Applied CFD Project-1

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NO COLLABORATION

In this case, we begin by modeling a cylindrical-shaped water heater using SolidWorks software, keeping the design simple. Subsequently, we import the geometry into Ansys Workbench for further analysis. All units are assumed to be consistent with the MKS unit system. The orientation of the figure matches the attached problem statement, where the cylinder's axis aligns with the Y-axis, and the origin is at the center of the bottom surface.

We designate three named surfaces: the inlet, the outlet, and the bottom. The inlet is configured as a velocity-inlet with a constant velocity of 0.06 m/s and a temperature of 288.15 K (15°C). The outlet is set as an outflow boundary condition, while the bottom is defined as a wall with a constant temperature of 318.15 K (45°C).

Deliverable 1:

(a) The required deliverables are below in sequential order

D1

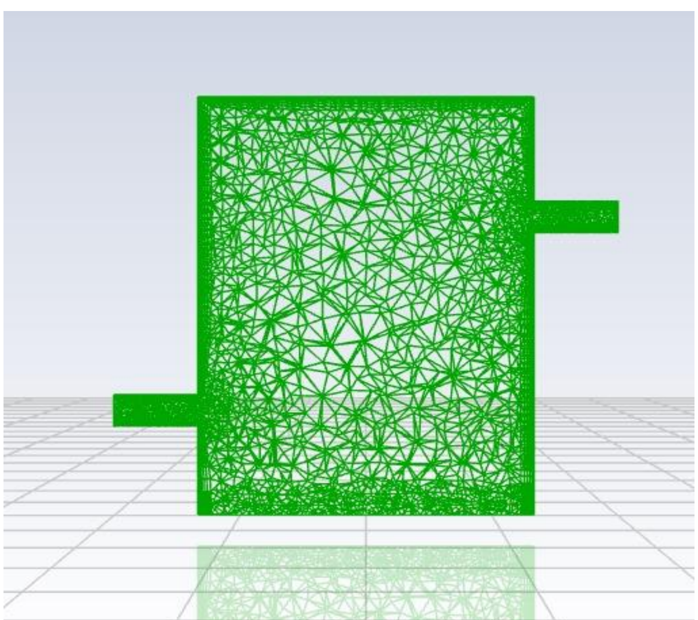


Figure D1 – Plot of Mesh Along Plane of Symmetry

Operating Temperature :- 30 °C 323 K

Operating Density:- 994.02 Kg/m3

Thermal Expansion Coefficient:- 0.000345 K-1

Time size: 0.5s iterations 120 for 1 minutes

Time size: 1s iterations 300 for 5 minutes

D2. :- Contour plots of the y-velocity (not to be confused with velocity magnitude) and temperature in
the plane of symmetry for the solution at t = 1 minute.

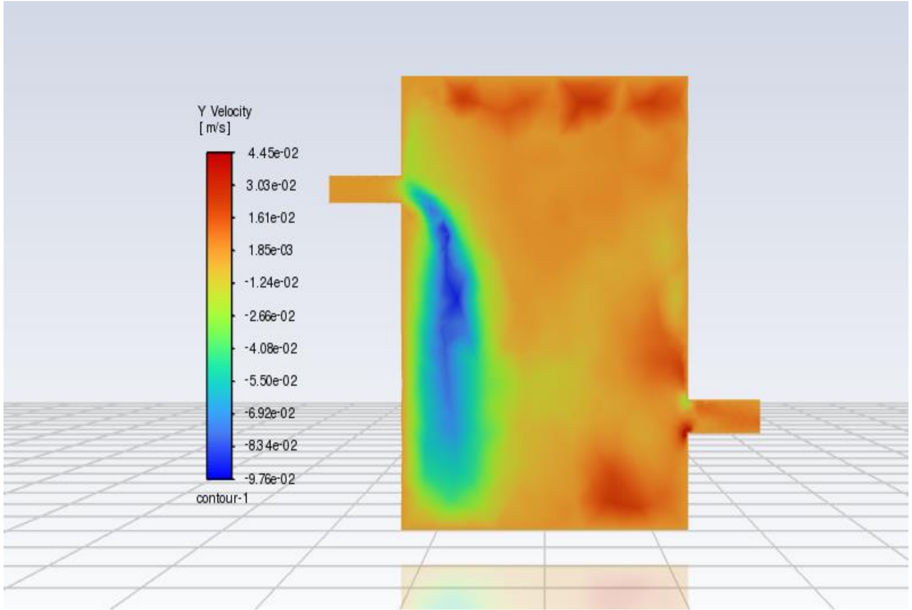


Figure D2 Y-Velocity contour plot in the Plane of Symmetry

D3 :- Contour plots of the y-velocity and temperature in the plane of symmetry for the solution at t = 5 minutes.

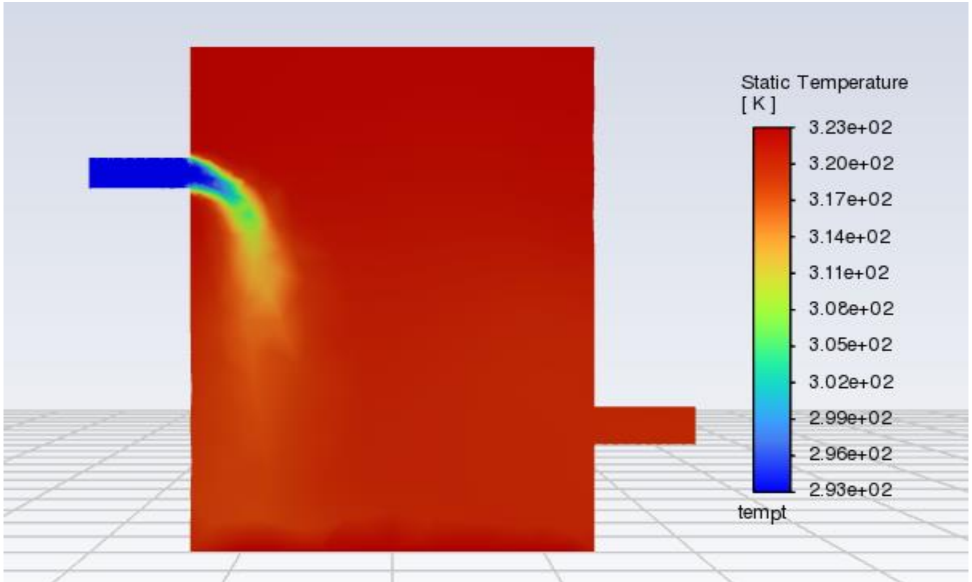
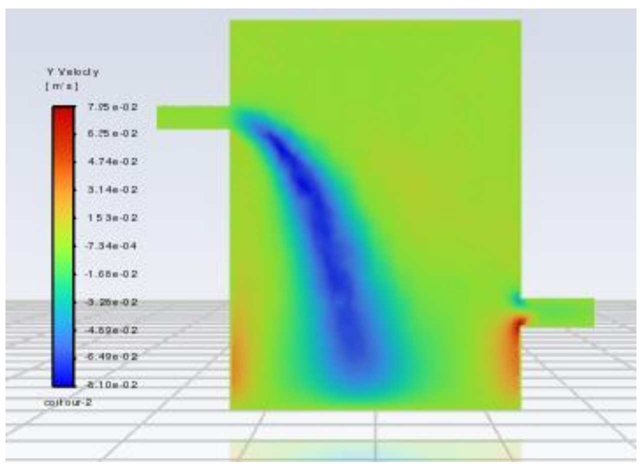
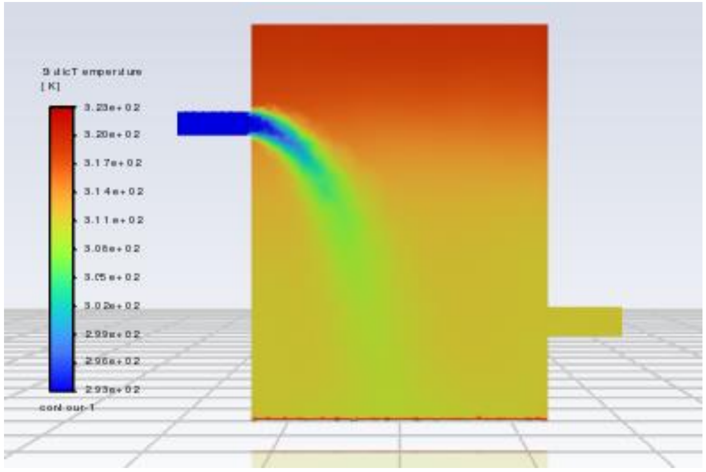


Figure D3 Temperature Contour Plot in the Plane of Symmetry

<u>Deliverables 3</u>



Contour plot showing the Y component velocity along symmetric half plane at t= 5 minutes



Contour plot showing the static temperature along symmetric half plane at t=5 minutes

D4:- The value of average temperature (TAVE as defined in Eq. (1)) at t = 5 minutes. In addition, a line plot of the average temperature, TAVE, as a function of time over the range of 0 ≤ t ≤ 5 minutes.

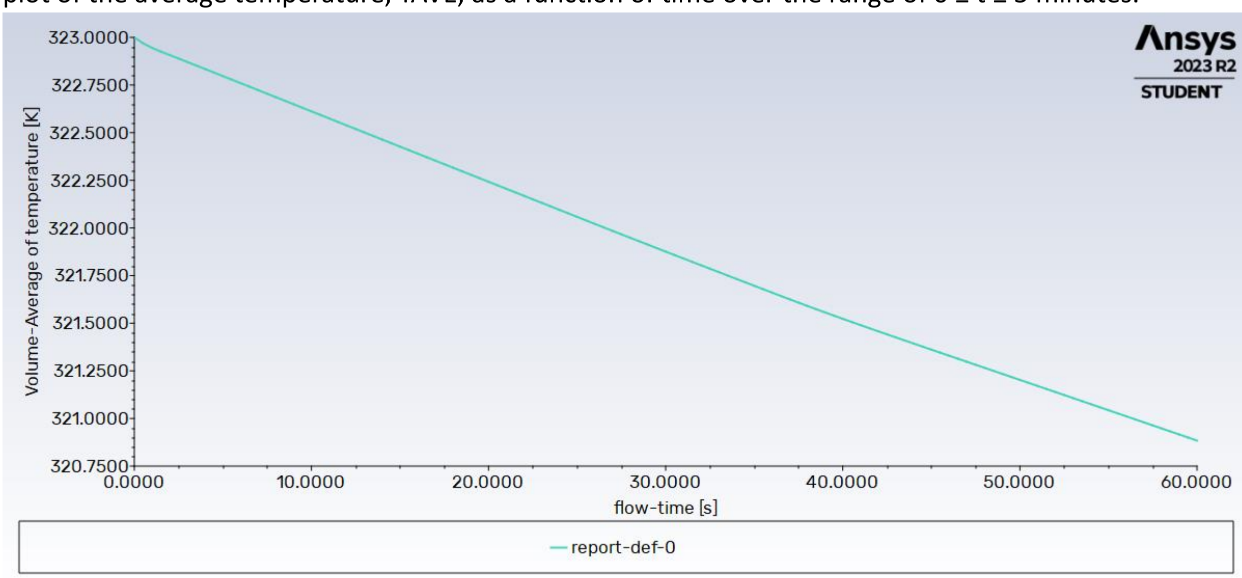


Figure D4. Line Plot of Outlet Temperature vs. Number of Iterations

Line plot of the Average temperature as a function of the time

The Average temperature value T avg = 326.152.

Task 1b. Transient solution with Moon gravity:-

Repeat the simulation in Task 1a, except changing gravity in y-direction from –9.81 to –1.62ms2. (This is the gravity at the surface of the Moon.) Run the simulation to at least t = 1 minute. The deliverables are.

(D5) Contour plots of the y-velocity and temperature in the plane of symmetry for the solution at t = 1 minute.

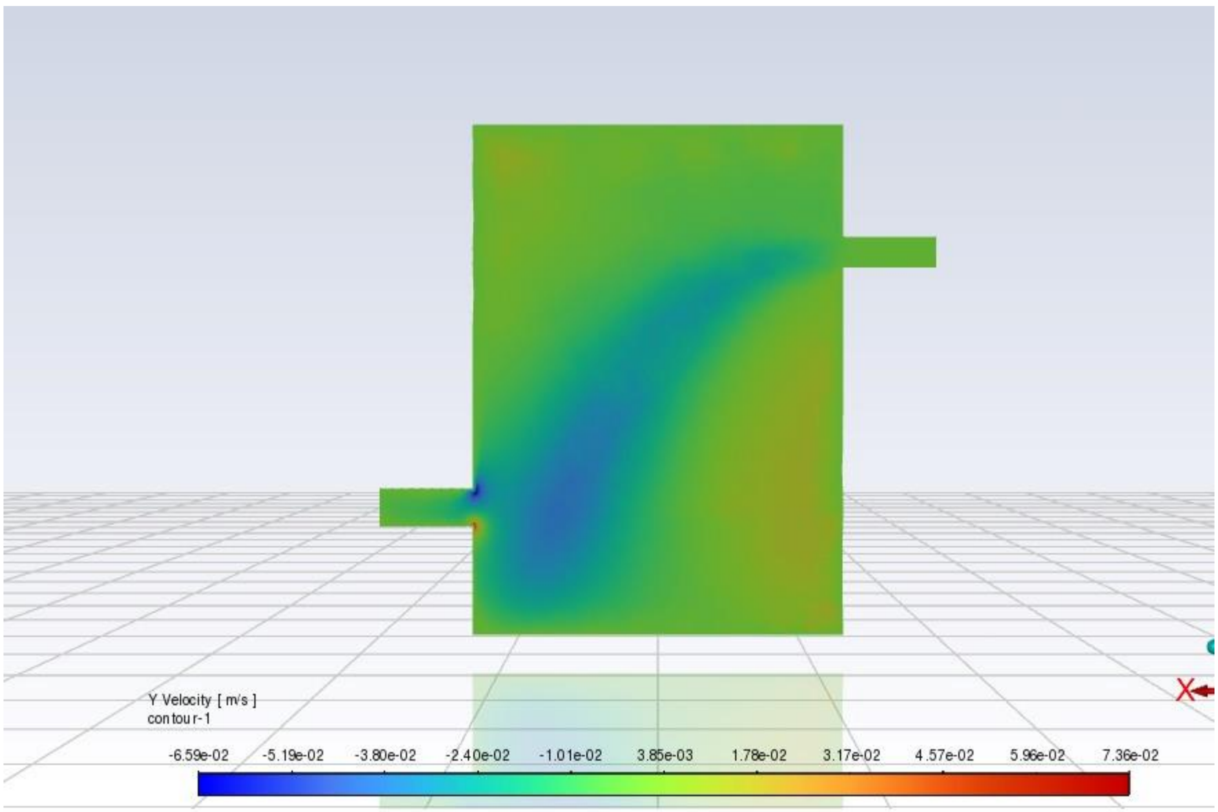


Figure D5 Y-Velocity Contour Plot in the Plane of Symmetry

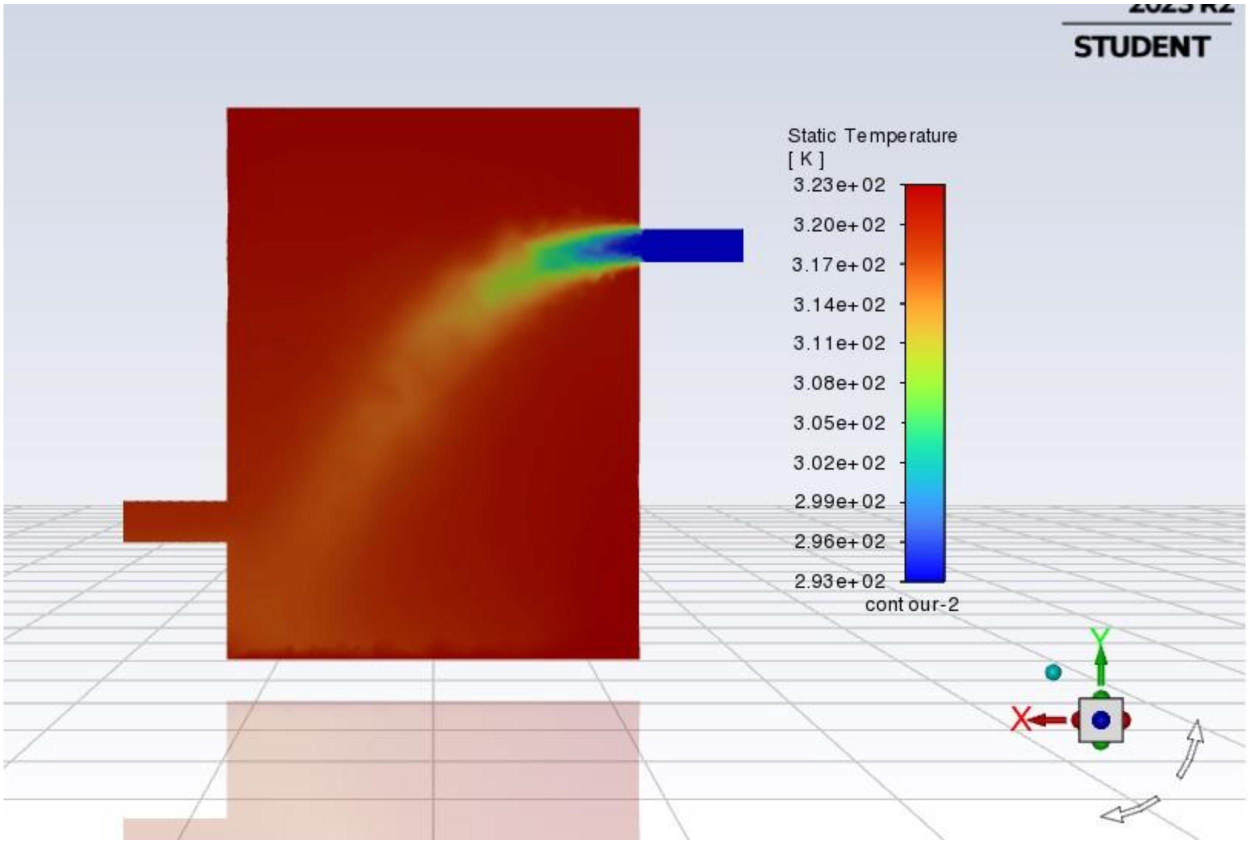


Figure D6 Temperature Contour Plot in the Plane of Symmetry

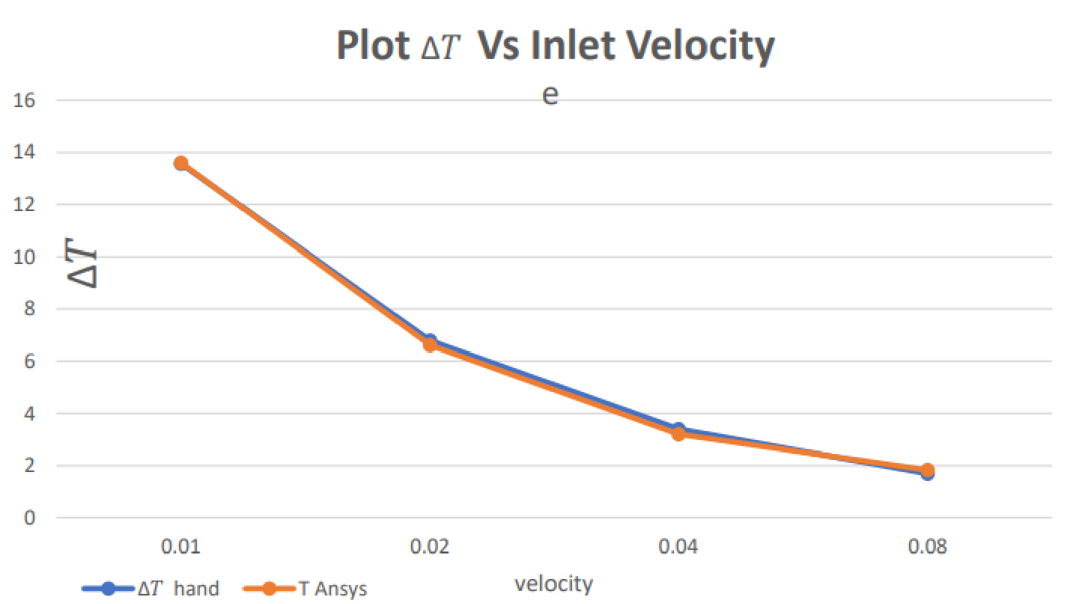
Task 2 :- Flow with heated wall

D6 :- In this phase of the analysis, it's important to note that the inlet temperature, Tin, remains constant at 300 K throughout these simulations. The variable ΔT (temperature difference) is defined as $Tout - Ti$n, where $Tout$ represents the outlet temperature. By configuring an outlet report variable to calculate the area-averaged temperature, we can quantify the temperature increase across the spiral pipe heater for each simulation case. Running multiple simulations with varying inlet velocities enables us to establish the relationship between inlet velocity and heating performance. Using the averaged outlet temperature as the convergence metric ensures that each case reaches a steady-state, mesh-independent result.

As anticipated, the trend of increasing temperature difference with lower velocity is observed. Slower flow rates allow for more effective heat transfer to the fluid, resulting in a greater temperature rise. This parameterized analysis provides valuable insights into the thermal and hydraulic characteristics of the spiral pipe heater.

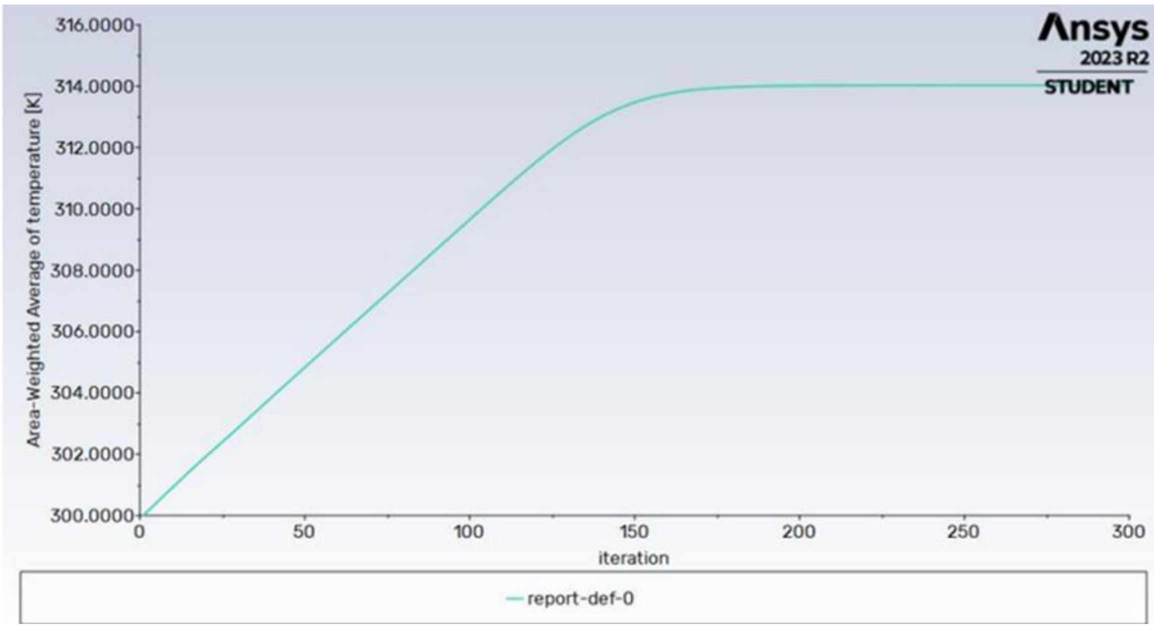
Excel Sheet:-

Velocities	ΔT (hand calculation)	ΔT (Ansys)
0.01	13.59	13.63
0.02	6.789	6.59
0.04	3.389	3.2
0.08	1.689	1.82

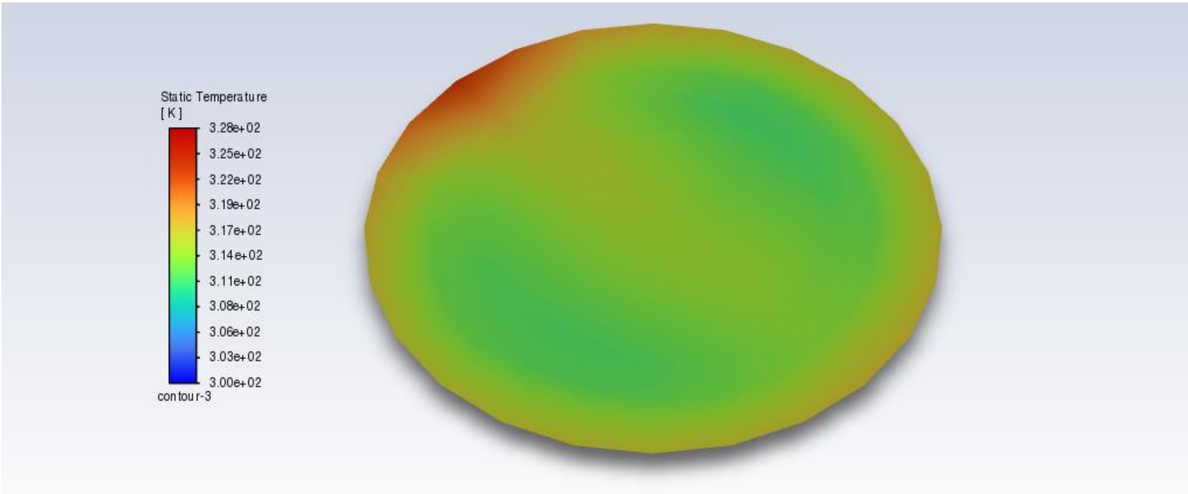


D7.

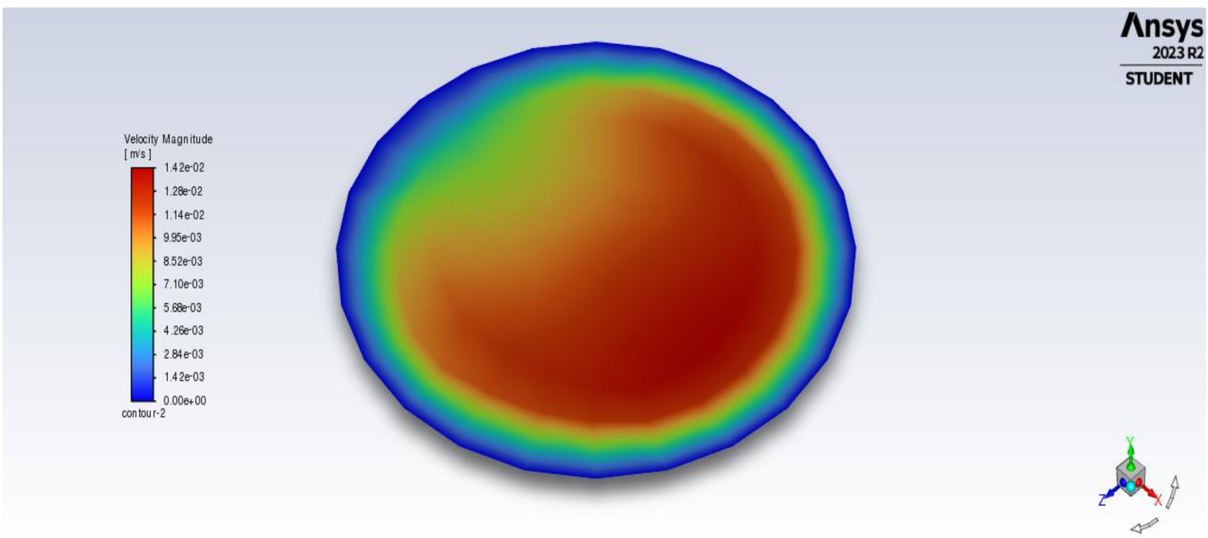
For the case with inlet velocity = 0.01 m/s only, a line plot of Tout as a function of the number of iterations



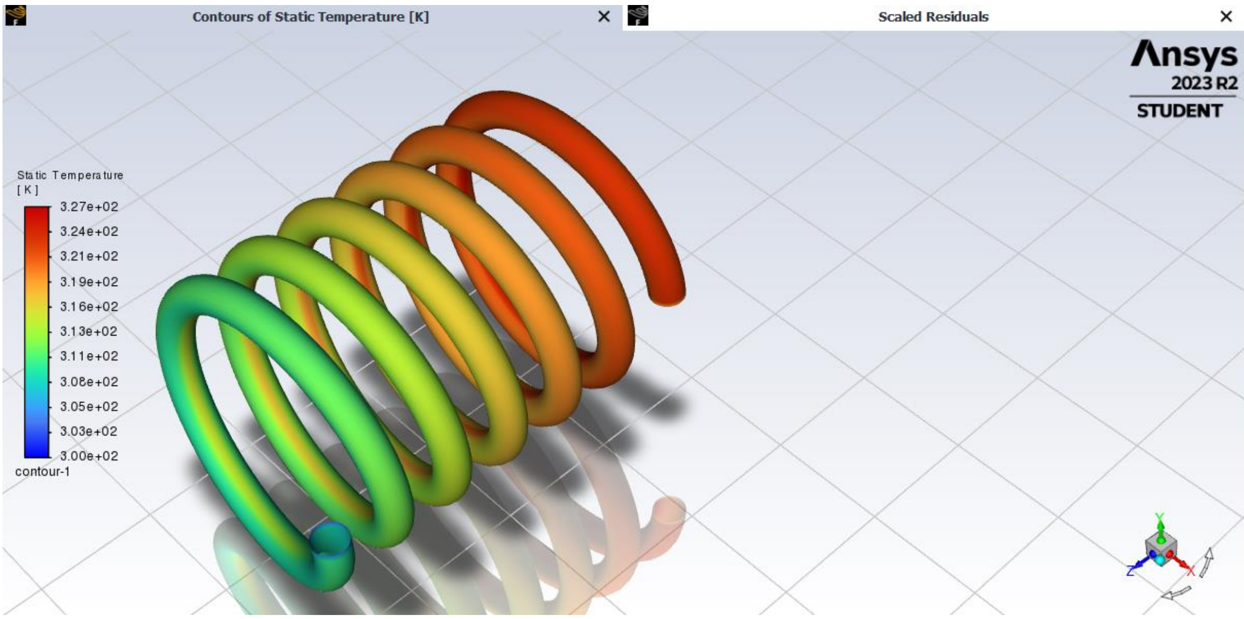
D8:- For the case with inlet velocity = 0.01 m/s only, contour plots of temperature and velocity magnitude over the circular opening of outlet. Please indicate the inner and outer edges of the pipe in the contour plots. In addition, a contour plot of temperature for the outer boundary of the whole system (the “skin” of the helix), in isometric view.



Contour plot of static temperature over the outlet



Contour plot of velocity magnitudes over the outlet cross-section

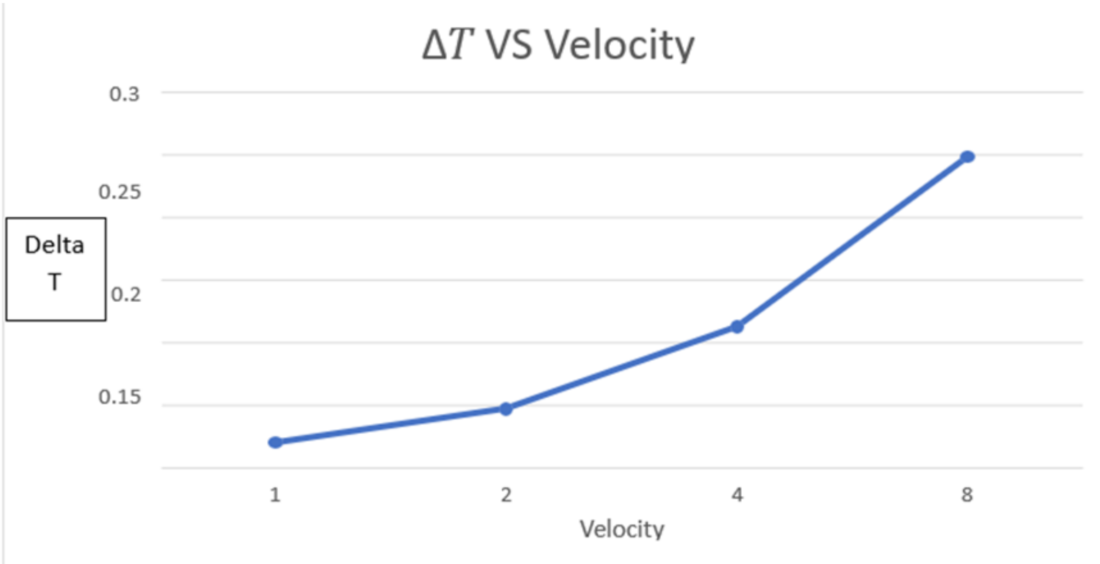


Isometric View of Temperature Contour Plot

TASK 2 B

Deliverables 9

Velocities	ΔT out	ΔT In	$\Delta T = Tout - Tin$
1	300.01897	300	0.01897
2	300.0420	300	0.0420
4	300.115	300	0.115
8	300.2489	300	0.02489



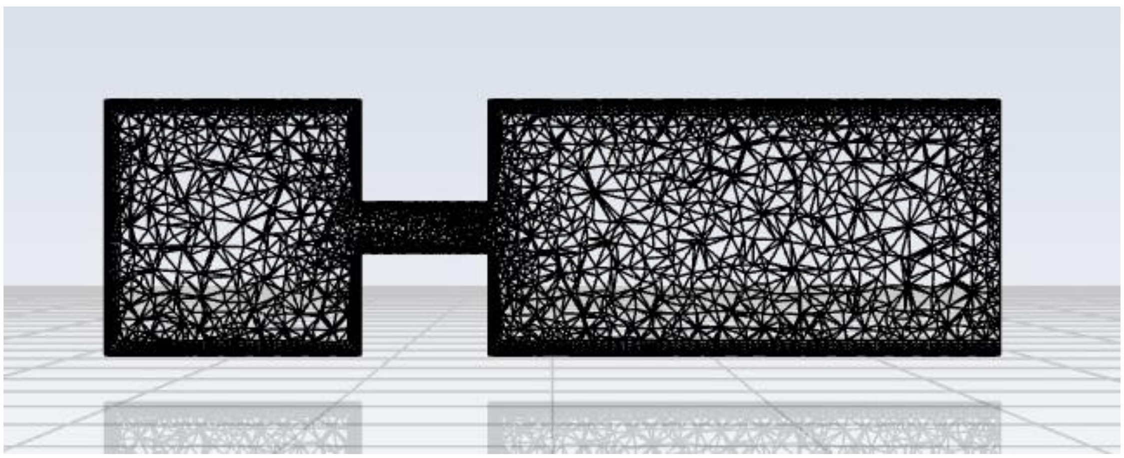
Deliverables 10

In Task 2a, the decline in ΔT as the inlet velocity rises can be ascribed to the decreased duration the fluid spends within the heated pipe at greater velocities. This shortened residence time restricts the potential for efficient heat transfer to occur.

Conversely, in Task 2b, the elevation in ΔT as the inlet velocity increases is a consequence of viscous heating. At heightened velocities, there is a greater extent of viscous dissipation within the fluid, resulting in an increased generation of internal heat. This effect of viscous heating becomes more pronounced than the reduction in residence time at higher velocities, leading to the observed greater temperature increase (ΔT).

Task 3: A simple compressible flow

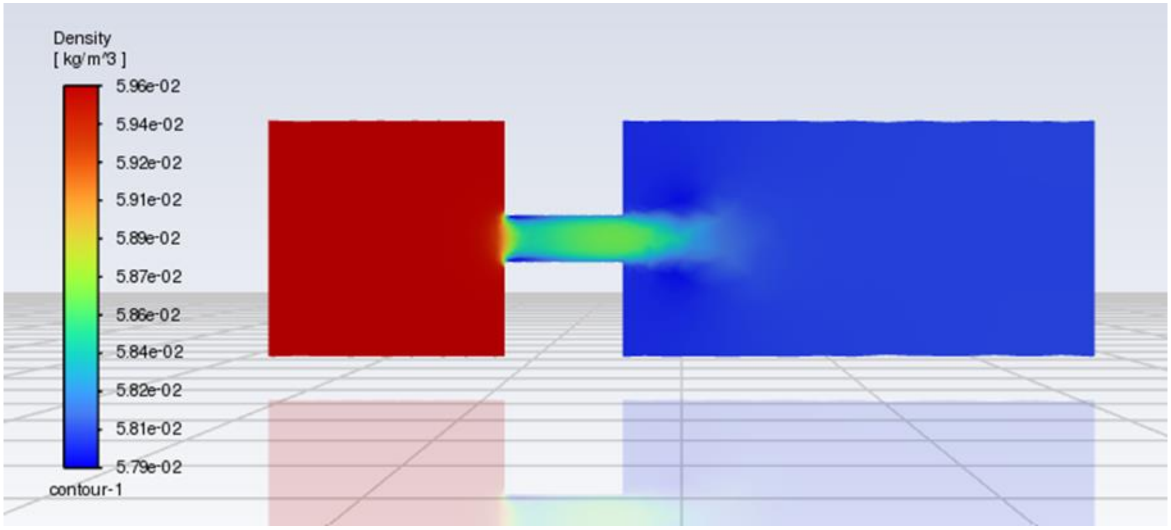
D11- A statement that indicates your choice of time step size and maximum number of iterations per time step, for the transient simulation. In addition, a plot of the mesh along the plane of symmetry.



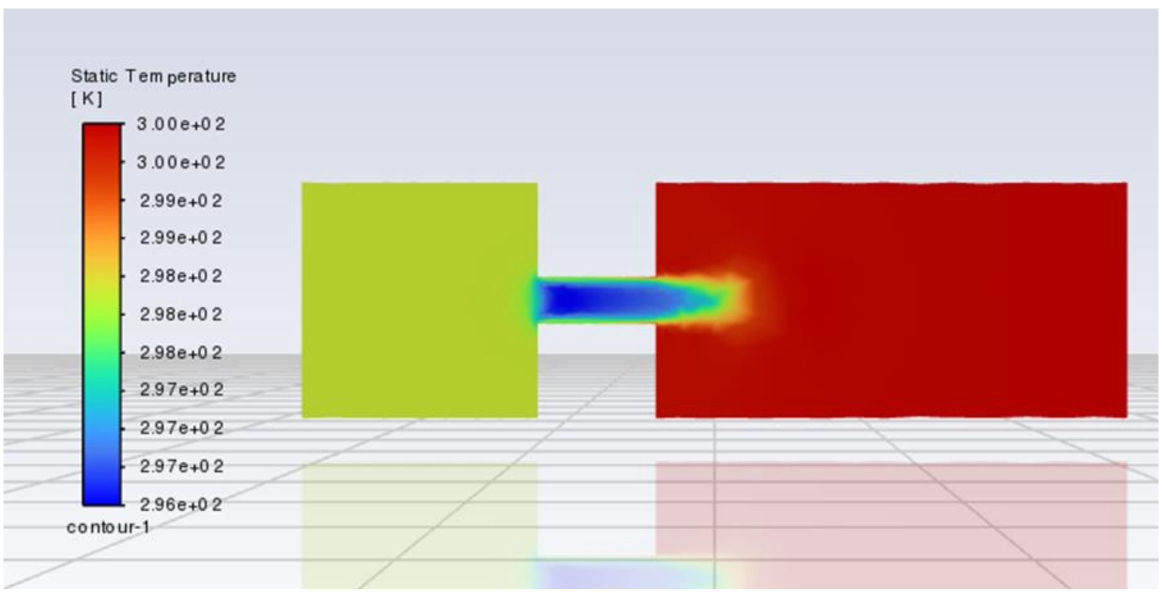
Mesh on Plane of Symmetry

Time Step size is 0.001 and max iterations is 200

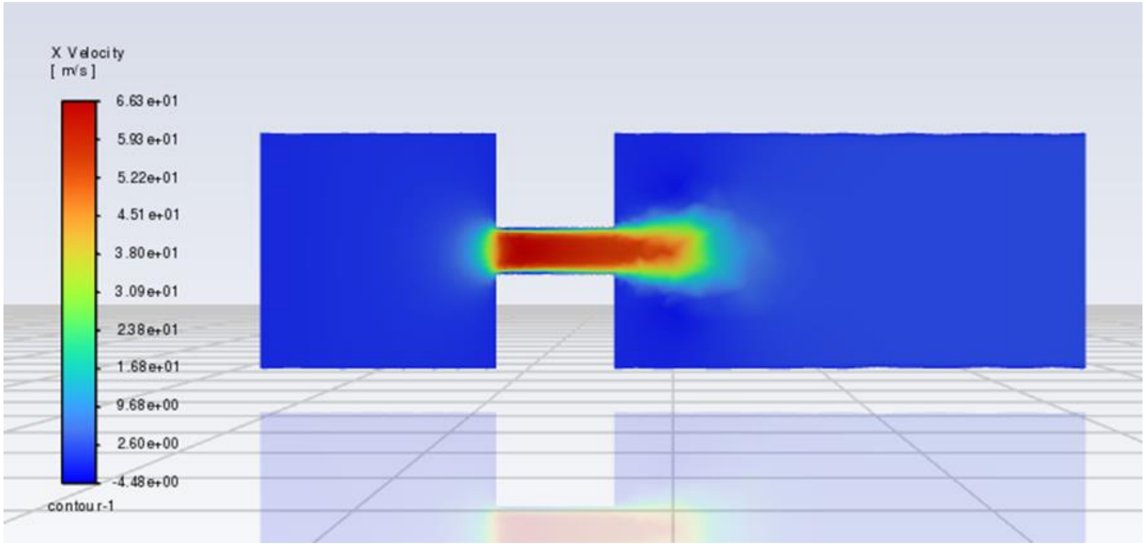
Deliverables 12



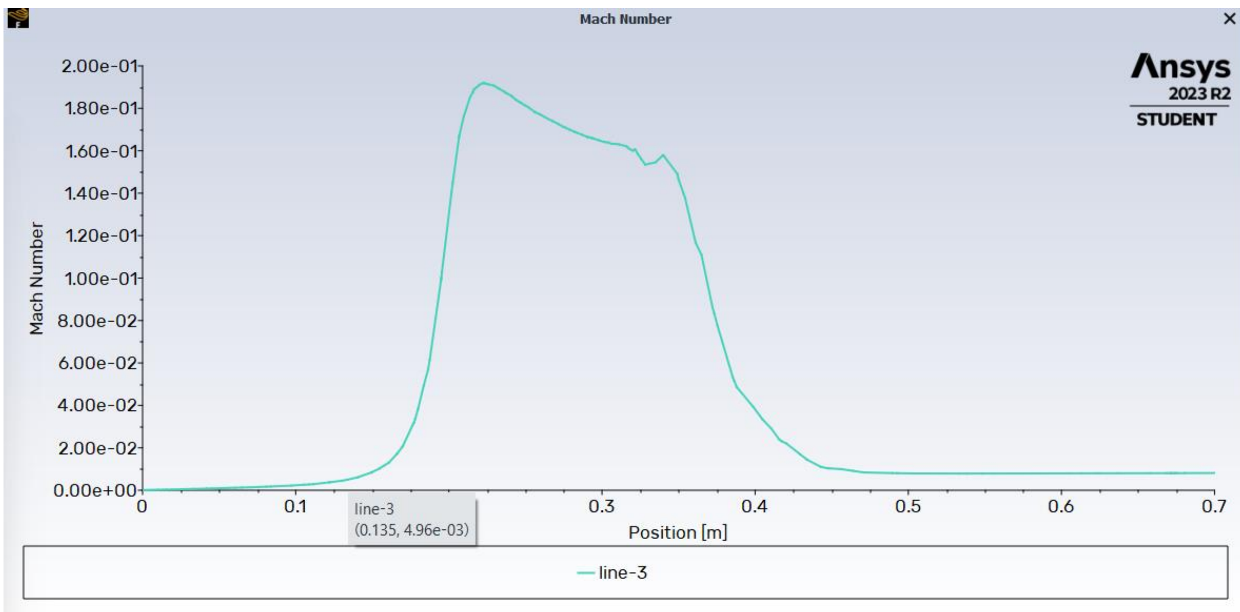
Contour plot of static temperature along symmetric plane at 0.005 seconds of transient simulation



Contour plot of Density along symmetric plane at 0.005 seconds of transient simulation

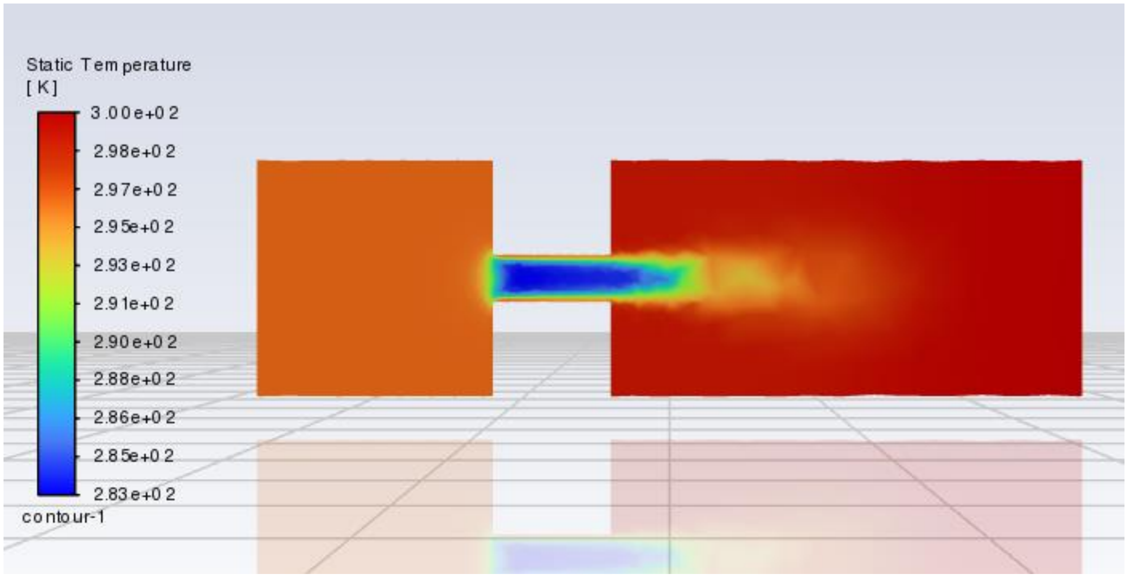


Contour plot of X velocity along symmetric plane at 0.005 seconds of transient simulation. The velocity is in x direction because the 2D surface model was produced

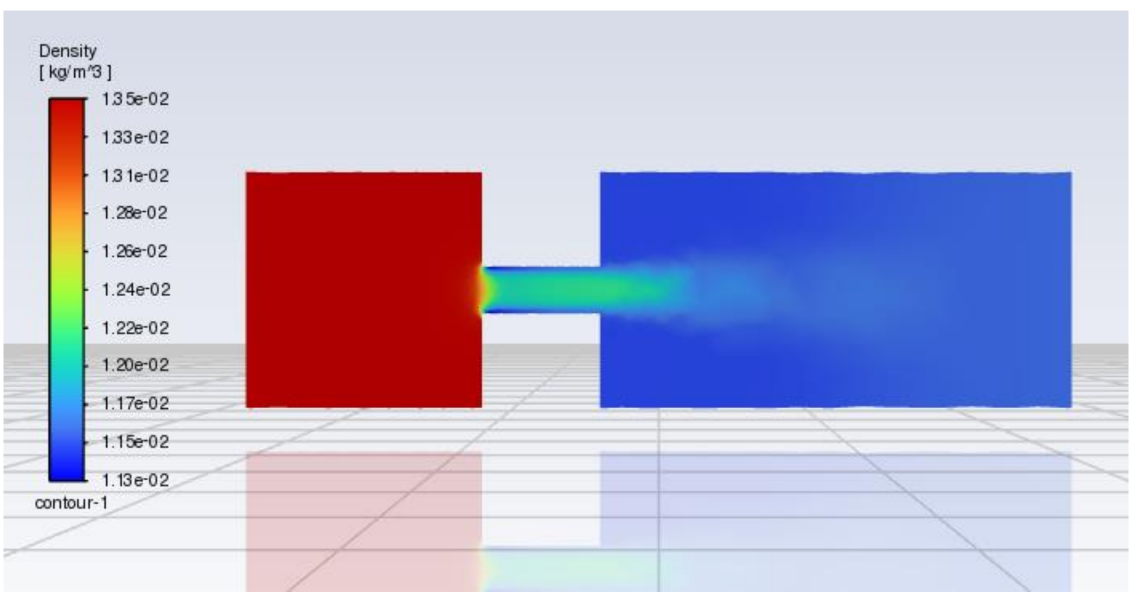


Mach number

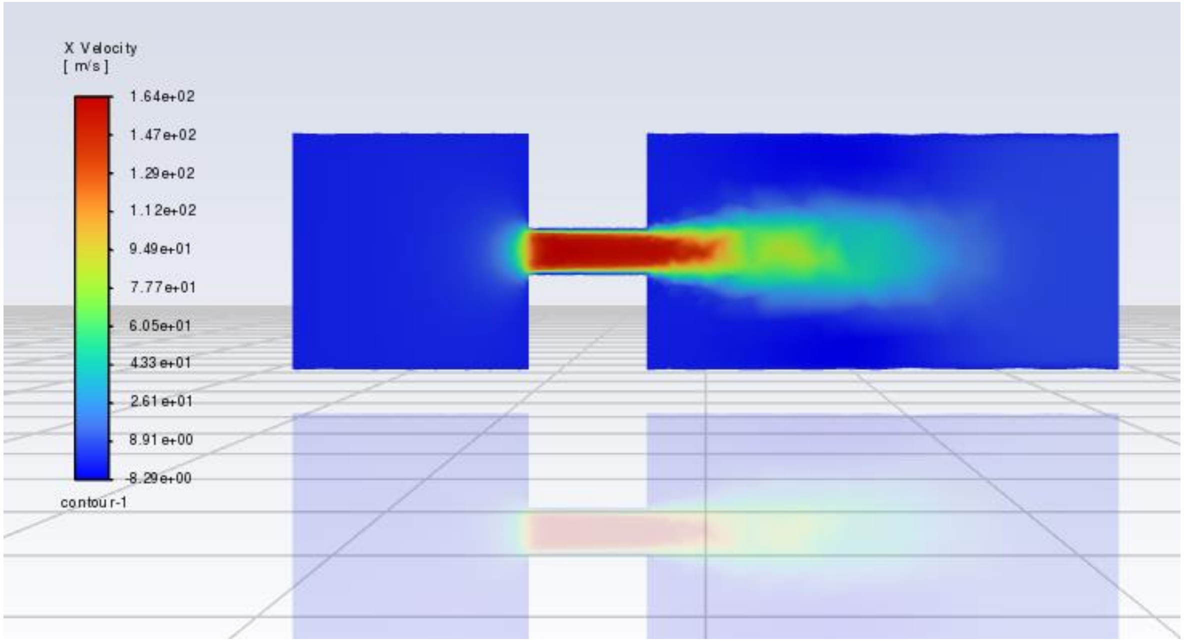
Task 3b



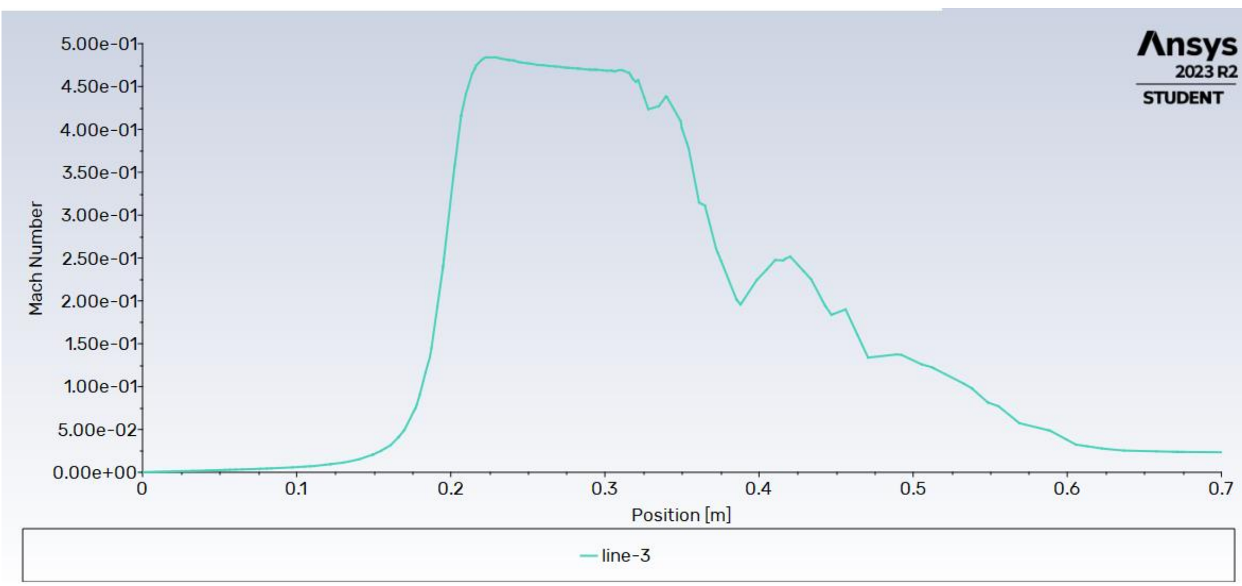
Contour plot of static temperature along symmetric plane at 0.005 seconds of transient simulation



Contour plot of Density along symmetric plane at 0.005 seconds of transient simulation



Contour plot of velocity along symmetric plane at 0.005 seconds of transient simulation

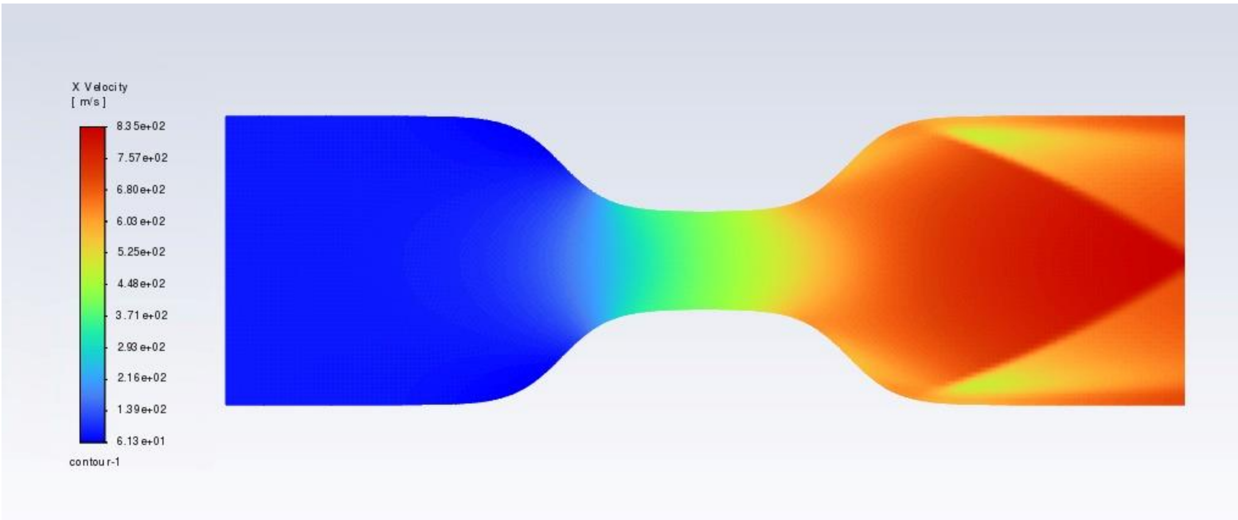


Mach Number

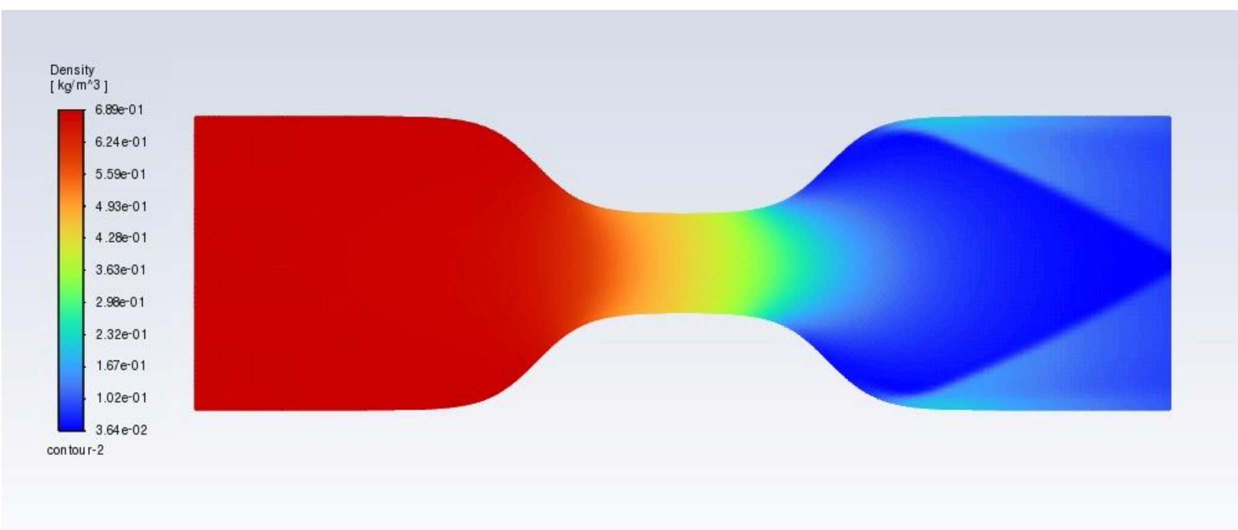
Task 4 :- Compressible flow through a nozzle

Task 4a: Supersonic case

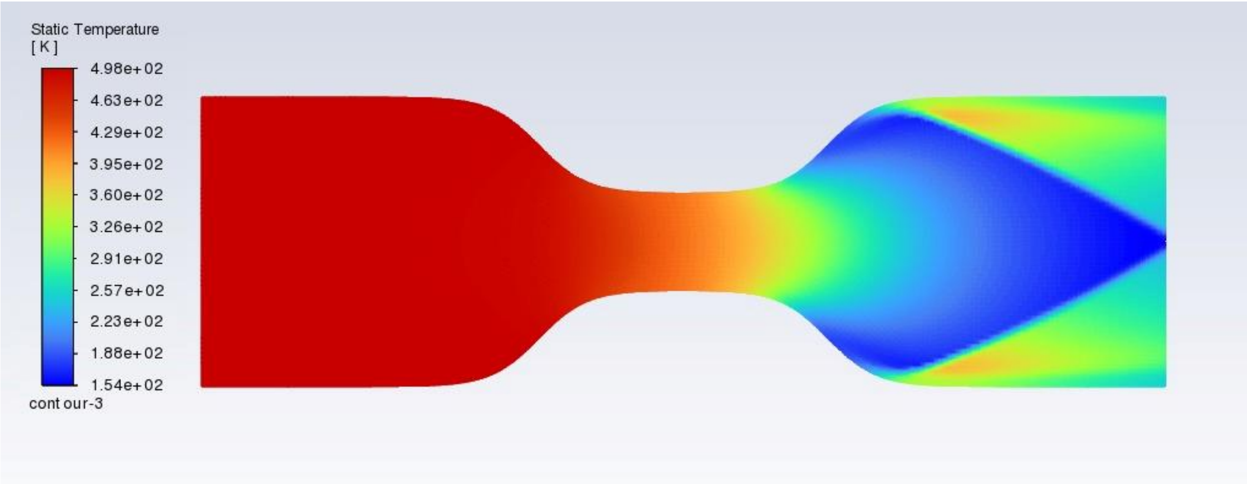
Contour plots of x-velocity, density, and static temperature



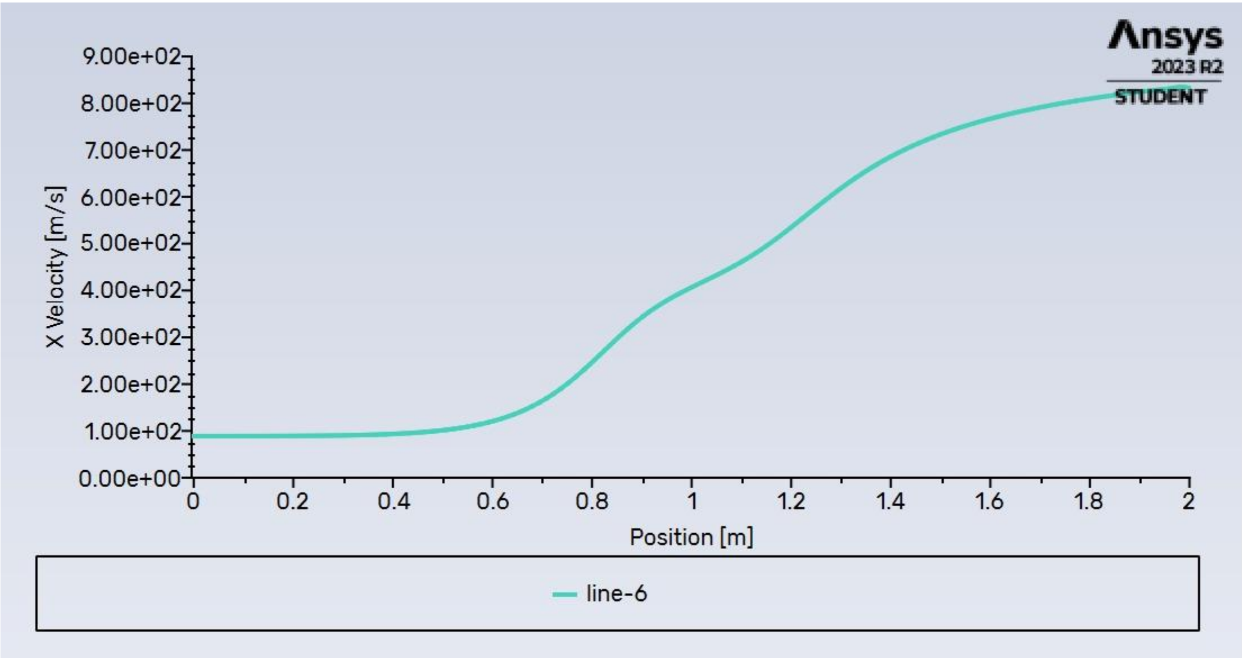
Contour plots of x-velocity



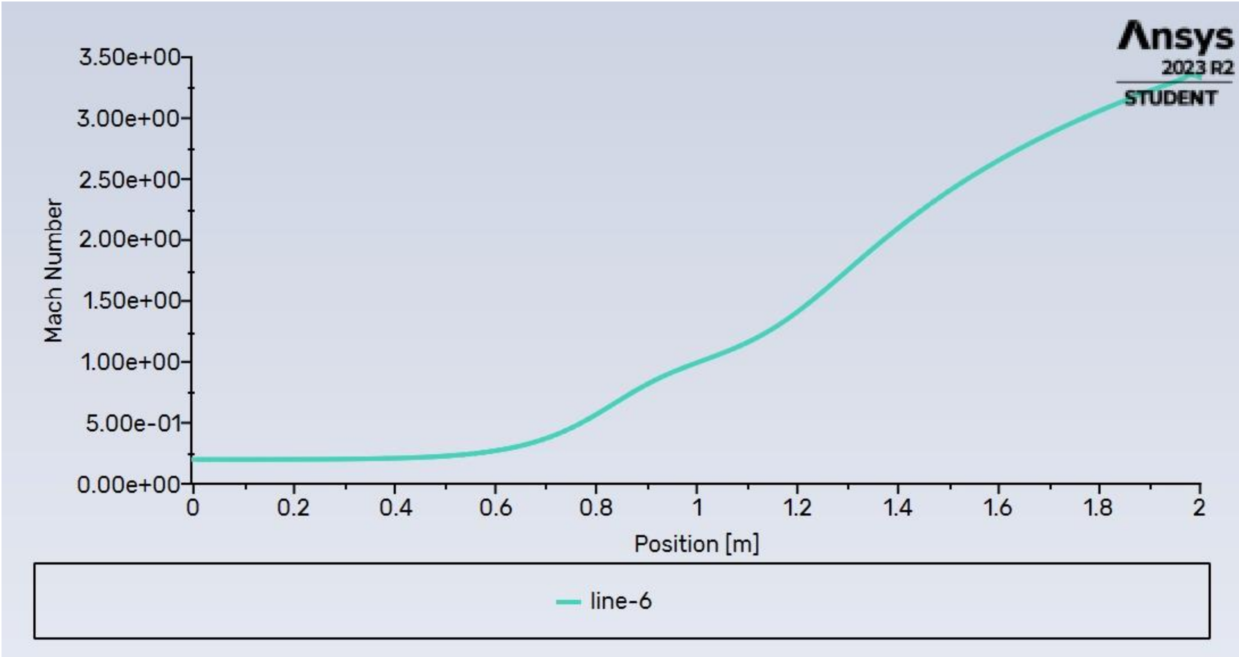
Contour plots of Density



Contour plots of Static Temperature



Line plots of X-Velocity



Line plot of Mach Number

Task 4b: Subsonic case

Repeat Task 4a but change the boundary conditions to the following:

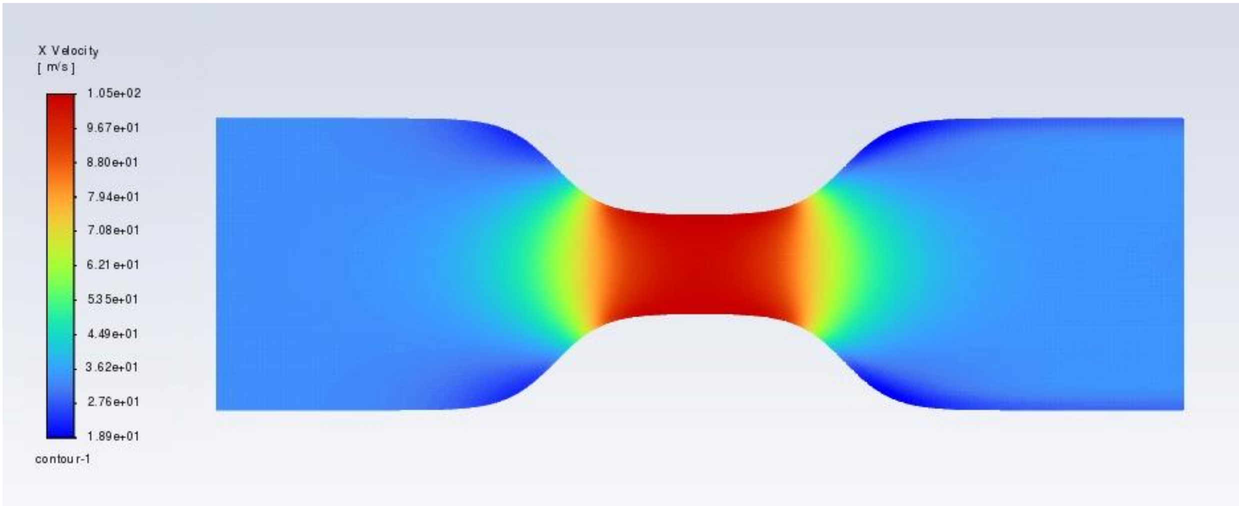
(5) Set the left opening as a pressure inlet and impose

(i) Gauge total (stagnation) pressure = 100000 Pa

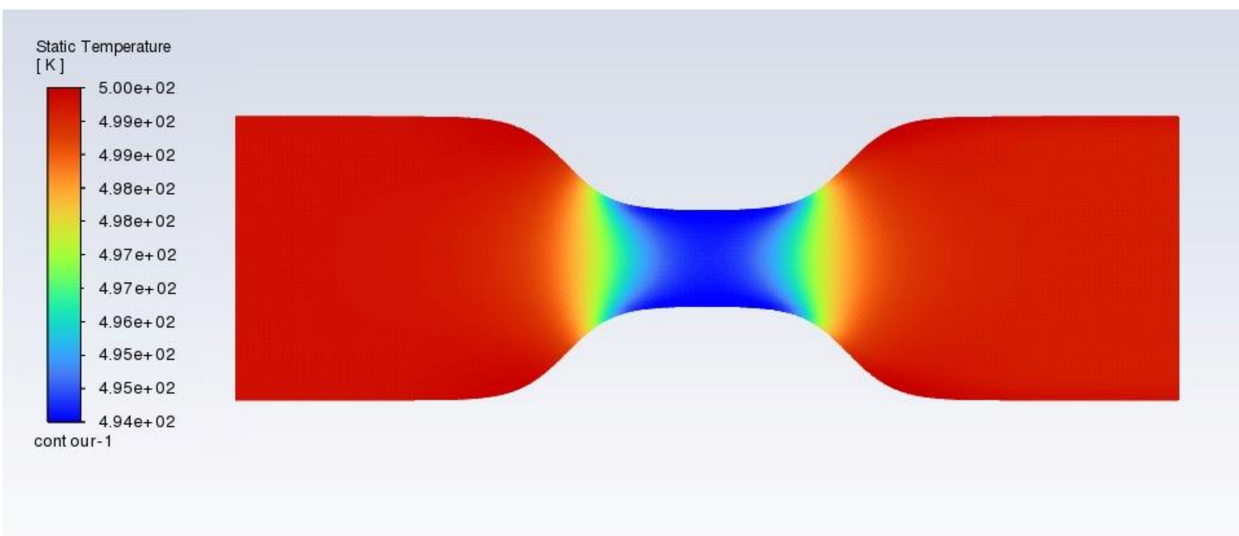
(ii) Supersonic/Initial gauge pressure = 99900 Pa

(iii) Total temperature = 500°K.

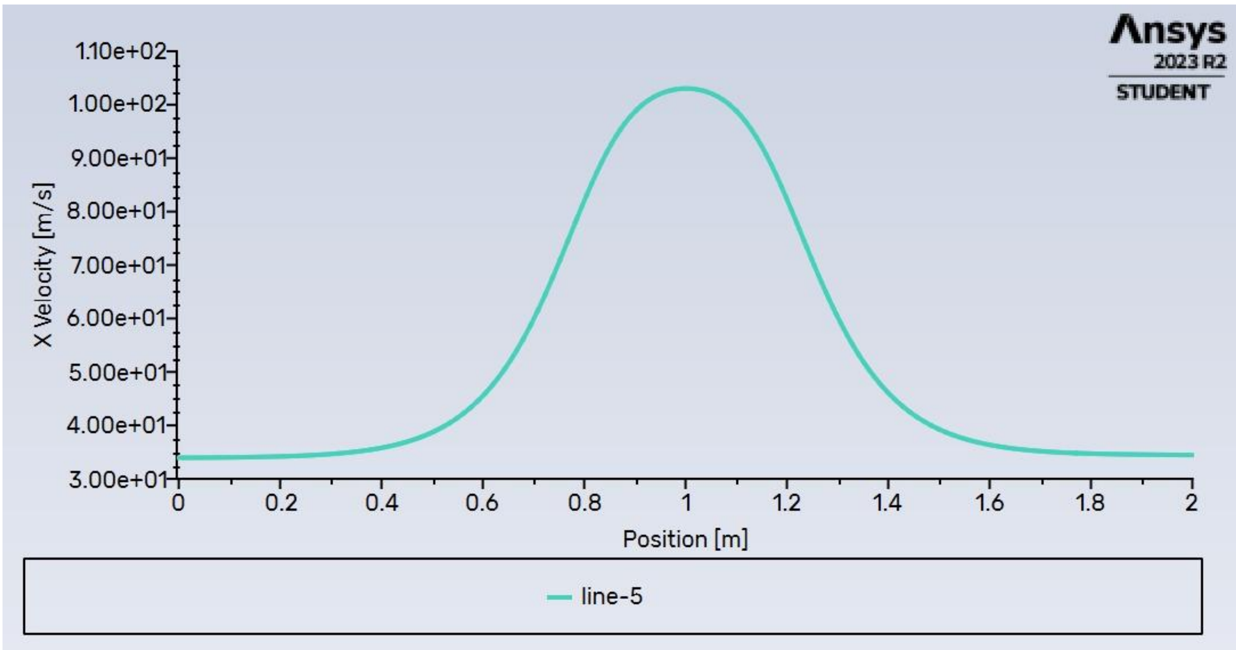
(6) Set the right opening as a pressure outlet and impose Gauge pressure = 99500 Pa. Set the temperature of backflow to 500°K.



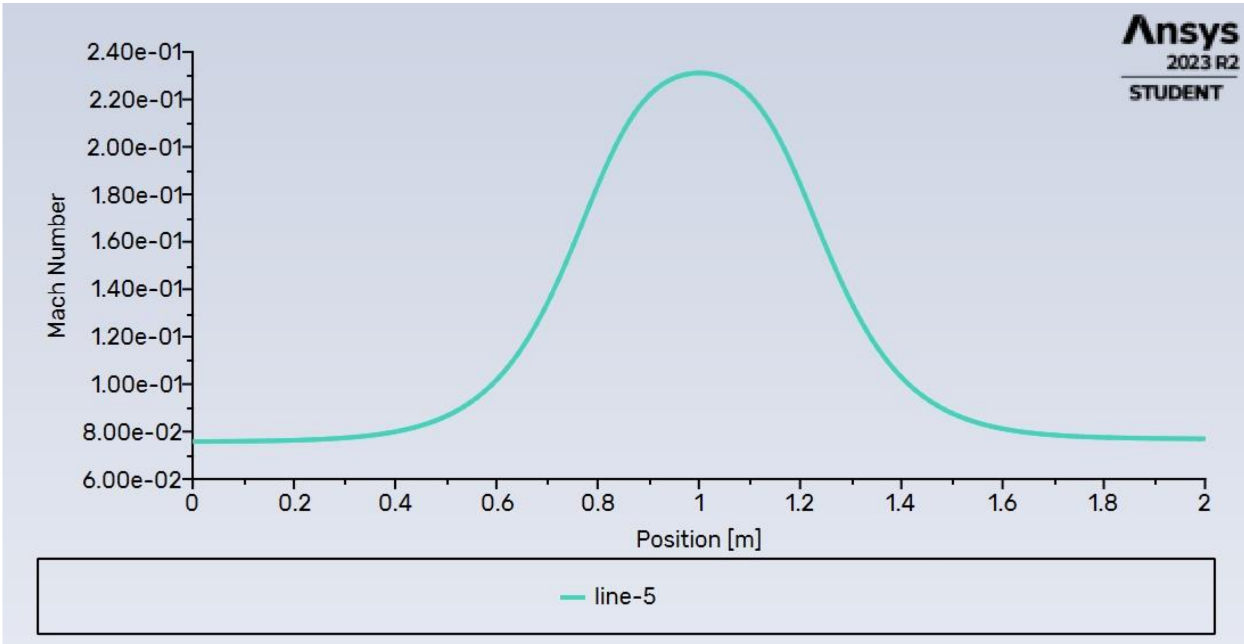
Contour plots of x-velocity



Contour plots of Static Temperature



Line plot of x-velocity



Line plot of Mach Number