Collaboration: Krishna Koparde
In Task 2, For 40 degree helped to find out viscus and pressure force.

Task 1

Task 1 is a 2-D transient simulation of incompressible flow passing a cylinder. In part a, the cylinder is circular with a radius of 4 cm. In part b, 2 runs are performed with an elliptical cylinder. In the first run, the major axis is perpendicular to the flow while in the second run, the major axis is parallel to the flow. In both runs, the major axis is 10 cm and the minor axis is 6 cm. The computational domain is a 50cm x 100cm rectangle. The left side of the domain is a velocity inlet with a constant x-velocity of 4 cm/s. The right side of the domain is a pressure outlet with zero-gauge pressure. All other boundaries are walls.The transient simulation was run to 3 minutes with a time step of 0.1s. The maximum number of iterations per time step is set to 10. The 3 minutes of the simulation are used to estimate the amplitude and period of the lift force.

Task 1a Deliverables:

(i) $Re = \rho V D / \mu$

$\rho = 998.2\ kg/m^3$

$V = 0.04\ m/s$

$D = 0.08\ m$

$\mu = 0.001003\ kg\ m\ s$

$Re = (998.2)(0.04)(0.08)/0.001003 = 3184.68$

(ii)

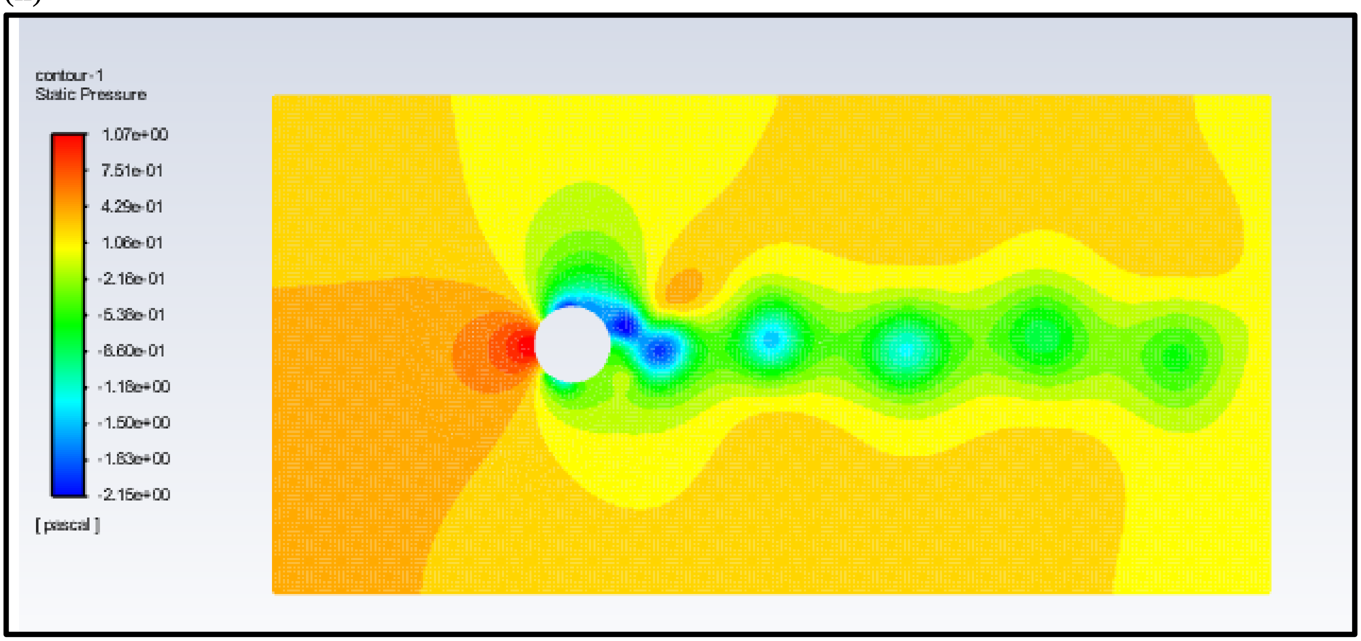

Figure 1. Contour plot of the static pressure at t = 3 min.

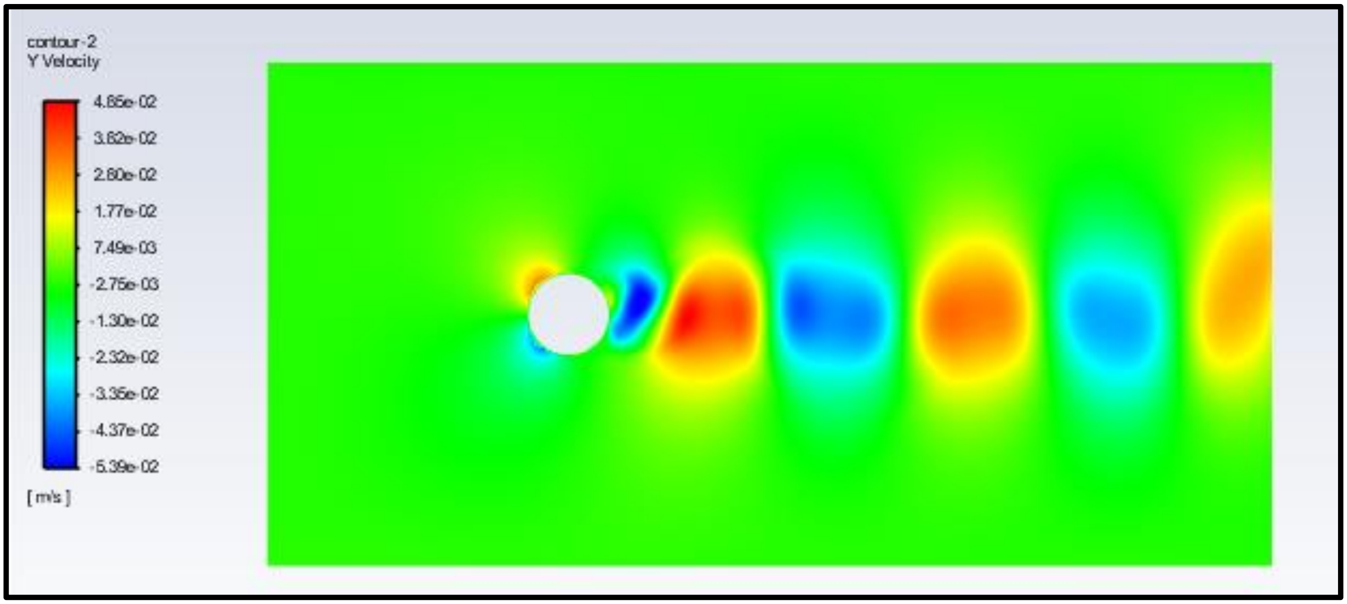

Figure 2. Contour plot of the y-velocity at t = 3 min.

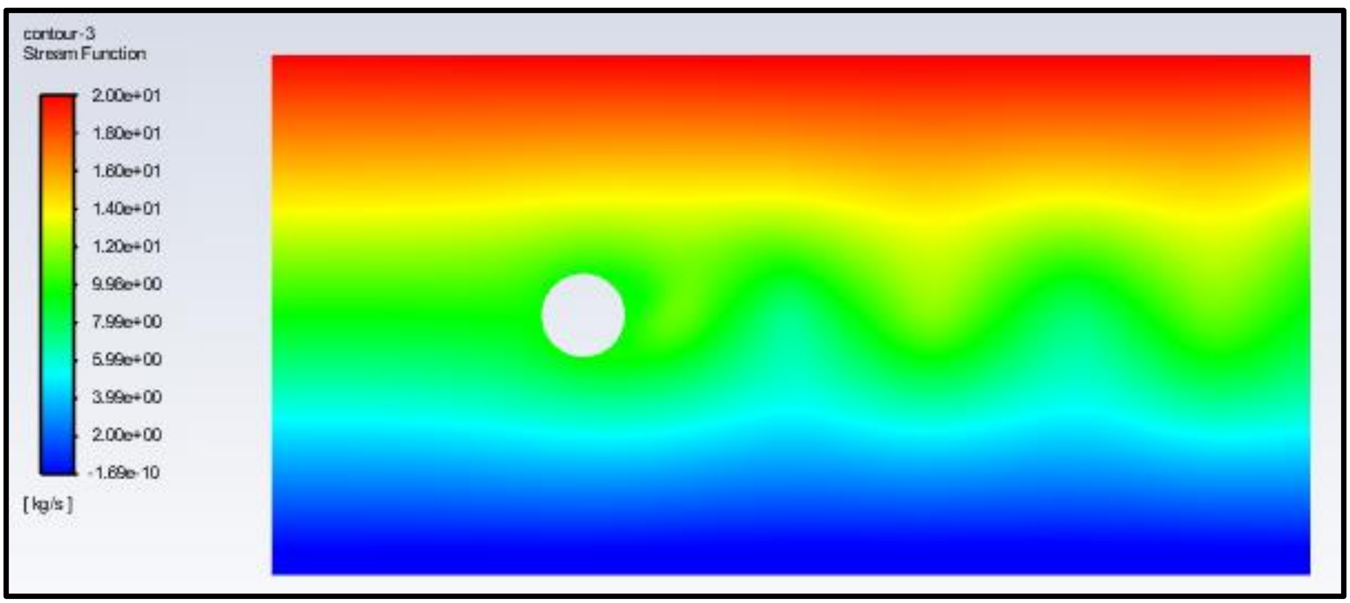

Figure 3. Contour plot of the stream function at t = 3 min

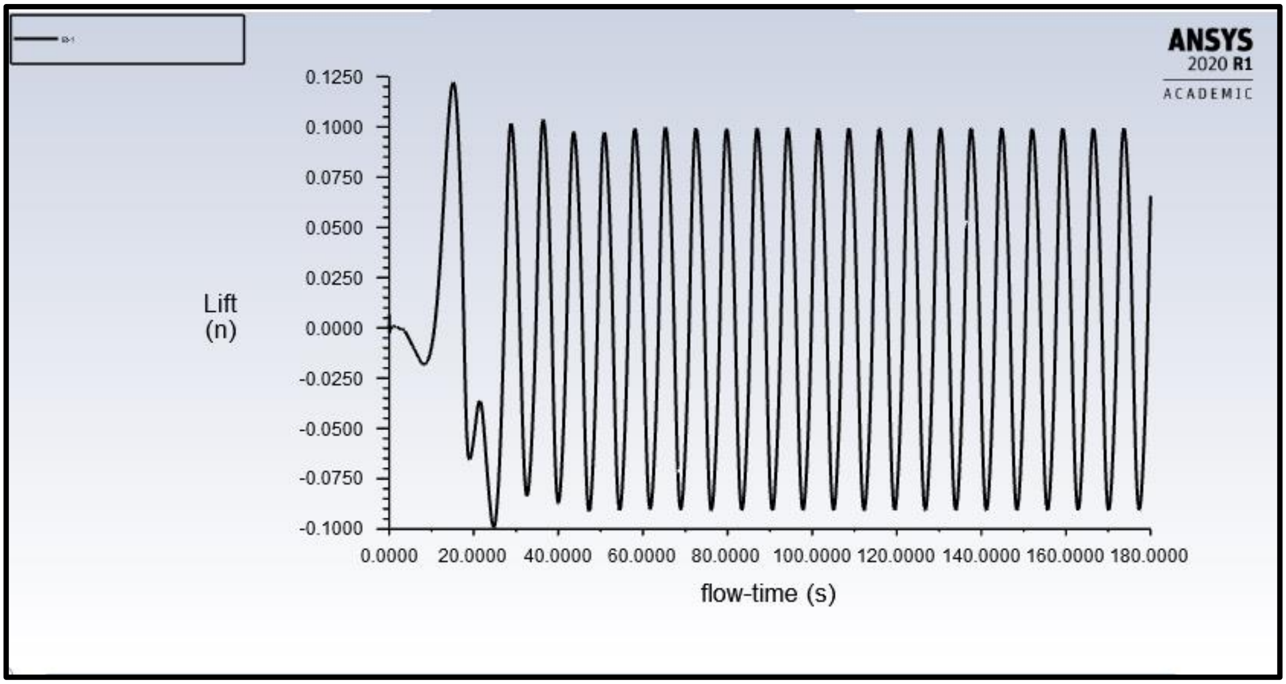

Figure 4. Line plot of the lift force as a function of time for the last 3 minutes of the Task 1a simulation.

By taking the mean value of the difference between the maximum and minimum values in Figure 4, the amplitude is estimated to be 0.1024 N. The period is estimated to be 8.4 s by counting the time between peaks.

Task 1b Deliverables:

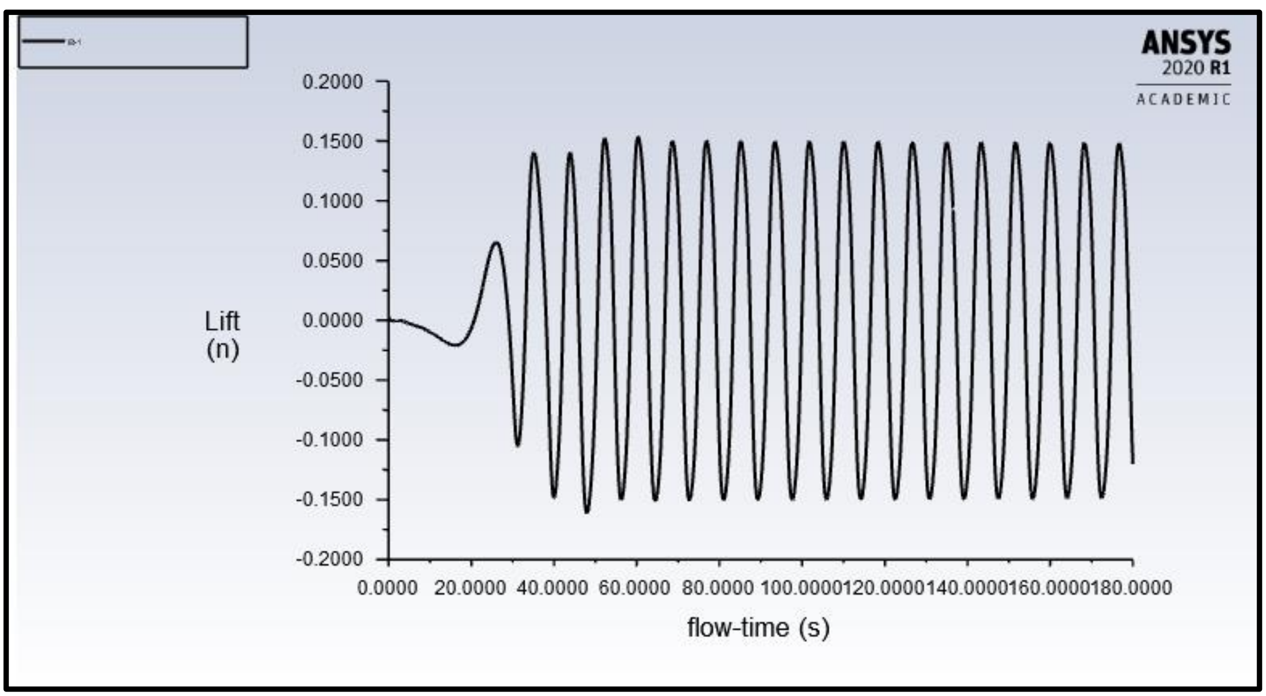

Figure 5. Line plot of the lift force vs. time for the last 3 minutes of Task 1b Run#1.

For run #1, the last 5 peaks and the last 5 valleys were averaged to estimate an amplitude of 0.1436N. The period of 9.9 **s** is estimated.

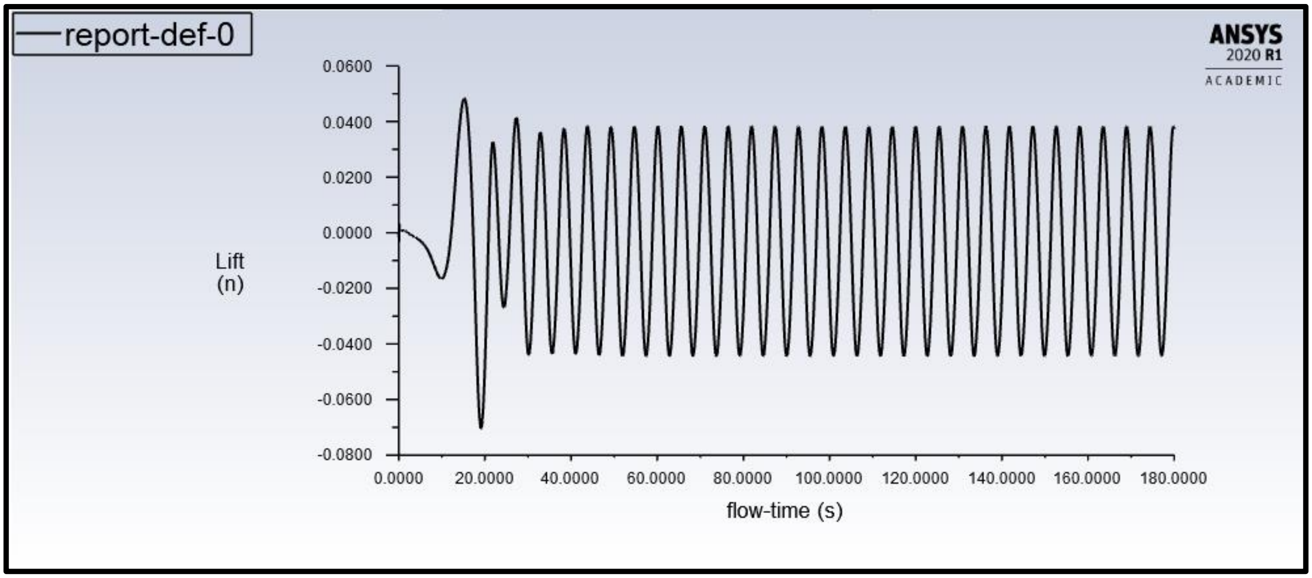

Figure 6. Line plot of the lift force vs. time for the last 3 minutes of Task 1b Run#2.

For run #2, the last 5 peaks and the last 6 valleys were average to estimate an amplitude of 0.0419N. In the data sampled, there is no clear pattern to the period. The nine possible periods from the data sampled were averaged to estimate a period of 6.31s.

Run	Lift Force Amplitude (N)	Lift Force Period (s)
Task 1a	0.1024	8.4
Task 1b	0.1436	9.9
Task 1c	0.0419	6.31

Figure 7. Table of results for all Task 1 runs for comparison.

From comparing the results, it is possible to conclude that a larger cross-sectional area perpendicular to the flow results in a larger lift force amplitude and a longer time period.

Task 2

Task 2 is a 3-D simulation that models a flying saucer in a cylindrical wind tunnel. The properties of air are set to a constant density of 0.4 kg/m3 and a constant viscosity of 1.44e-5 N s m-2 which approximately models the cruising altitude of a commercial airliner. Three different runs of this simulation were completed using varying tilt angles of the saucer about the z-axis. These angles are 0, 20 and 40 degrees. The following table shows the element size and the number of elements in each of the 3 simulations. It is interesting to note that as the angle of tilt increased, the element size needed to be increased in order to keep the maximum number of elements under 512k.

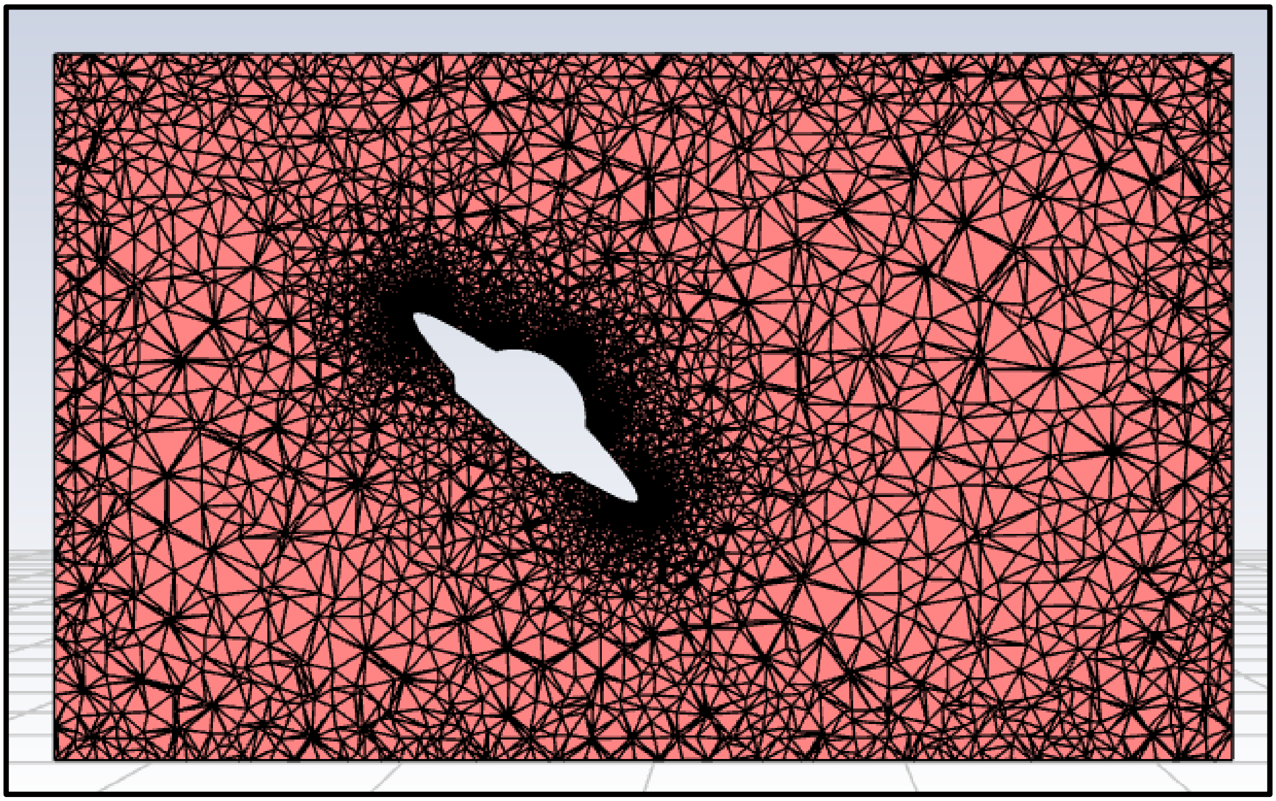

Figure 1. Mesh on the vertical plane of symmetry used during the 40-degree tilt angle run.

Task 2 Deliverables:

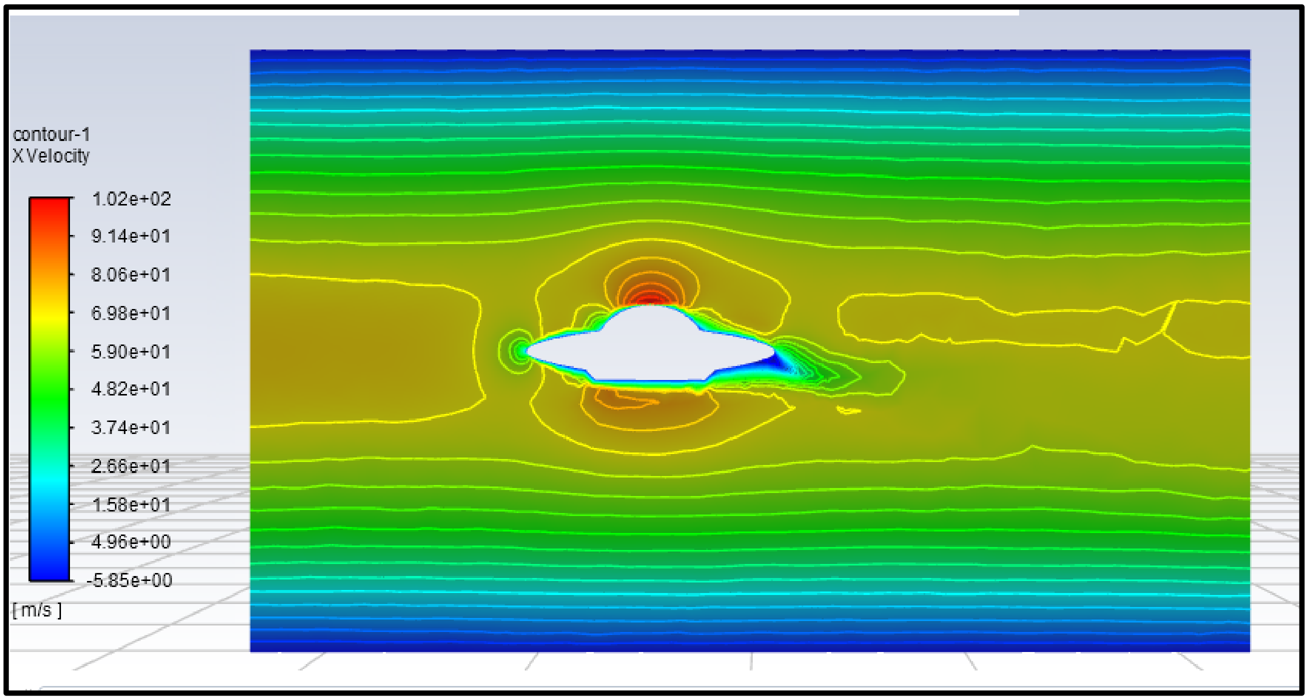

Figure 2. Contour plot of the x-velocity on the plane of symmetry when tilt angle is 0 degrees.

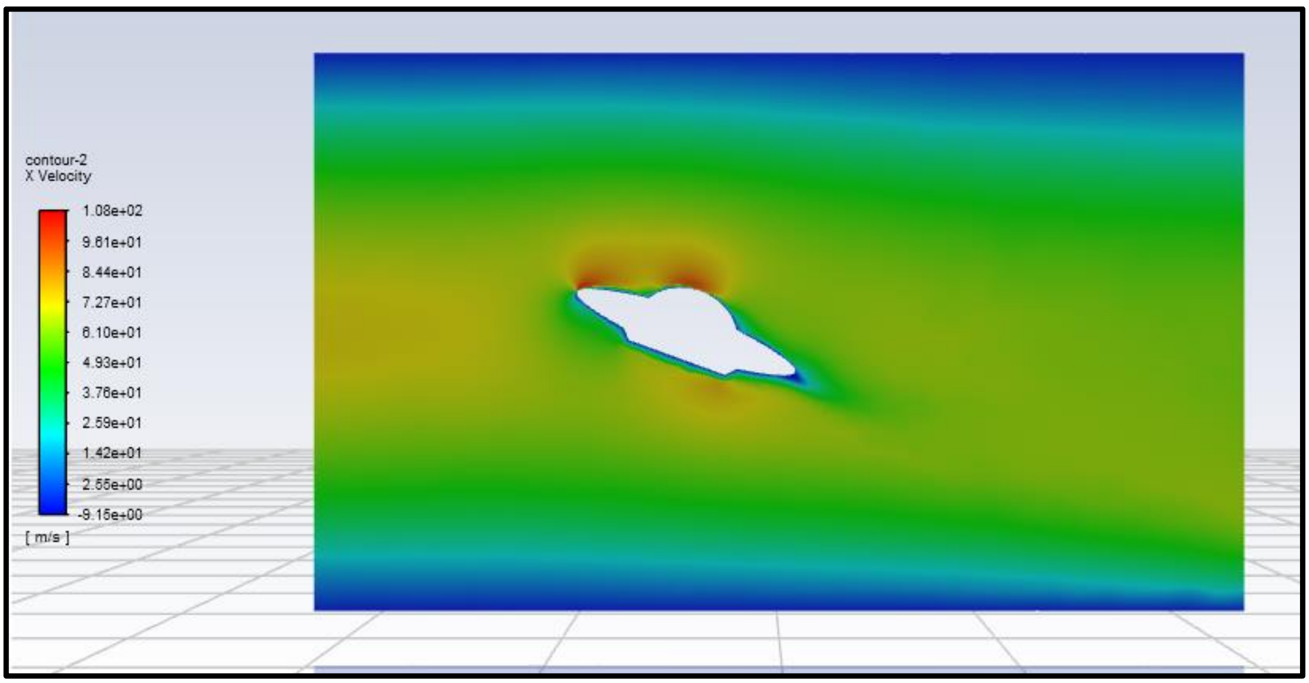

Figure 3. Contour plot of the x-velocity on the plane of symmetry when tilt angle is 20 degrees.

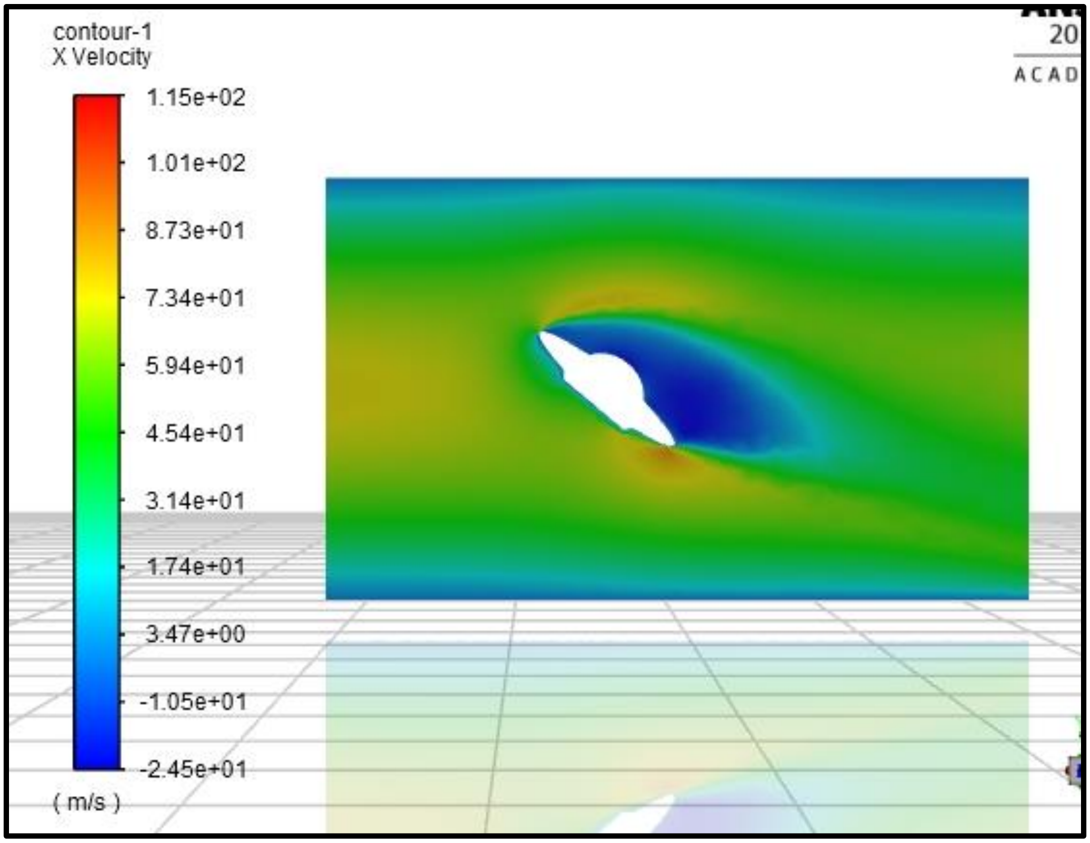

Figure 4. Contour plot of the x-velocity on the plane of symmetry when tilt angle is 40 degrees.

Tilt Angle (deg)	Lift Force (N)	Drag Force (N)
0	6.72	4.62
20	56.64	16.402
40	42.79	55.96

Figure 5. Numerical values of Lift and Drag Force at different angles.

Task 3:

Task 3 simulates the flow of air over a pentagonal building in a rectangular virtual wind tunnel. The building is 1.5 m tall and each side of the pentagon is 0.8 m long. The computational domain is 8 x 12 x 10 m and the building is positioned centrally on the base of the wind tunnel. The left and right openings are set to either a velocity inlet or a pressure outlet depending on the direction of the flow being simulated. Two different runs are performed for flow in each direction. The goal of the task 3 runs is to explore the effects of the upwind geometry on the drag force exerted onto the building. The simulation uses the standard k-epsilon model and seeks the steady solution. The inlet velocity is set to a constant 30 m/s and the default properties of air are used.

The results presented in the following deliverables sections allow for interesting observations with respect to the structures of pressure and velocity and their effect on the drag force acting on the building. It is important to note that the largest cross-sectional area perpendicular to the flow is the same in both simulations; however, in part a, the largest crosssectional area is behind the center of the pentagon while in part b, this area is in front of the center of the pentagon. As a result, in part a, the flow hits the flat side of the pentagon then runs against the 2 sides with a large portion of their direction parallel to the flow. With the flat side encountering the flow first, the velocity running along the sides of the building is faster allowing for a greater contribution from the viscosity to the drag force. Also, in part a, the position of the largest cross-sectional area behind the center of the pentagon results in a lower pressure acting on the building. Since the pressure is the largest contributor to the drag force, the drag force is lower in part a as a result. In part b, the flow encounters the largest cross-sectional area in front of the center of the pentagon and the two sides preceding this area have the largest part of their direction perpendicular to the flow. As a result, the contribution of viscosity to the drag force is very low in part b, especially since the flow is pushed away from the building and the remaining 3 sides are shielded from the flow. Furthermore, encountering the large cross-sectional area before the center of the pentagon results in a larger pressure force acting on the building. As a result, the overall drag force is much larger in part b.

Task 3a Deliverables:

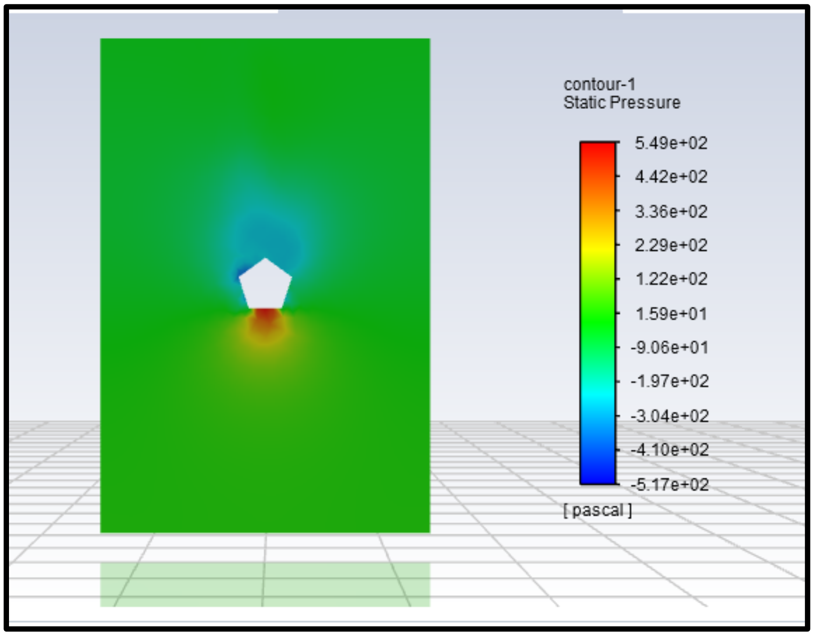

Figure 1. Contour plot of static pressure on the horizontal plane at z=0.75.

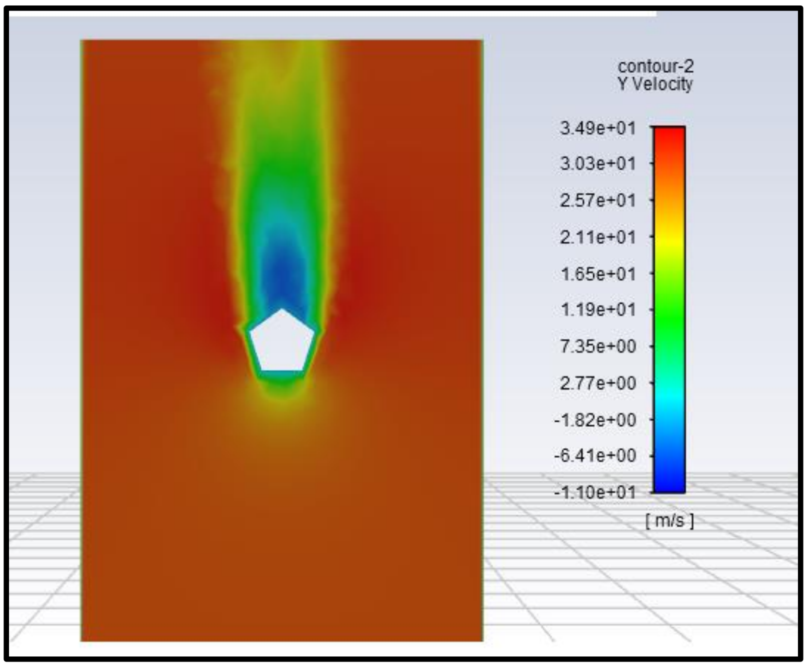

Figure 2. Contour plot of y-velocity on the horizontal plane at z=0.75.

Task 3b Deliverables:

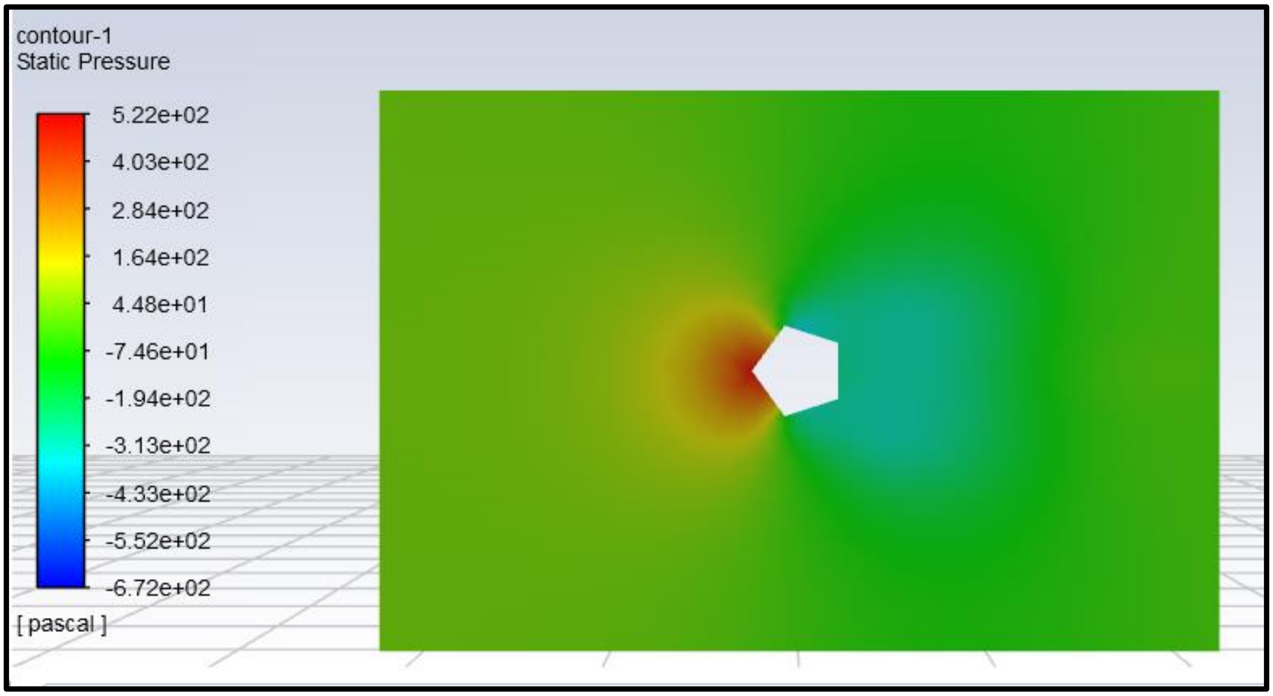

Figure 3. Contour plot of static pressure on the horizontal plane at z=0.75.

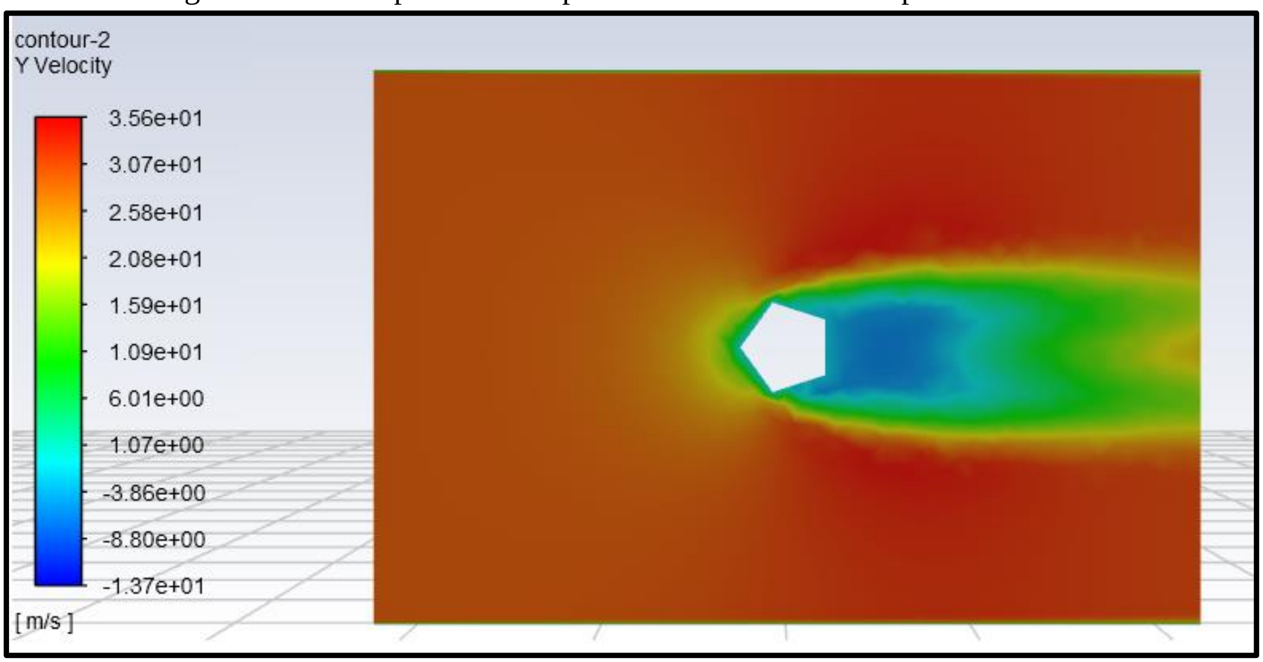

Figure 4. Contour plot of y-velocity on the horizontal plane at z=0.75.

Case	Total	Pressure	Viscus
a)	786.98	784.50	2.48
b)	1083.727	1082.80	0.9274

Figure 5. Table of Viscus and Pressure Forces with different condition