Arizona State University

MAE 560: Applied Computational Fluid Dynamics

Fall 2022

Project 3

Report

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Statement of Collaboration: No Collaboration

<u>Task 1:</u> Von-Karmann Vortex Street. Flow over Cylinder (Laminar and Transient)

D1: Description of *mesh resolution, time step size,* and *maximum number of iterations per time*.

Mesh resolution: 2e-3 m | Time step size: 0.05s | Iterations per time step: 10

<u>Reynolds Number Calculation:</u>
The values of density and dynamic viscosity were determined from the fluent database.

$$Re = \frac{\rho v D}{\mu} = \frac{730\left[\frac{\text{kg}}{m^3}\right] * 0.04\left[\frac{m}{s}\right] * 0.04[m]}{0.0024\left[\frac{kg}{m*s}\right]} = 486.67$$

D2: Contour plots of *y-velocity, stream function,* and *vorticity magnitude* at t = 1 min

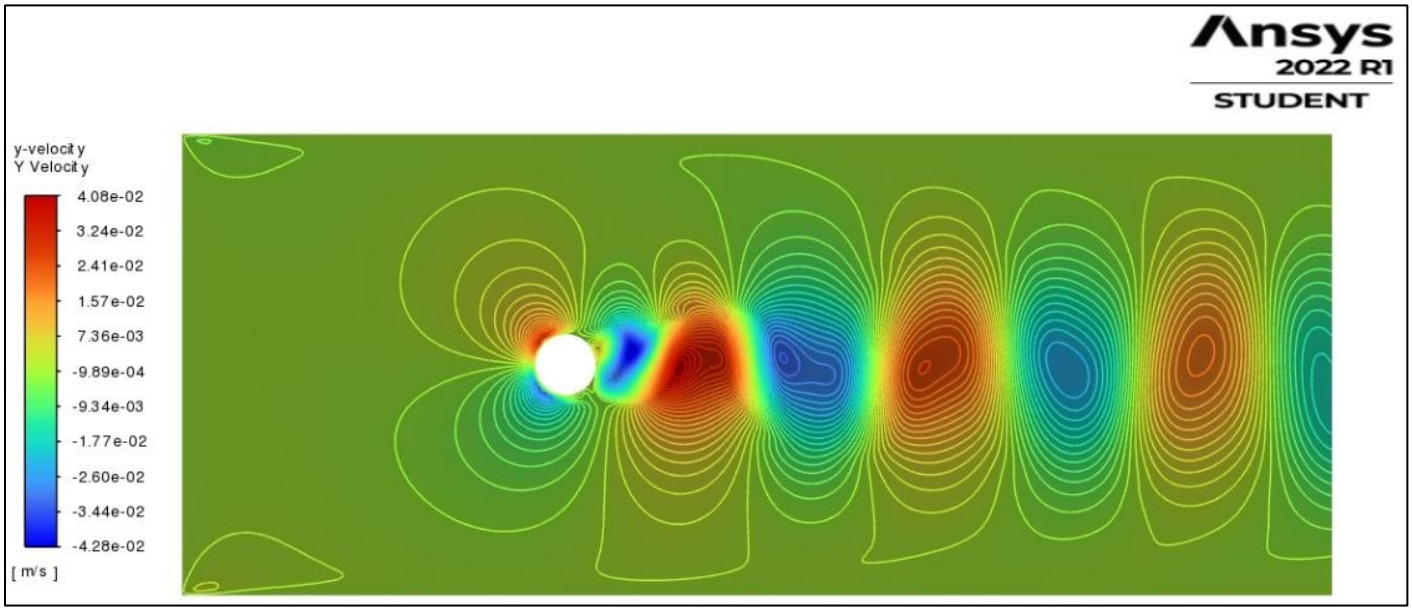

Figure 1: Y-Velocity at t = 1min for Task 1

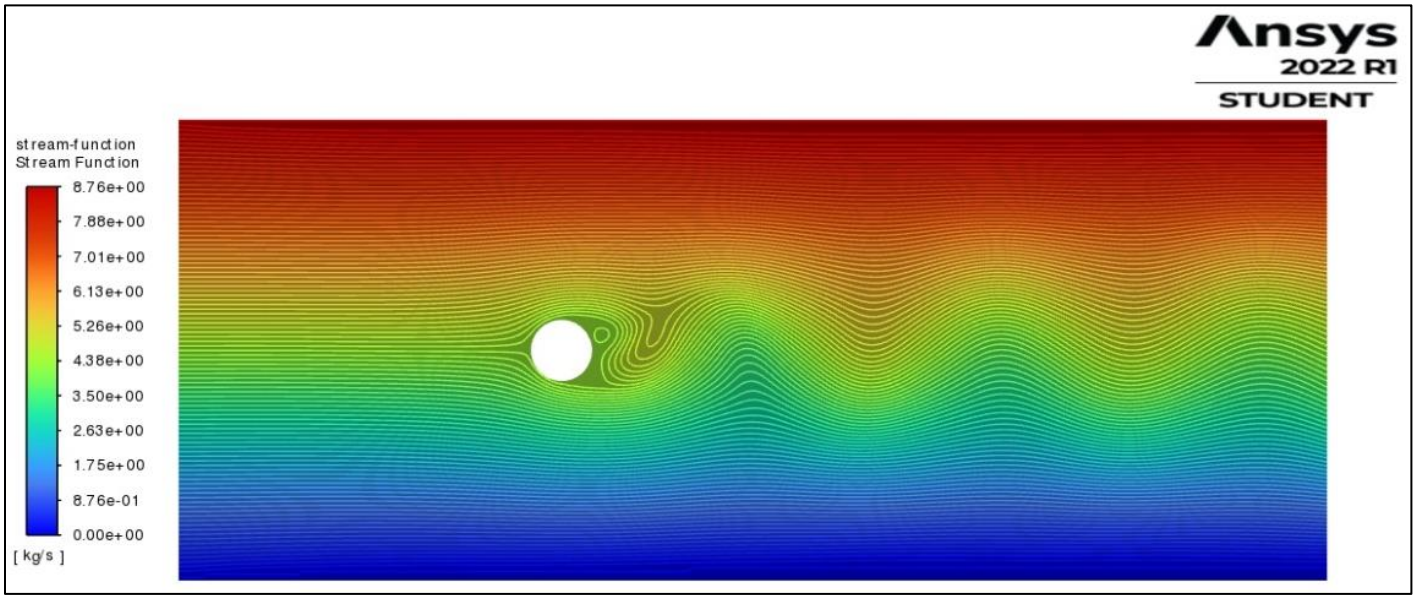

Figure 2: Streamline function at t = 1 min for Task 1

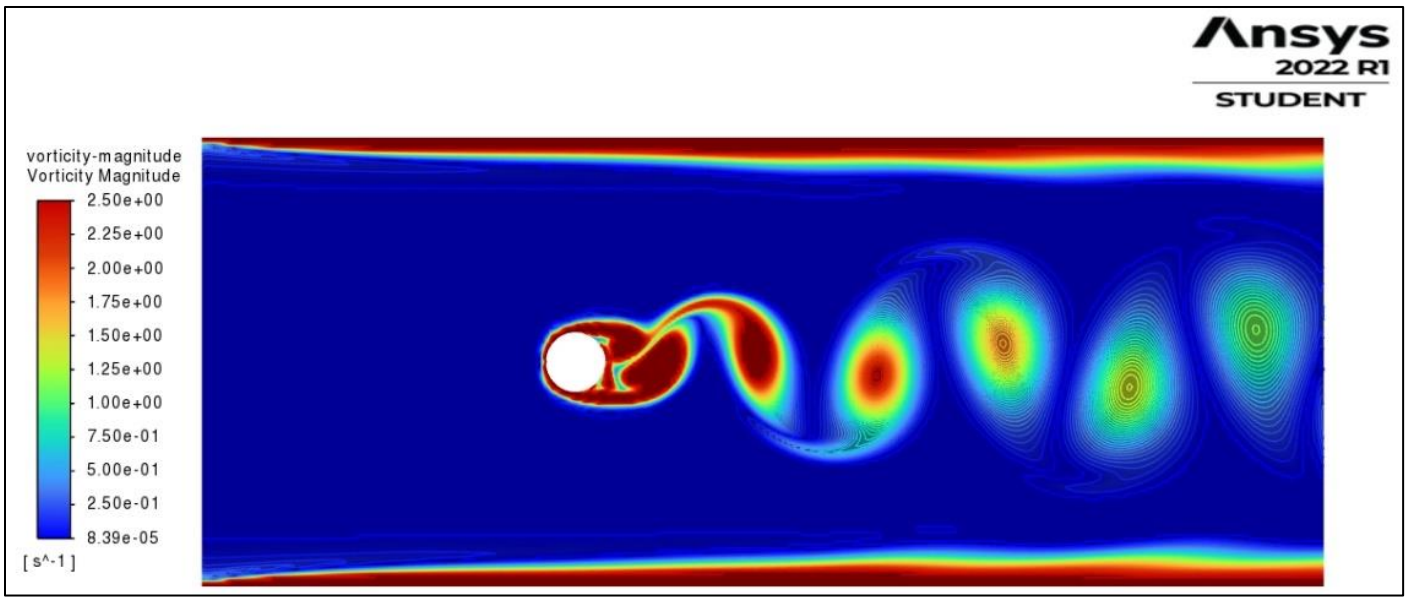

Figure 3: Vorticity Magnitude at t = 1min for Task 1

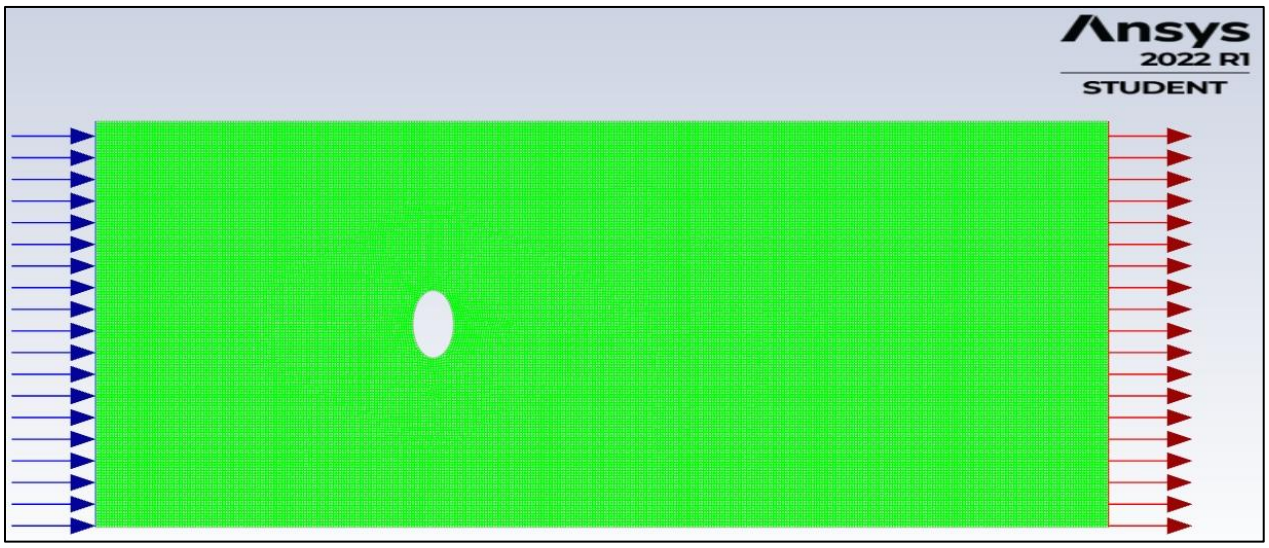

Figure 4: Geometry and Mesh representation for Run1 - Vertical Ellipse

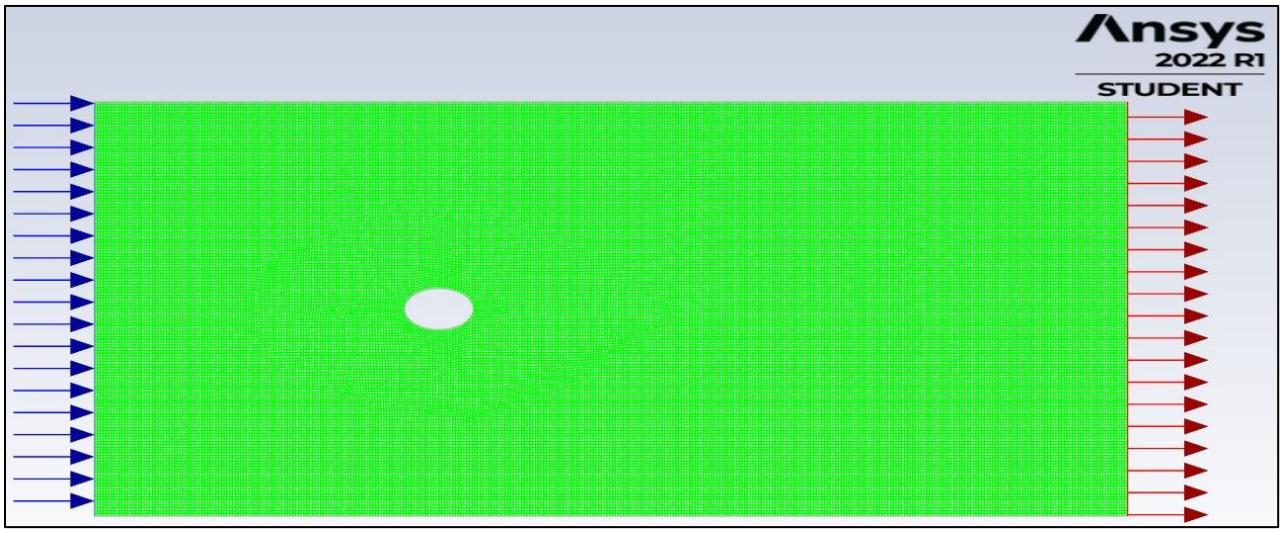

Figure 5: Geometry and Mesh representation for Run 2 - Horizontal Ellipse

D3: Plot of the *lift force v/s time* for all three cases

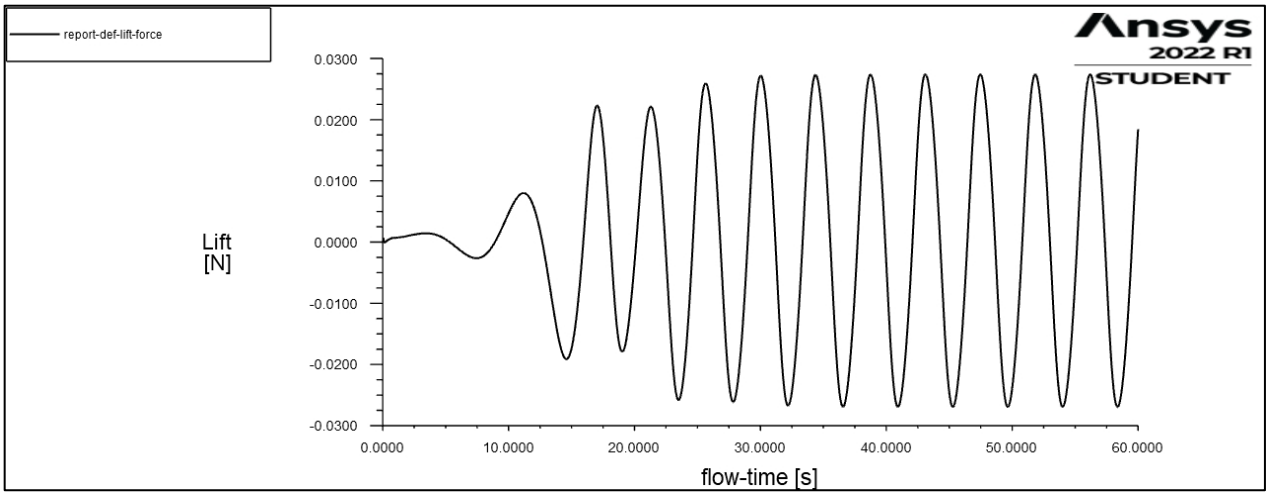

Figure 6: Lift Force v/s flow time plot from t=0 to t=1 min for Task 1 – Circular Cylinder

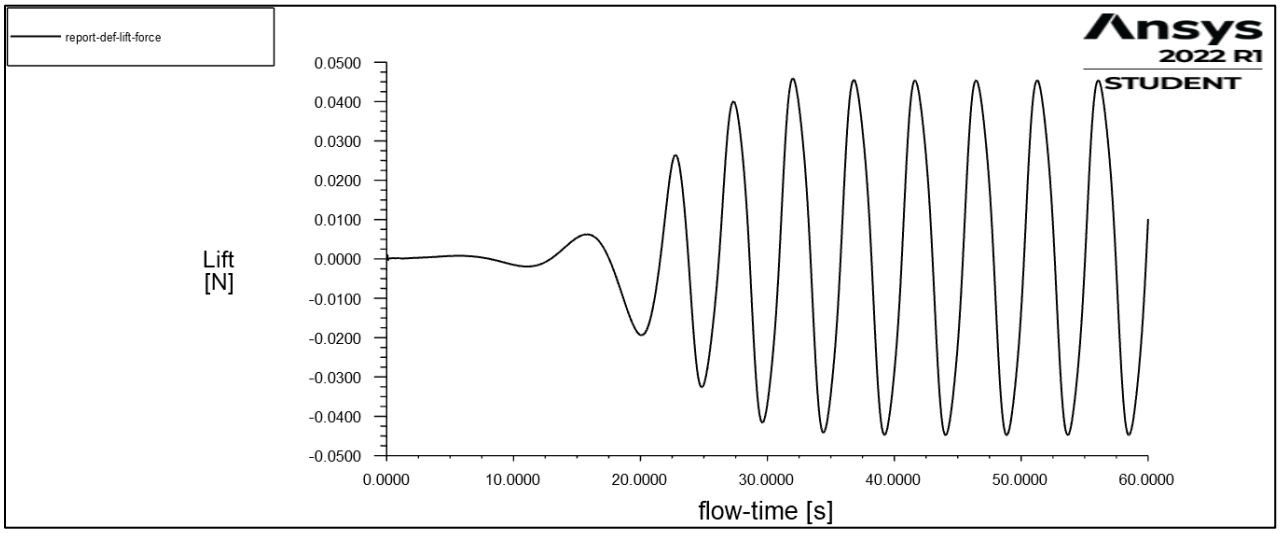

Figure 7:Lift Force v/s flow time plot from t=0 to t=1 min for Run 1 - Vertical Ellipse

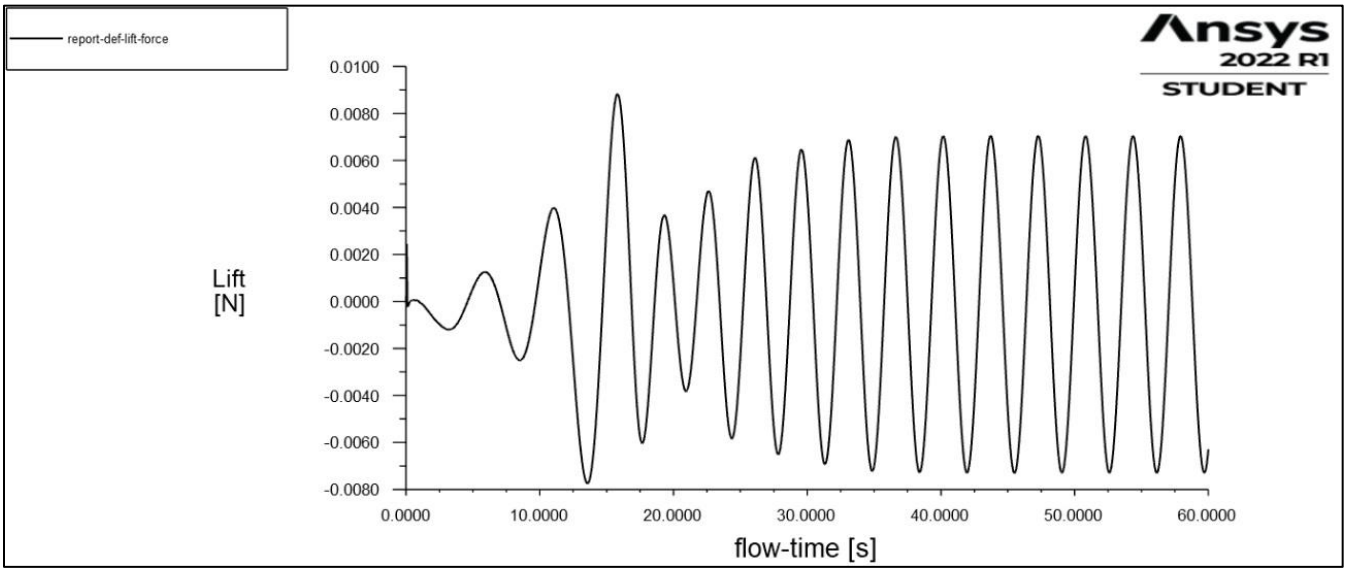

Figure 8: Lift Force v/s flow time plot from t=0 to t=1 min for Run 2 - Horizontal Ellipse

D4: Amplitude and period of oscillation for circular cylinder, Run 1 (ellipse with major axis along y-axis) and Run 2 (ellipse with major axis along x-axis)

Table 1: Amplitude and Period of oscillation for Task 1 all conditions

	Amplitude (in Newton)	Period (in second)
Circular	0.02719 N	4.35 s
Elliptical cylinder, Run 1	0.0453475 N	4.85 s
Elliptical cylinder, Run 2	0.0071735 N	3.55 s

<u>Task 2:</u> Lift and Drag forces on Flying Saucer at 10km altitude.

D5: A plot of the mesh along the plane of symmetry for the case with θ = 25° and *Mesh Size*
Mesh Size: 4e-2 m

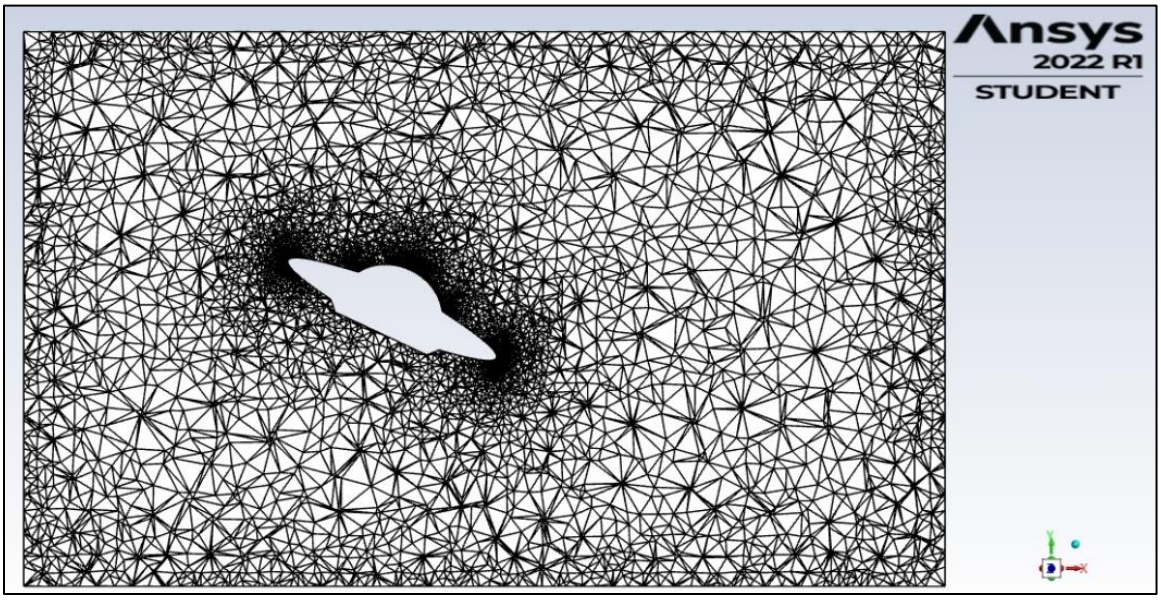

Figure 9: Plot of mesh along the plane of symmetry with Flying Saucer at 25° inclination

D6: Contour plots of x-velocity on the plane of symmetry for the three cases with θ = 0°, 25°, and 50°.

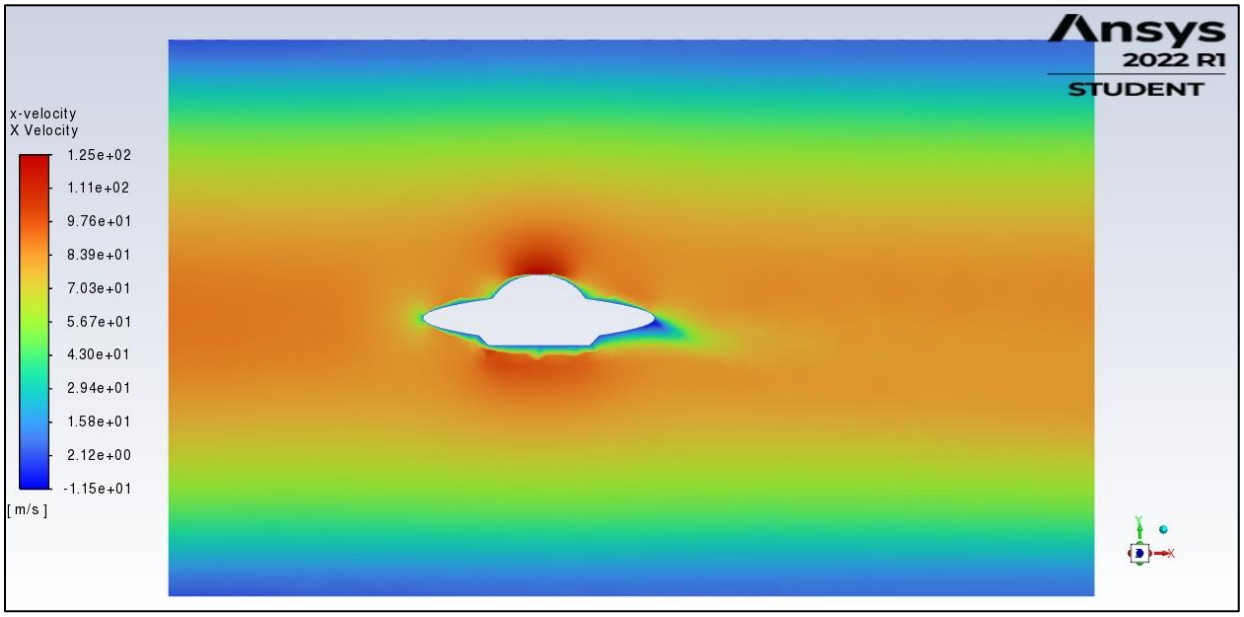

Figure 10: Contour plot of x-velocity at ϑ = 0°

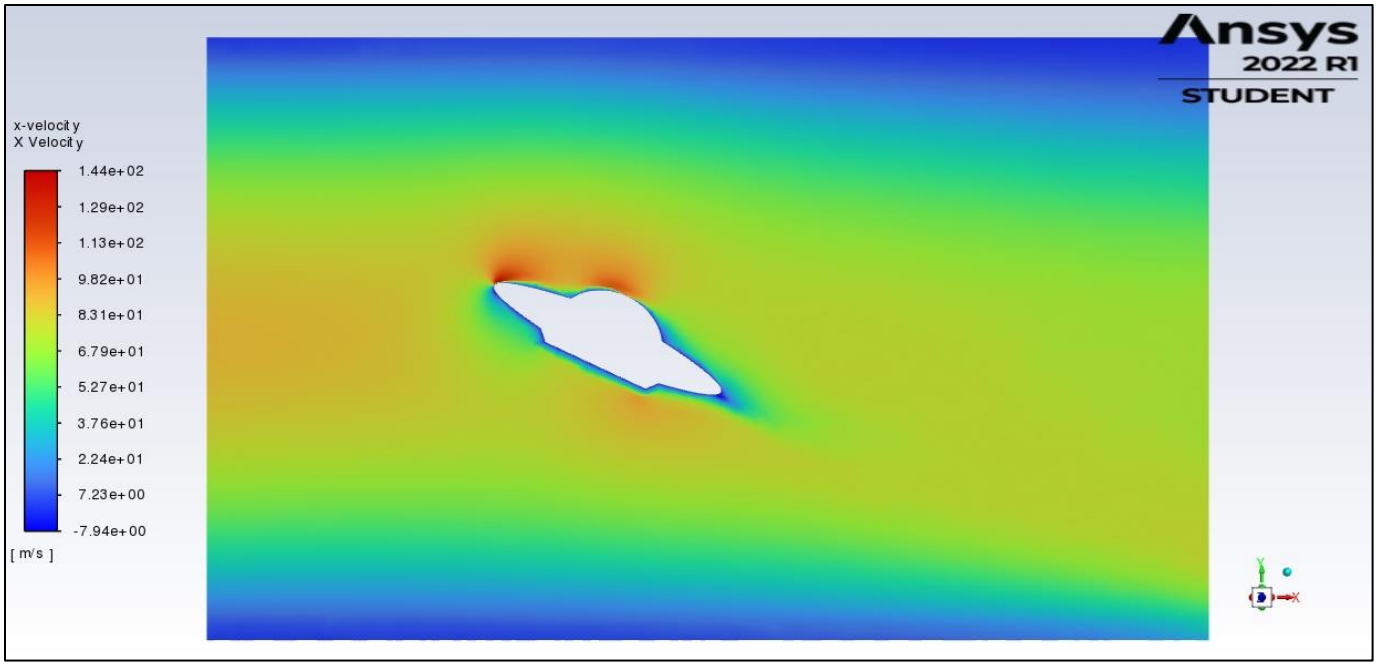

Figure 11: Contour plot of x-velocity at ϑ = 25°

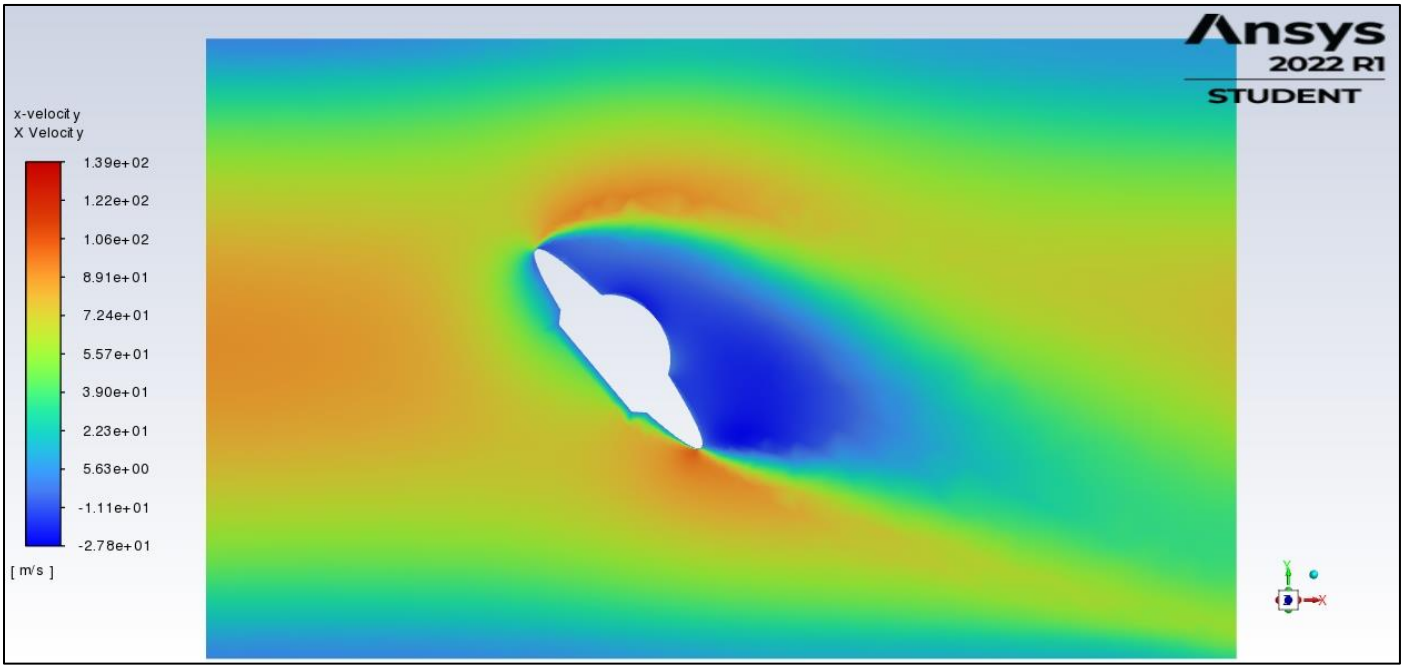

Figure 12: Contour plot of x-velocity at ϑ = 50°

D7: Values of lift force and drag force (that fluid exerts on the flying saucer) as a function of the tilt angle.

With *Standard initialization*:

	Lift force (in Newton)	***Drag force (in Newton)***
θ = 0°	12.68314 N	8.179693 N
θ = 25°	122.05 N	40.03 N
θ = 50°	80.60215 N	129.8938 N

Table 2: Lift and Drag Force as function of tilt angle for Task 2

Task 3: 3D Air flow passing over a pentagon-shaped building

D8: Contour Plots of y-velocity at z = 2.5m and at plane of symmetry

For Run 1

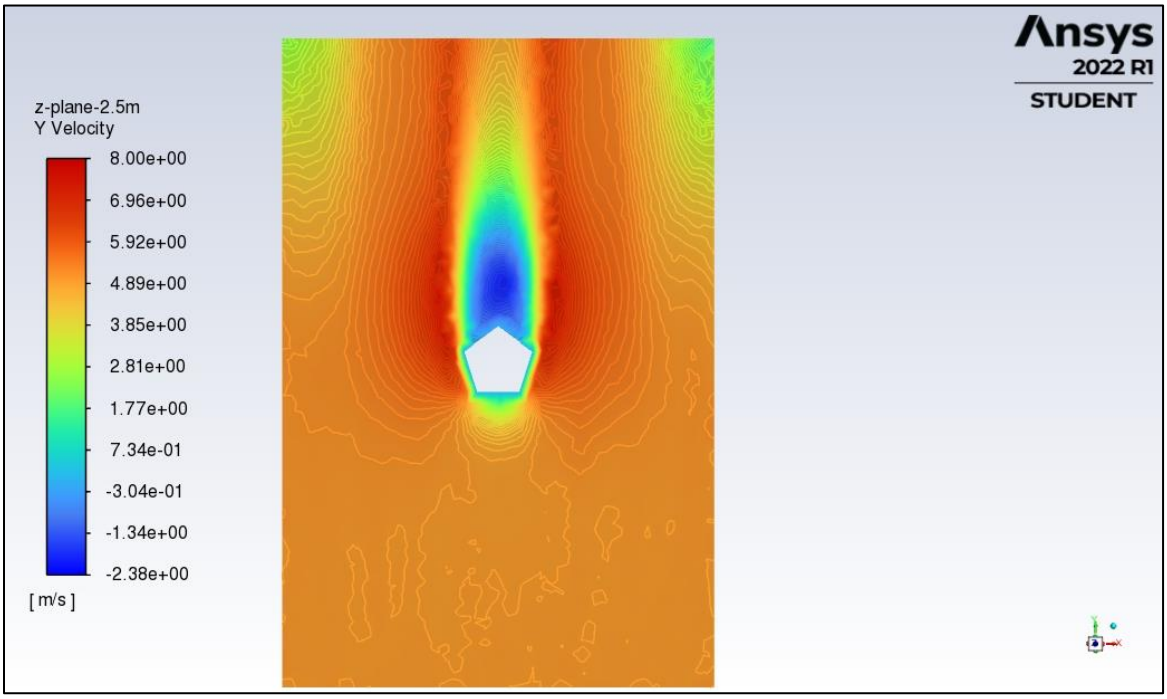

Figure 13: Contour plot of y-velocity along z-plane at 2.5m for Task 3 (Run 1)

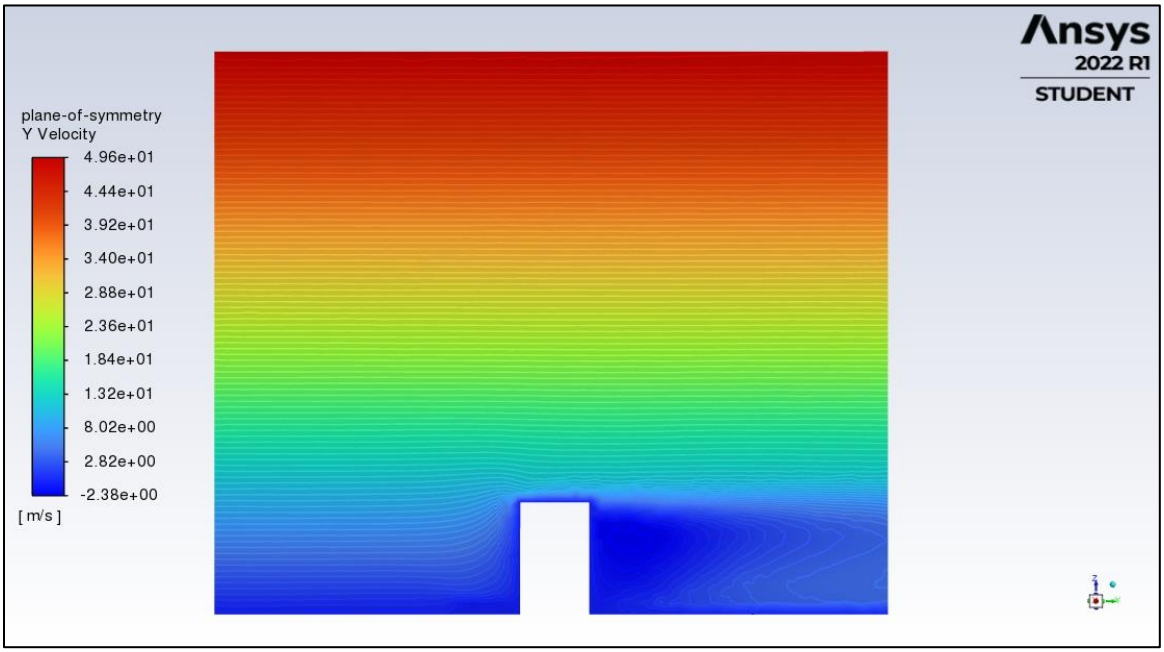

Figure 14: Contour plot of y-velocity along plane of symmetry for Task 3 (Run 1)

Description: From the above contours, it is observed that the wake formation (shadow region) has a velocity in the negative direction. Additionally, as we go above the pentagon building, the effect of building on the air flow (wind velocity) is reducing to a point that at the highest layers are practically at the same velocity i.e., ≈ 49.6 m/s.

For Run 2

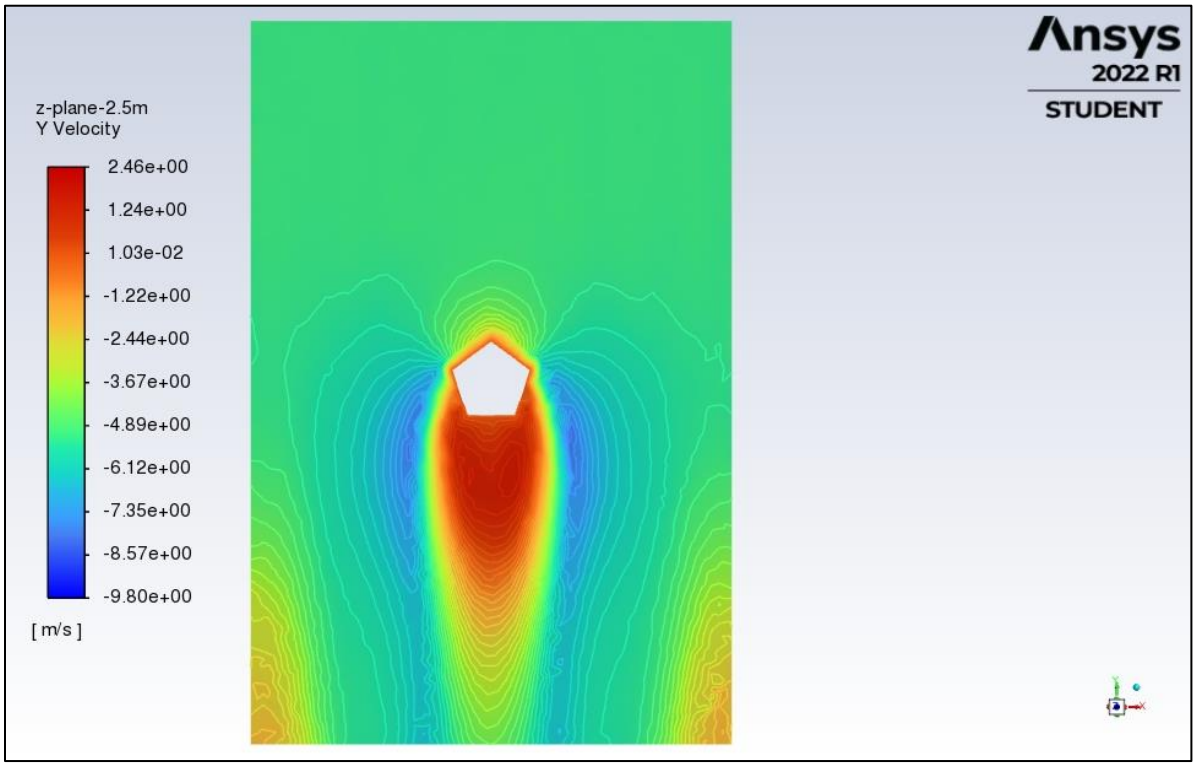

Figure 15: Contour plot of y-velocity along z-plane at 2.5m for Task 3 (Run 2)

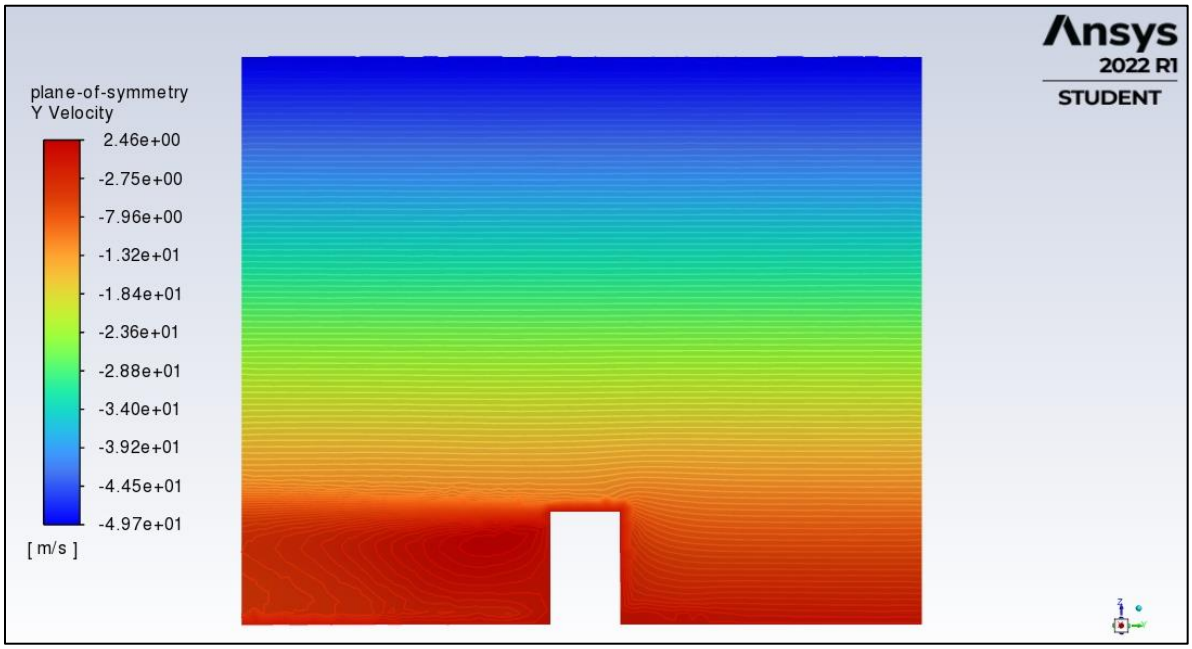

Figure 16: Contour plot of y-velocity along plane of symmetry for Task 3 (Run 2)

D9: Values of total drag force and individual pressure and viscous term

	Total drag (N)	Pressure term of drag (N)	Viscous term of drag (N)
Run 1	363.95924	363.26703	0.69220895
Run 2	488.82443	488.48224	0.34219116

Table 4: Values of total drag force and individual pressure and viscous term for Task 3

Note: For *Run 2*, the inlet velocity is entered in the -y direction. Therefore, the higher velocity magnitude is observed in the negative range and the wake region has positive velocity, contrary to the contour of *Run 1*.

Task 4: Laminar flow over an asymmetric shape for 1 min

D10: Contour plot of the stream function at t = 1 min

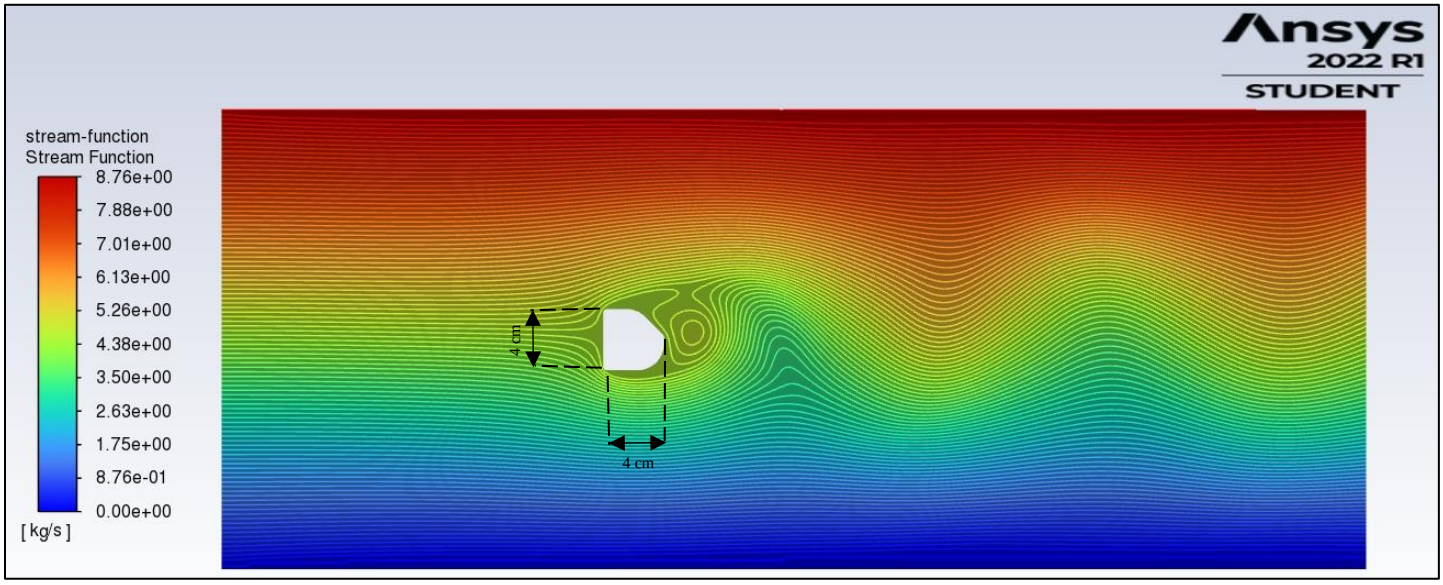

Figure 17: Stream-function over an asymmetric shape at t = 1 min

D11: Plot of lift force vs. time

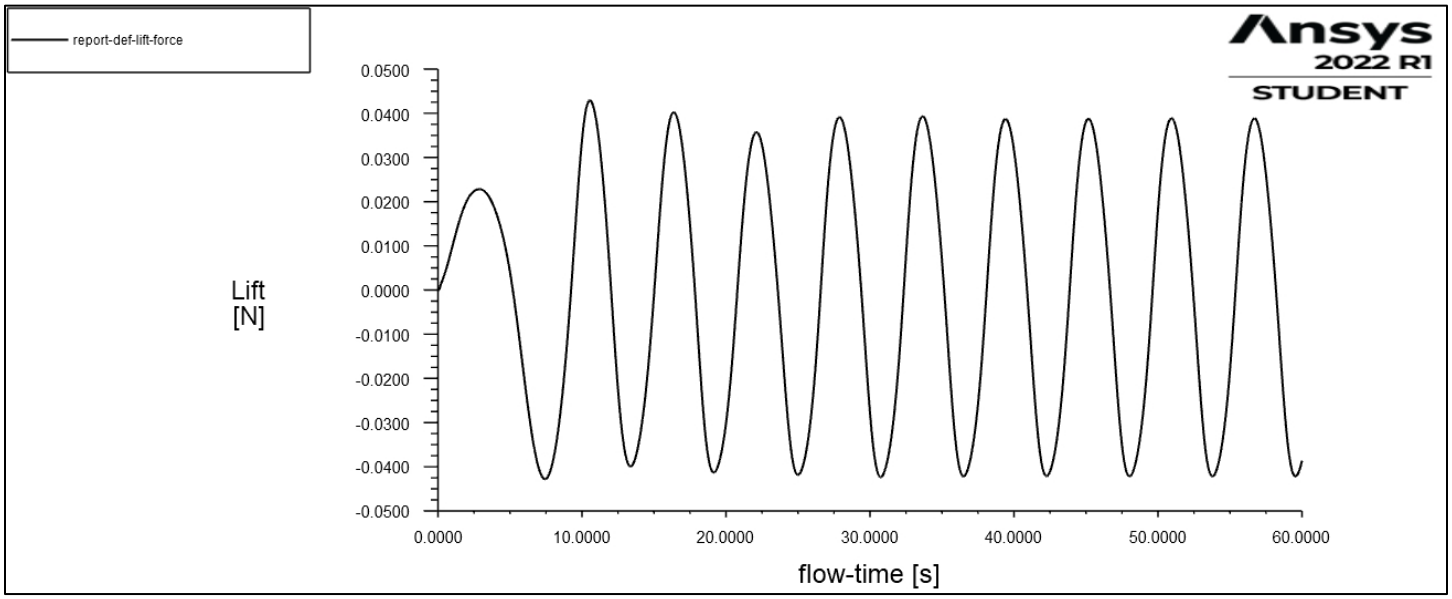

Figure 18: Plot of lift force v/s flow time for 1 min

Geometry: The overall width and height of the geometry is *4 cm*. Comparable with the Task 1 circular geometry.

Description: With the above asymmetric geometry, it is evident that the *Lift Force [N]* is oscillating between ± 0.05 N which is relatively higher than the circular and vertical ellipse cross-section cylinder. The period is ≈ 6 sec.