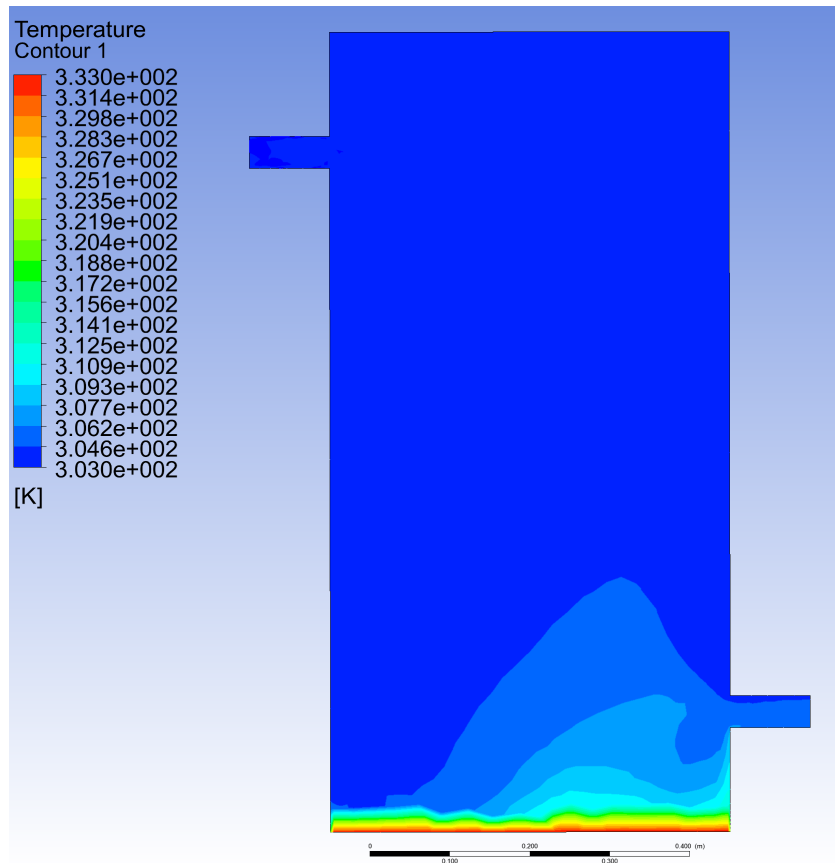


Figure 13: Contour plot of temperature in the plane of symmetry Task 3

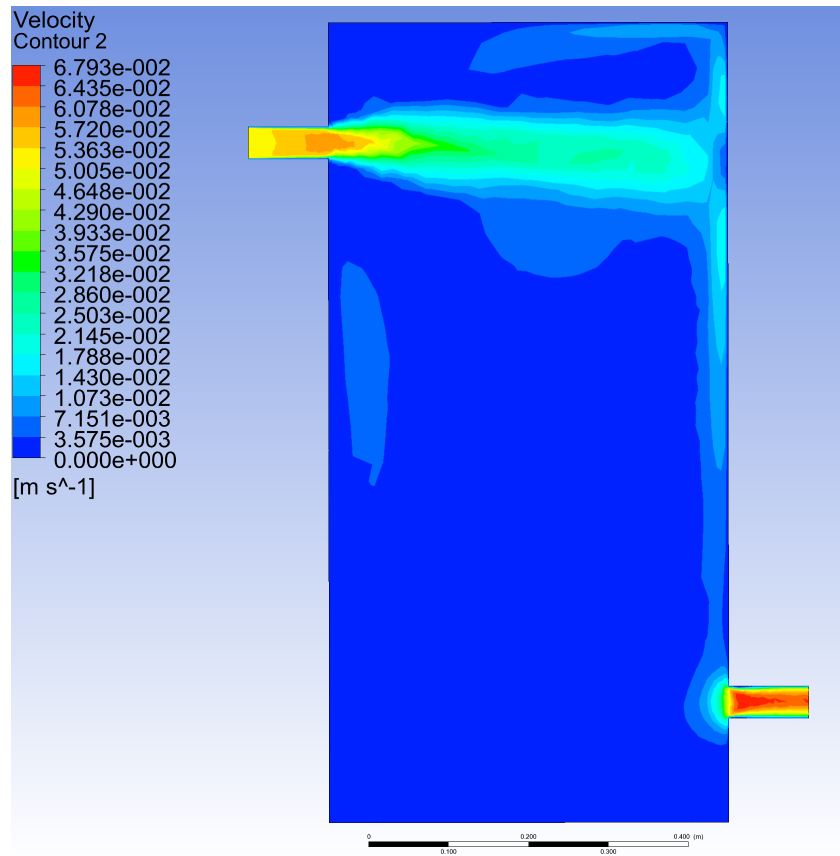


Figure 14: Contour plot of velocity magnitude in the plane of symmetry Task 3

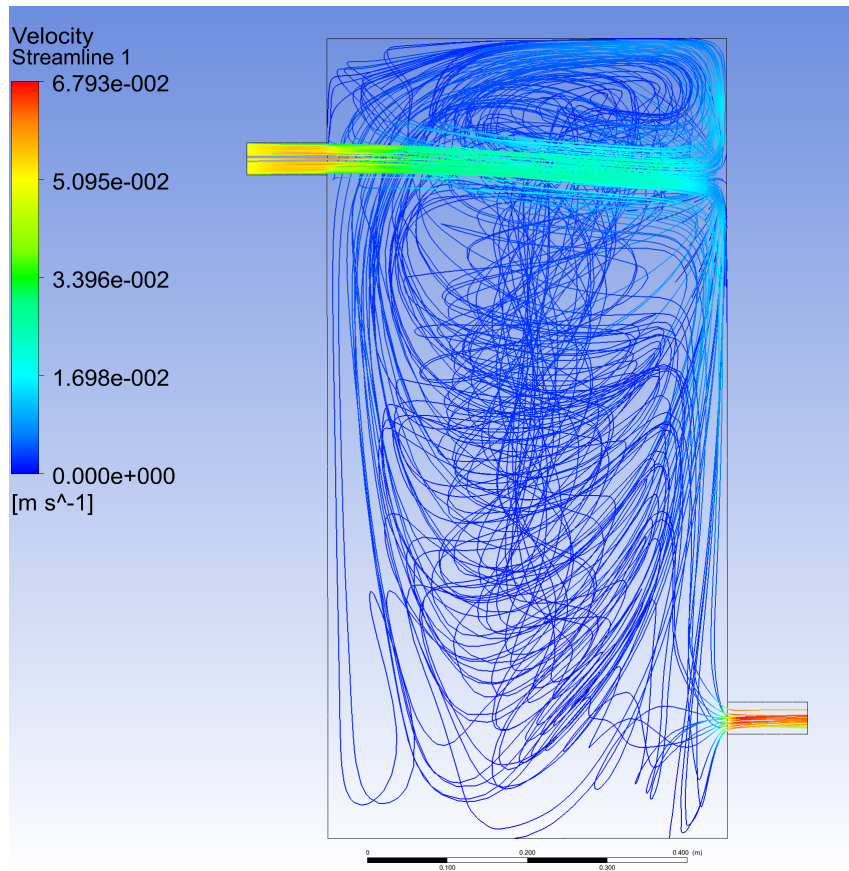


Figure 15: Plot of stream lines Task 3

The following table shows the T_{out} values for Tasks 1 - 3 for comparison.

Table 1: Results of Surface Integrals

	Temperature (K)
Task 1	313.1630
Task 2	310.6601
Task 3	304.6504

Clearly, the temperatures decrease every time. Since the force of gravity in Task 1 directs more of the flow from the inlet towards the bottom plate, more heated water flows to the outlet, which could account for the higher temperature. The velocity contour plots of Tasks 2 and 3, where gravity points toward the outlet or is not accounted for, show that the water near the bottom of the tank has a lower velocity profile, and thus interacts less with the water leaving the tank. This results in less heat transfer into the water, and thus the outlet temperature decreases.

Task 4

Now the same parameters as Task 1 are analyzed using a transient solution. The simulation is run at least until the difference between the steady state solution of Task 1, T_s , and the time-dependent outlet temperature is less than 0.3 K. The simulation is then repeated with the water temperature of the tank initialized at 40°C instead of 30°C.

The following figure shows the plots of these temperatures with respect to time. Clearly, both simulations show convergence to the steady state solution found in Task 1.

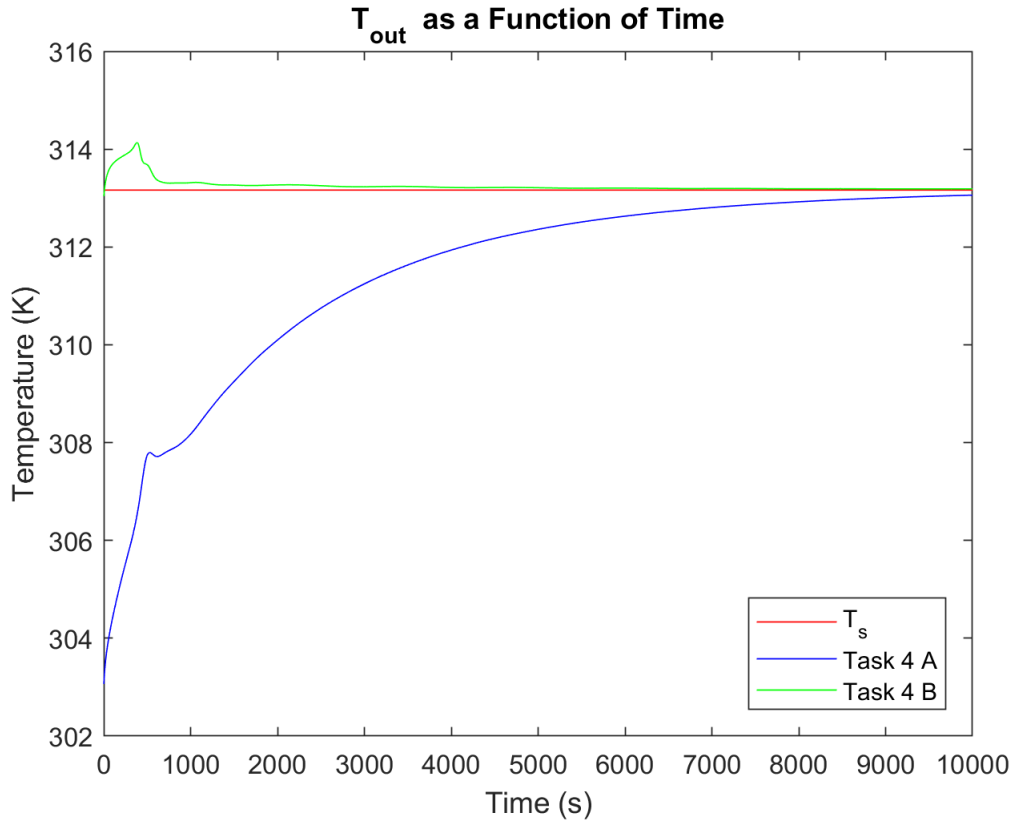


Figure 16: Outlet temperatures from Tasks 1 and 4

Task 5

For the same settings as Task 1, a Flux Report is generated to calculate the total rate of heat transfer over the bottom plate. This value is divided by the half area of the bottom plate since the half geometry has been used with the assumed symmetry. This value is used in a new simulation where the constant temperature boundary condition of the base is replaced with an imposed constant heat flux boundary condition.

Total Heat Transfer Rate	(w)
base	1300.4221
Net	1300.4221

Figure 17: ANSYS Fluent heat transfer rate output for Task 5

The calculated rate of heat transfer from this value is:

$$q = 13246 \frac{W}{m^2}$$

From the surface integral calculations as described in the definition of the outlet temperature used in Task 1:

Integral custom-function-0	
outflow	0.009625688
Integral Y Velocity	(m/s) (m2)
outflow	3.0738695e-05

Figure 18: ANSYS Fluent surface integral output for Task 5

$$T_{out,task5} = 313.1782K$$

$$T_{out,task1} = 313.1630K$$

Clearly, the temperatures produced by the simulation are nearly identical, which shows that either the imposed heat flux or imposed temperature is adequate for defining the heat input into the system.

Finally, the following figure shows the contour plot of the temperature of the bottom plate with the imposed heat flux boundary condition.

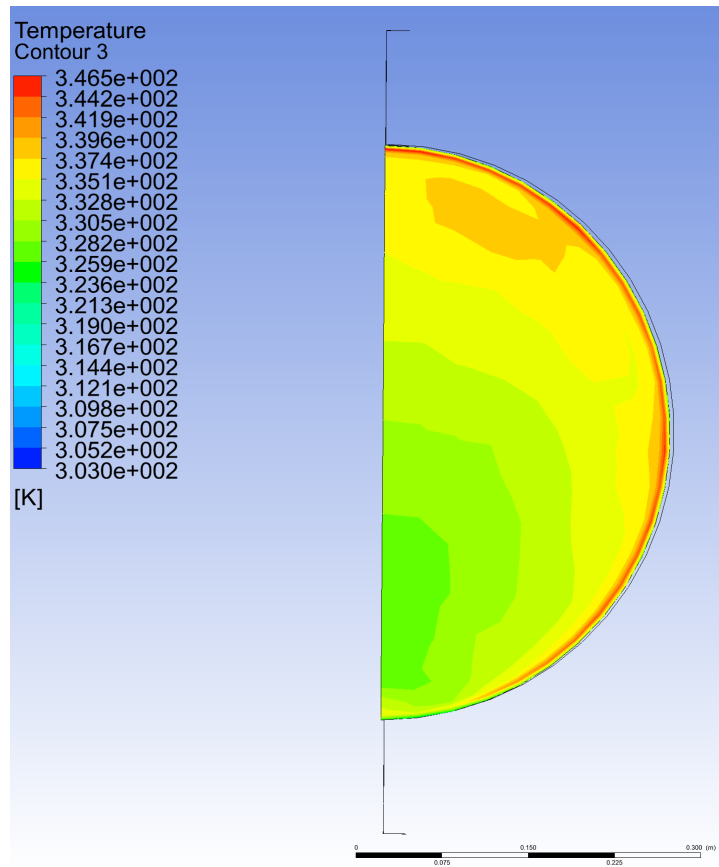


Figure 19: Contour plot of temperature of the base Task 5