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MAE598: Applied CFD
Project 4

Task 1:

Task one was completed using the geometry and boundary conditions provided. The mesh was created using the settings shown in Table 1 below. The mesh and mesh stats can be seen in Figure 1 below.

Table 1: Mesh Settings (other than default)

Mesh Settings	
Size Function	Proximity and Curvature
Relevance Center	Fine
Max Face Size	0.005m
Smoothing	High

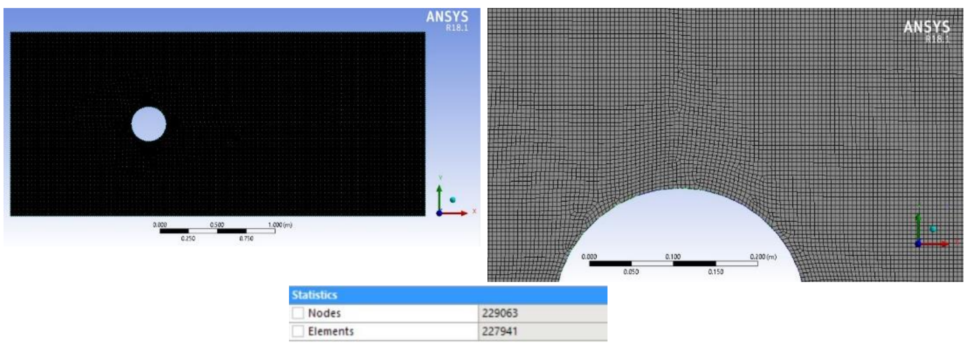


Figure 1: Shows the mesh as a whole (left) and zoomed in (right) as well as the mesh statistics (bottom).

For Task 1a, the Reynolds number, Re, was estimated to be 554 using equation (1) shown below.

$$Re = \frac{V_x L_c}{\nu} \quad (1)$$

Where V_x is the velocity along the x-axis (0.005 m/s), L_c is the characteristic length (the diameter of the circle) (0.3 m) and ν is the kinematic viscosity of kerosene (2.71E-06 m^2/s). The contour plots of the x-velocity, the y-velocity, and the static pressure for the solution at t = 1 hour are shown below in Figures 2, 3 and 4.

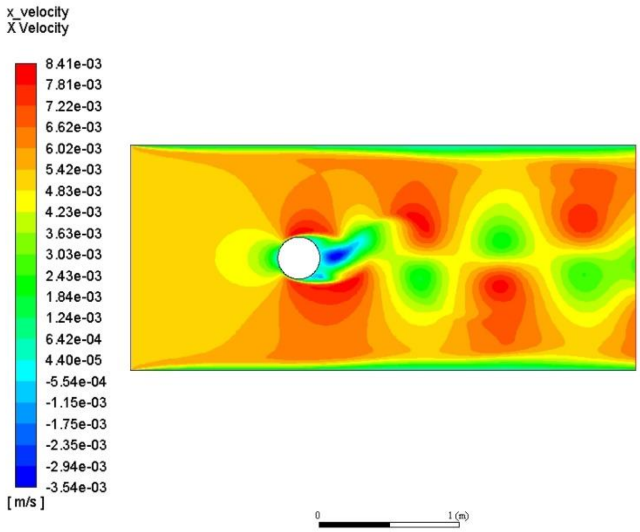


Figure 2: Shows the contour plot of the velocity in the x-direction at t=1hr.

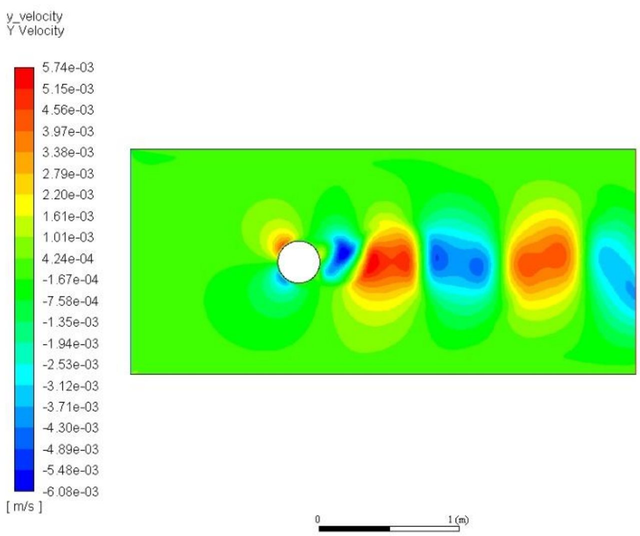


Figure 3: Shows the contour plot of the velocity in the y-direction at t=1hr.

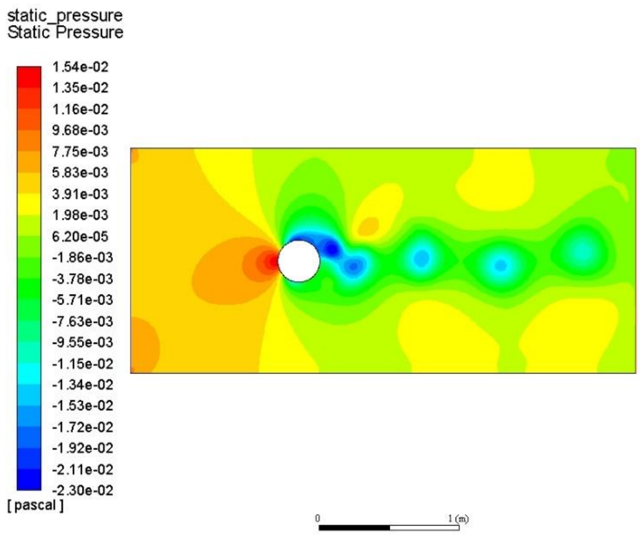


Figure 4: Shows the contour plot of the static pressure at t=1hr.

A plot of the drag coefficient and lift coefficient as a function of time over the last 30 minutes of the simulation is shown below in Figure 5. It is shown that both the drag and lift coefficients are oscillating with time. The flow was estimated to be oscillating in the x-direction with a period of 123 seconds and in the y-direction with a period of 246 seconds.

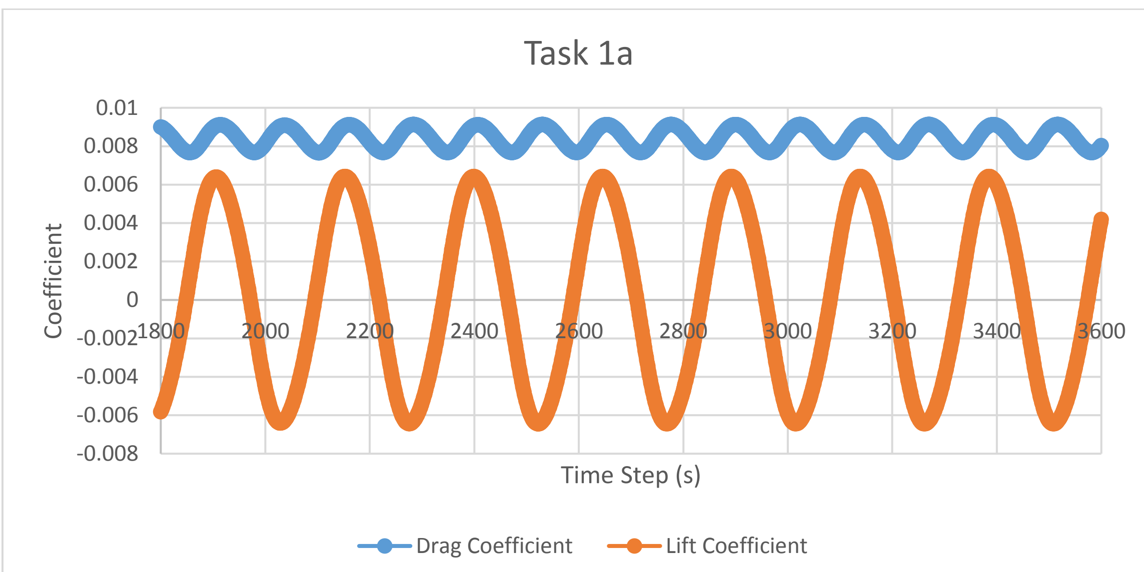


Figure 5: Shows the drag coefficient and lift coefficient as a function of time from t=30min to t=1hr.

For Task 1b, the Reynolds number was estimated to be 99 when the kinematic viscosity of air is 1.516E-05 m^2/s. The contour plots of the x-velocity, the y-velocity, and the static pressure for the solution at t = 1 hour are shown below in Figures 6, 7 and 8.

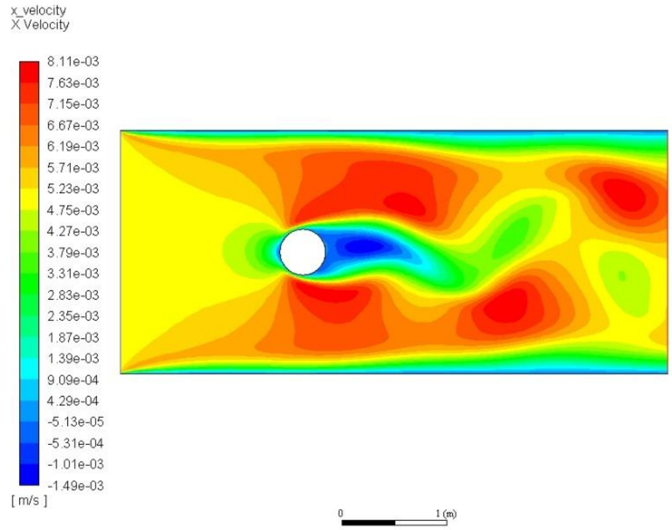


Figure 6: Shows the contour plot of the velocity in the x-direction at t=1hr.

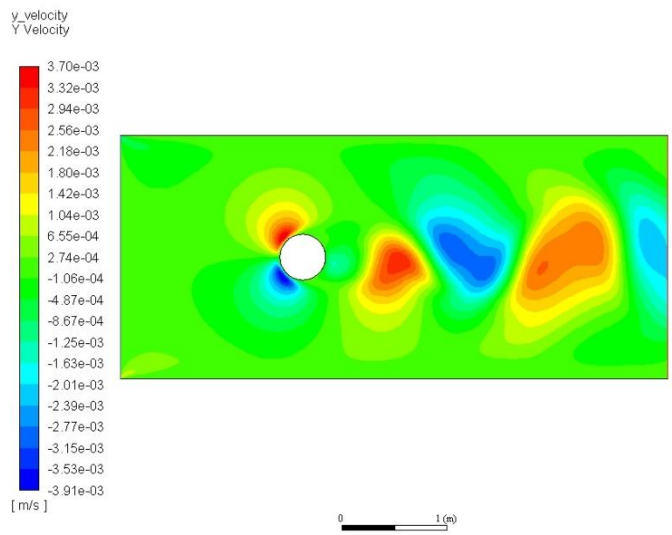


Figure 7: Shows the contour plot of the velocity in the y-direction at t=1hr.

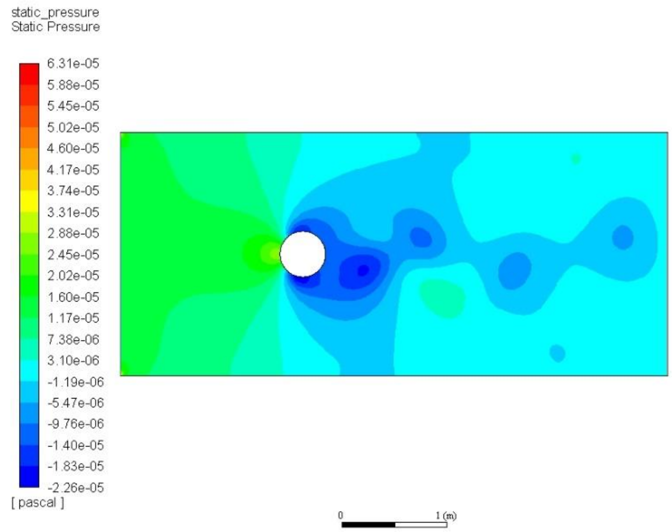


Figure 8: Shows the contour plot of the static pressure at t=1hr.

A plot of the drag coefficient and lift coefficient as a function of time over the last 30 minutes of the simulation is shown below in Figure 9. For this case, the drag coefficient is fairly constant showing a very slight upward oscillation while the lift coefficient has an oscillation with growing amplitude in time. The flow was estimated to be oscillating in the x-direction with a period of 152 seconds and in the y-direction with a period of 291 seconds.

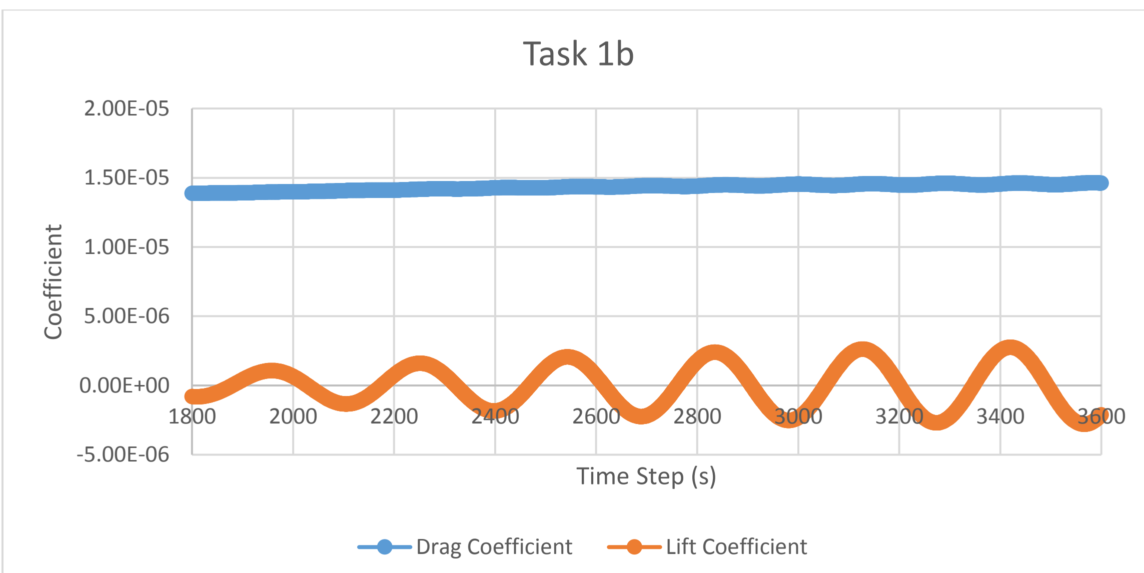


Figure 9: Shows the drag coefficient and lift coefficient as a function of time from t=30min to t=1hr.

For task 1c, two cases of an ellipse where analyzed, an ellipse elongated in the y-direction, with the lengths of its major and minor axes 36 cm and 24 cm (the major axis is parallel to y-axis) and an ellipse elongated in the x-direction, with the lengths of its major and minor axes 36 cm and 24 cm (the major axis is parallel to x-axis). The drag coefficient and lift coefficient as a function of time over the last 30 minutes of the simulations is shown below in Figures 10 and 11.

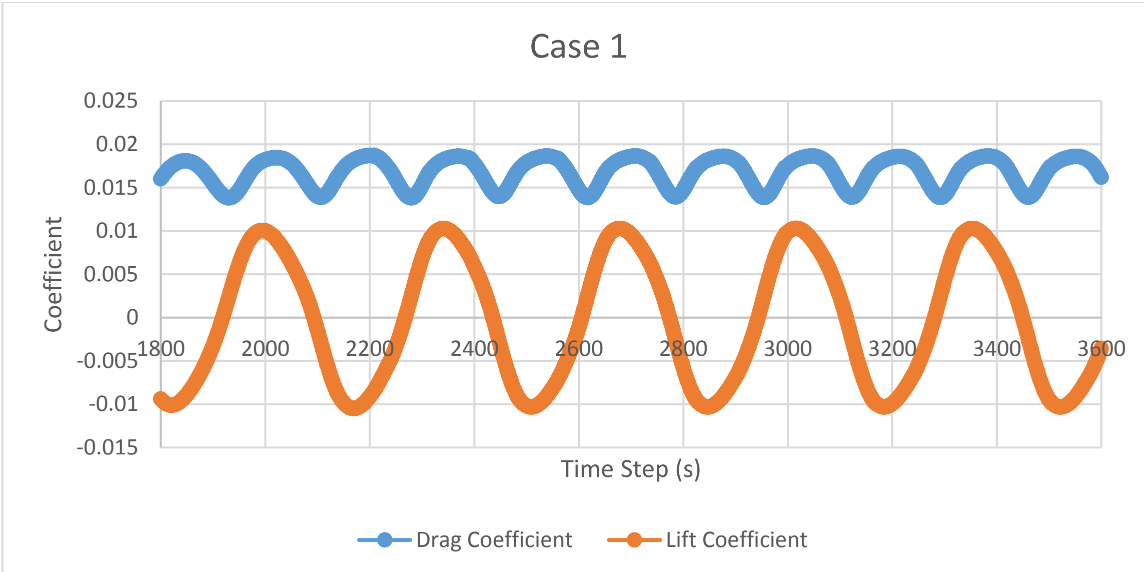


Figure 10: Shows the drag coefficient and lift coefficient as a function of time from t=30min to t=1hr for the case where the major ellipse is axis is oriented vertically.

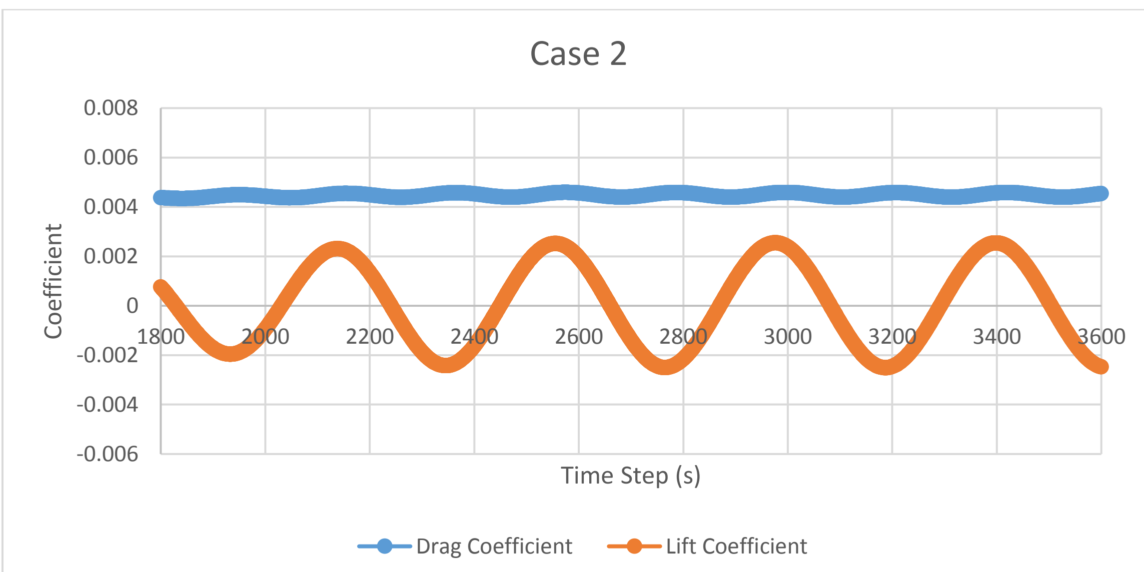


Figure 11: Shows the drag coefficient and lift coefficient as a function of time from t=30min to t=1hr for the case where the major ellipse is axis is oriented horizontally.

Table 2 below compares the period and amplitude of cases 1 and 2 to Task 1a.

Table 2: Comparison of Case 1 and 2 to Task 1a

	Drag Coefficient		Lift Coefficient	
	Amplitude	Period (s)	Amplitude	Period (s)
Case 1	0.01368	177	0.01030	347
Case 2	0.00423	206	0.00255	417
Task 1a	0.00732	123	0.00644	246

Task 2:

Task two was completed using the geometry and boundary conditions provided. The mesh was created using the settings shown in Table 3 below. The mesh and mesh stats can be seen in Figure 12 below.

Table 3: Mesh Settings (other than default)

Mesh Settings	
Size Function	Proximity and Curvature
Relevance Center	Fine
Max Face Size	0.005m
Smoothing	High

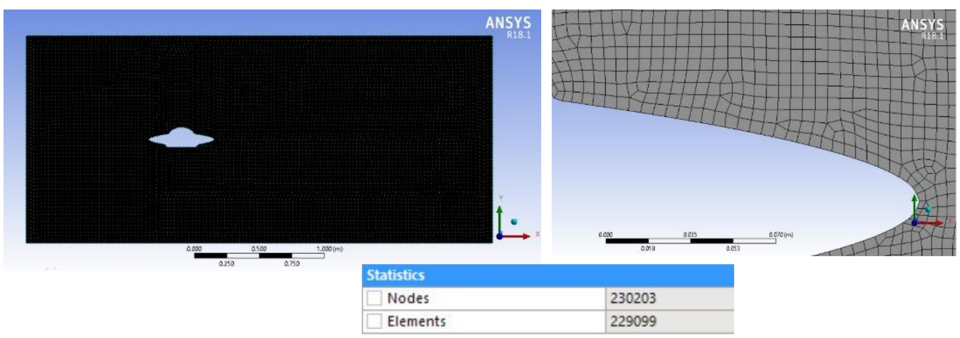


Figure 12: Shows the mesh as a whole (left) and zoomed in (right) as well as the mesh statistics (bottom).

For task 2a, the contour plots of the x-velocity, y-velocity and static pressure, for the steady state solution is shown below in Figures 13, 14 and 15.

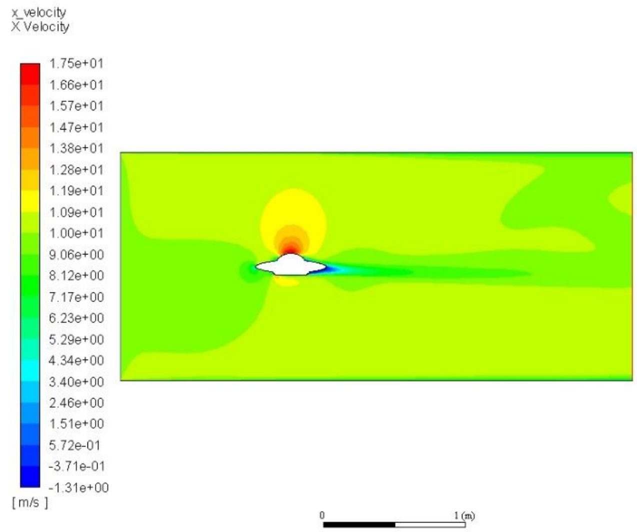


Figure 13: Shows the contour plot of the velocity in the x-direction at steady state.

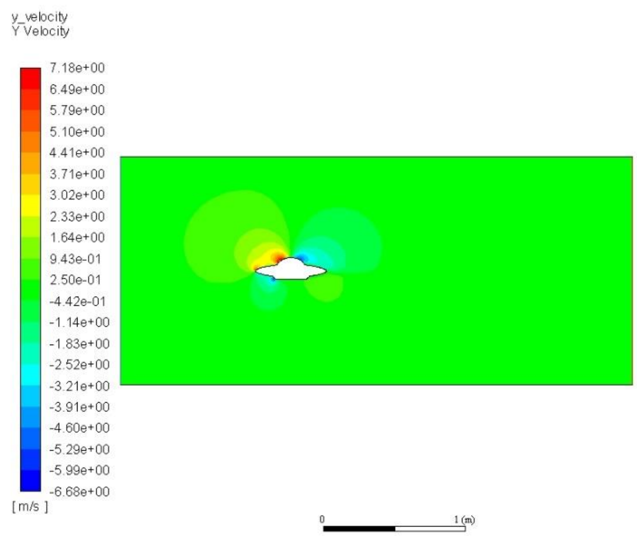


Figure 14: Shows the contour plot of the velocity in the y-direction at steady state.

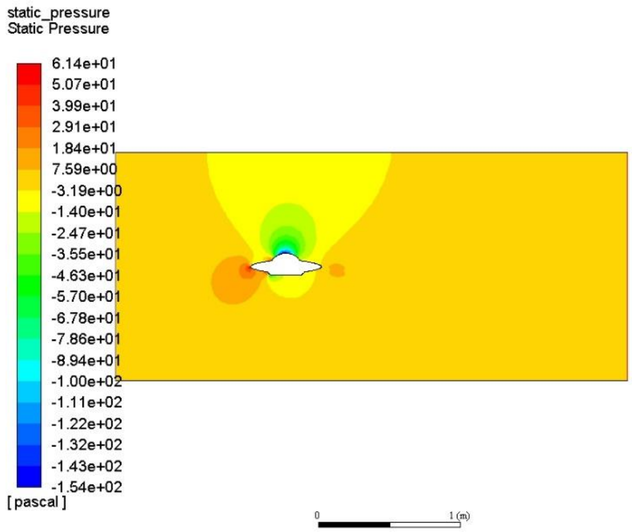


Figure 15: Shows the contour plot of the static pressure at steady state.

Using fluent's built-in force reporting, the drag force was found to be 2.599 N and the lift force was found to be 18.441 N when at steady state.

For task 2b, the saucer was rotated -30° and a transient simulation was run for t=1hr. The contour plots of the x-velocity, y-velocity and static pressure, for the steady state solution is shown below in Figures 16, 17 and 18.

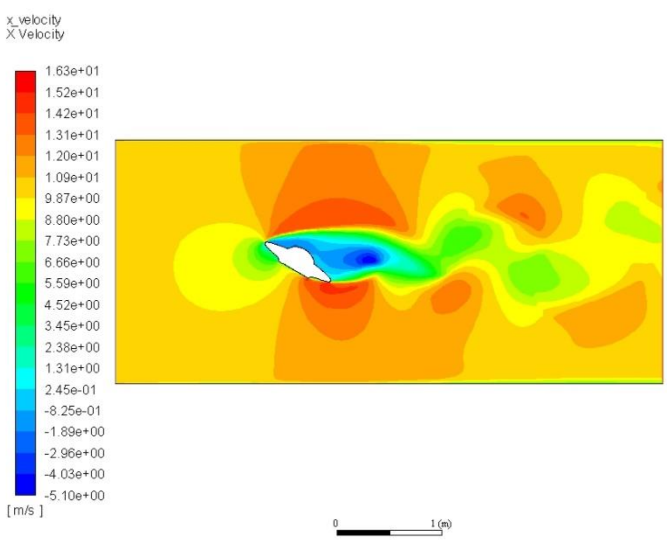


Figure 16: Shows the contour plot of the velocity in the x-direction at steady state.

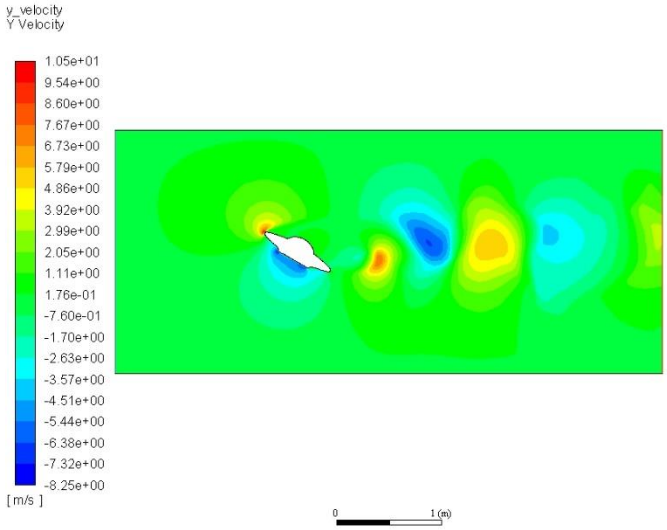


Figure 17: Shows the contour plot of the velocity in the y-direction at steady state.

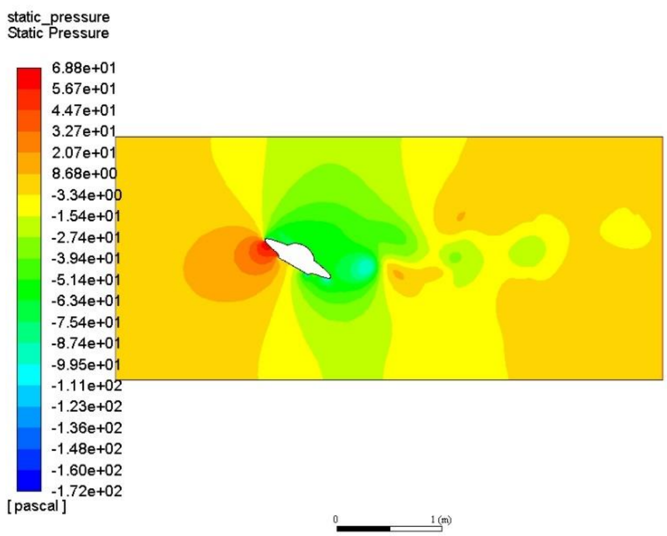


Figure 18: Shows the contour plot of the static pressure at steady state.

A plot of the drag force and lift force as a function of time over the last 30 minutes of the simulation is shown below in Figure 19. For this case, the drag force and lift force have a constant oscillation with respect to time. The drag force and the lift force oscillate in time with the same period of 78 seconds. Taking the averages over this oscillation, the average drag force was found to be 18.6 N and the average lift force was found to be 17.9 N.

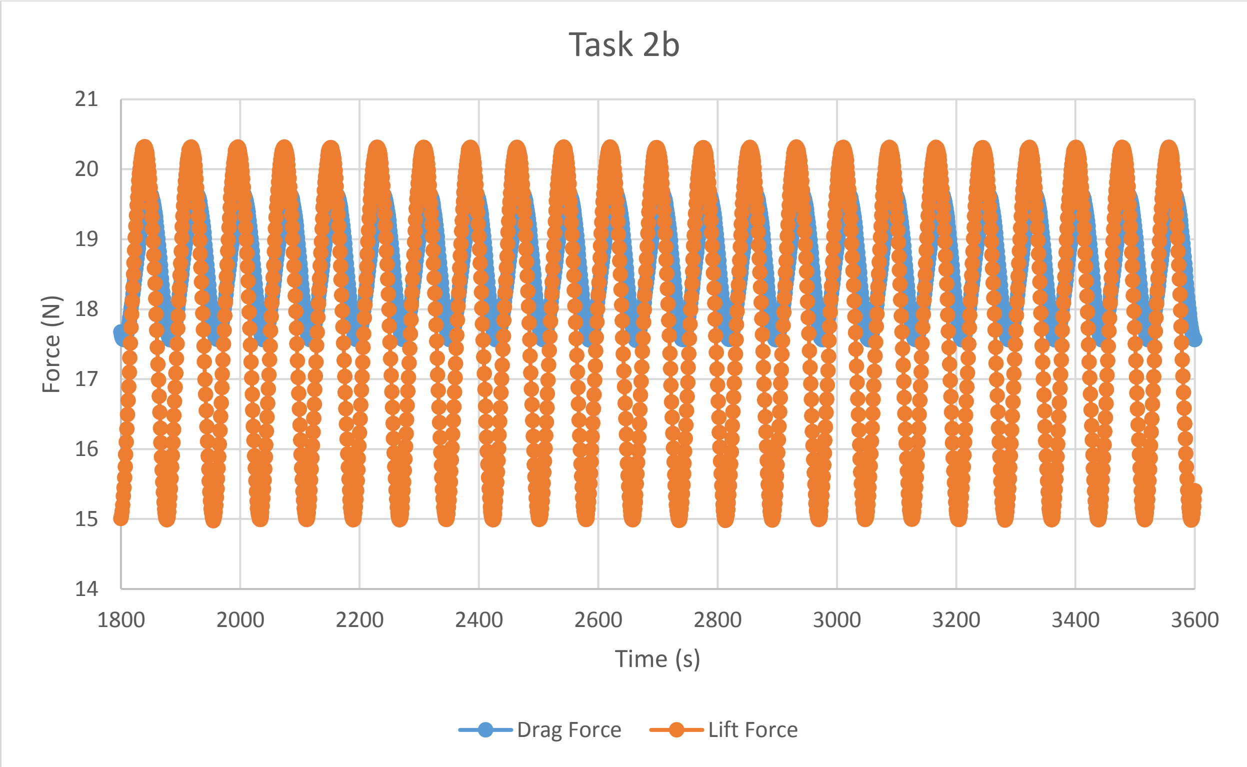


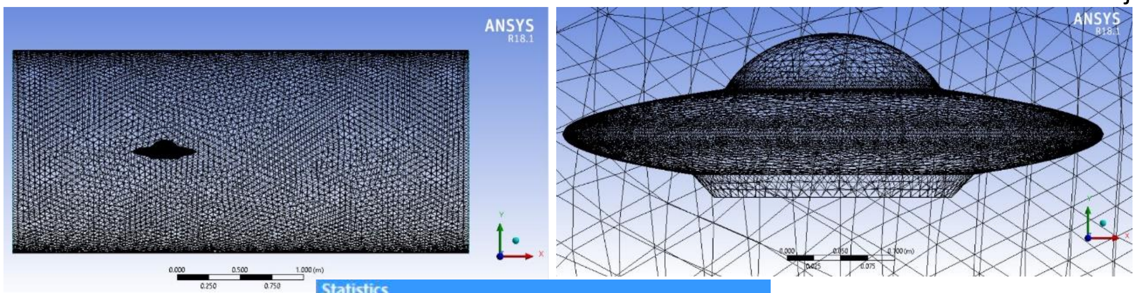
Figure 19: Shows the drag force and lift force as a function of time from t=30min to t=1hr.

Task 3:

Task three was completed using the geometry and boundary conditions provided. The mesh was created using the settings shown in Table 3 below. The mesh and mesh stats can be seen in Figure 20 below.

Table 3: Mesh Settings (other than default)

Mesh Settings	
Size Function	Proximity and Curvature
Relevance Center	Fine
Max Face Size	0.05m
Smoothing	High



Statistics	
Nodes	811733
Elements	578081

Figure 20: Shows the mesh as a whole (left) and zoomed in (right) as well as the mesh statistics (bottom).

For task 3a, the contour plots of the x-velocity and static pressure on the xy-planes and xz-planes, for the steady state solution is shown below in Figures 21, 22, 23 and 24.

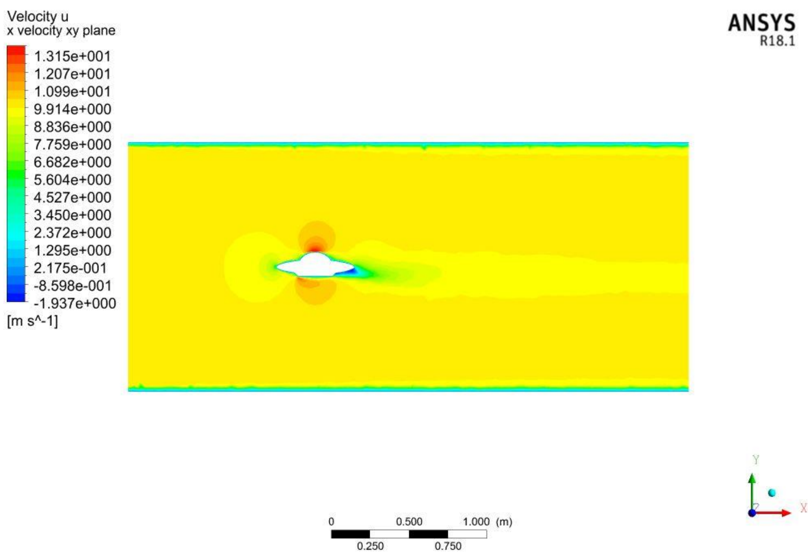


Figure 21: Shows the contour plot of the velocity in the x-direction on the xy-plane at steady state.

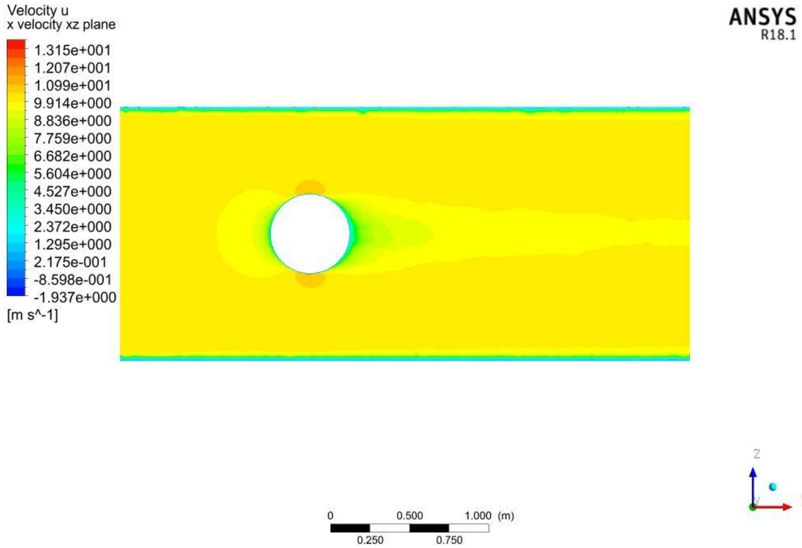


Figure 22: Shows the contour plot of the velocity in the x-direction on the xz-plane at steady state.

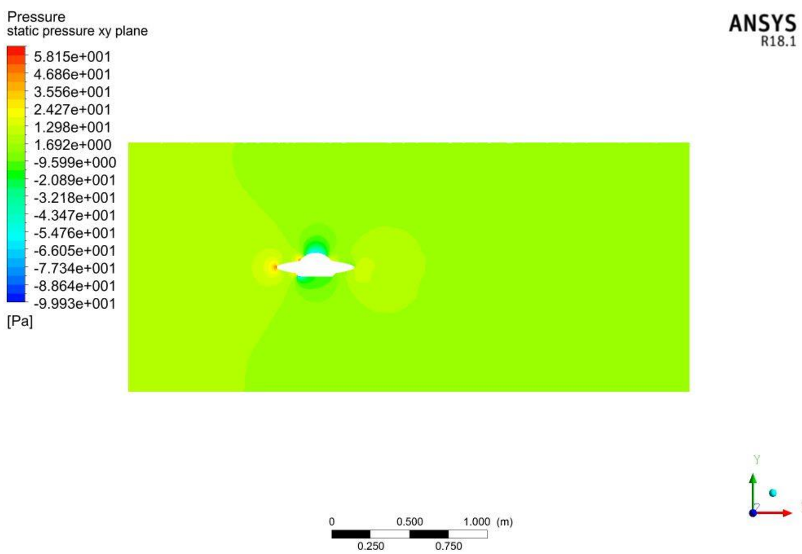


Figure 23: Shows the contour plot of the static pressure on the xy-plane at steady state.

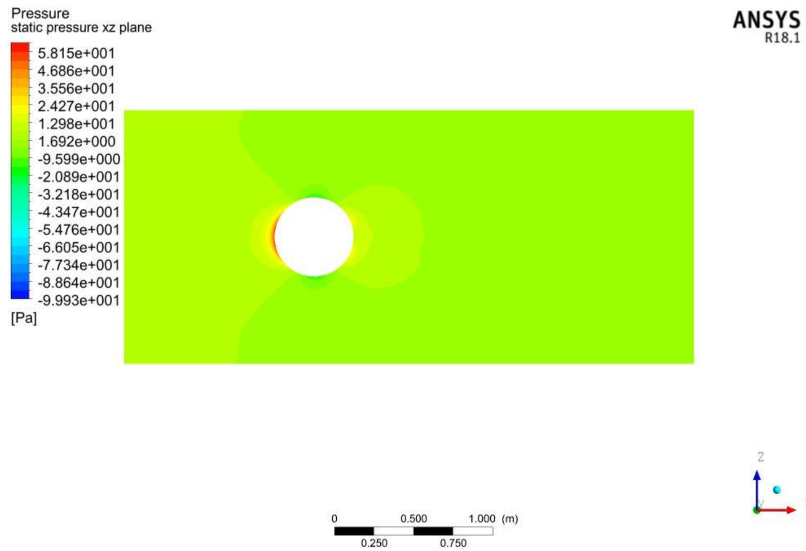


Figure 24: Shows the contour plot of the static pressure on the xz-plane at steady state.

Using fluent's built-in force reporting, the drag force was found to be 0.597 N and the lift force was found to be 0.515 N when at steady state.

For task 3b, the saucer was rotated about the origin to form angle θ with the xz-plane, which was set equal to 15°, 30° and 45°. The contour plots of the x-velocity along the plane of symmetry for the steady state solution of the three different angles is shown below in Figures 25, 26 and 27.

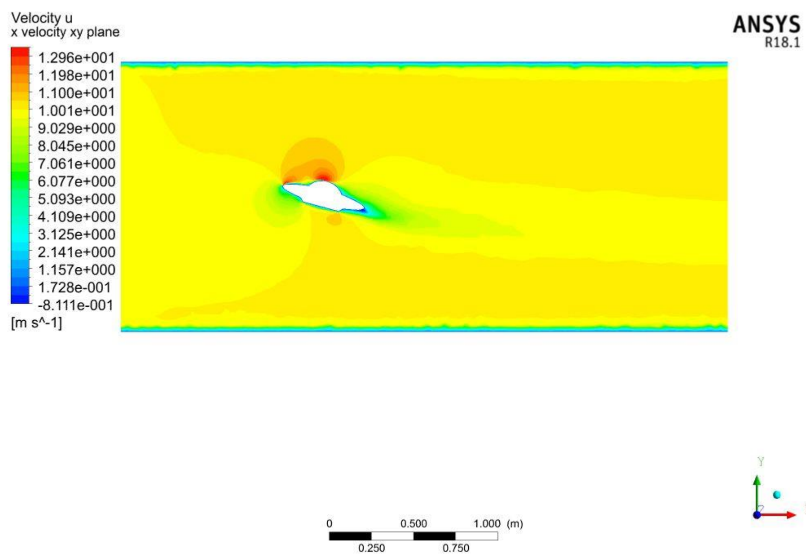


Figure 25: Shows the contour plot of the velocity in the x-direction along the plane of symmetry at steady state when the saucer is rotated by 15°.

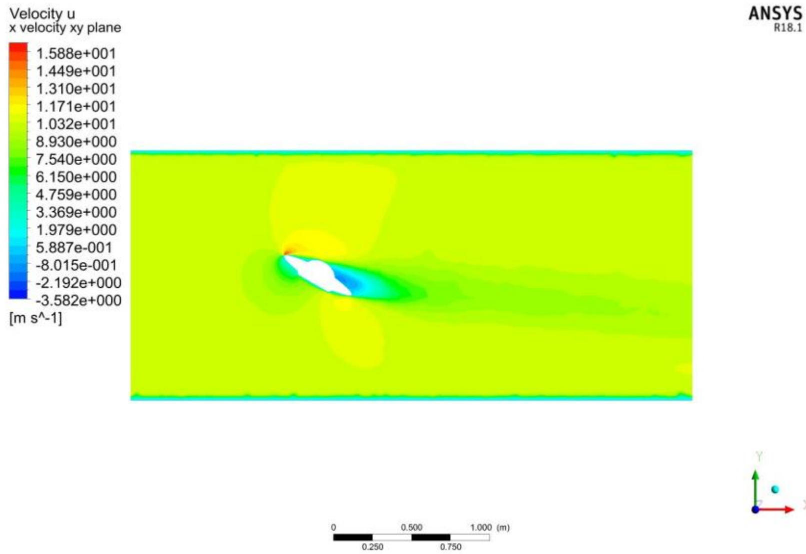


Figure 26: Shows the contour plot of the velocity in the x-direction along the plane of symmetry at steady state when the saucer is rotated by 30°.

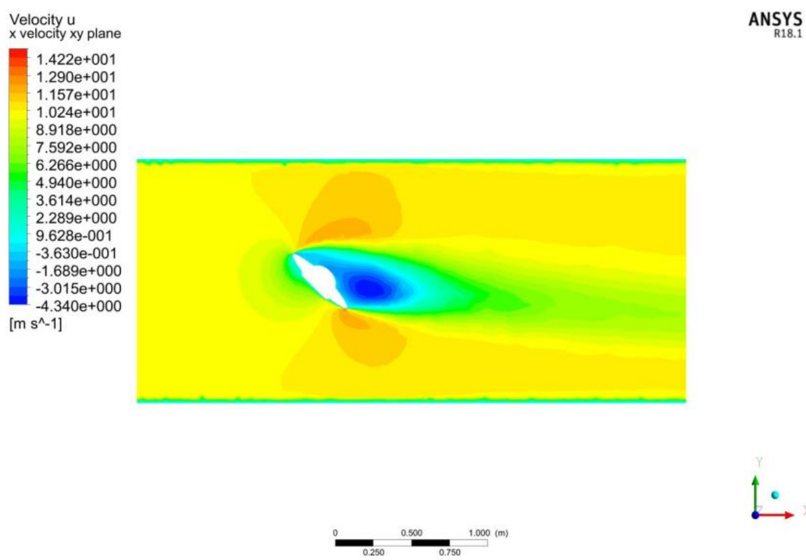


Figure 27: Shows the contour plot of the velocity in the x-direction along the plane of symmetry at steady state when the saucer is rotated by 45°.

The drag force and lift force were plotted as a function of the tilt angle θ and can be seen below in Figure 28.

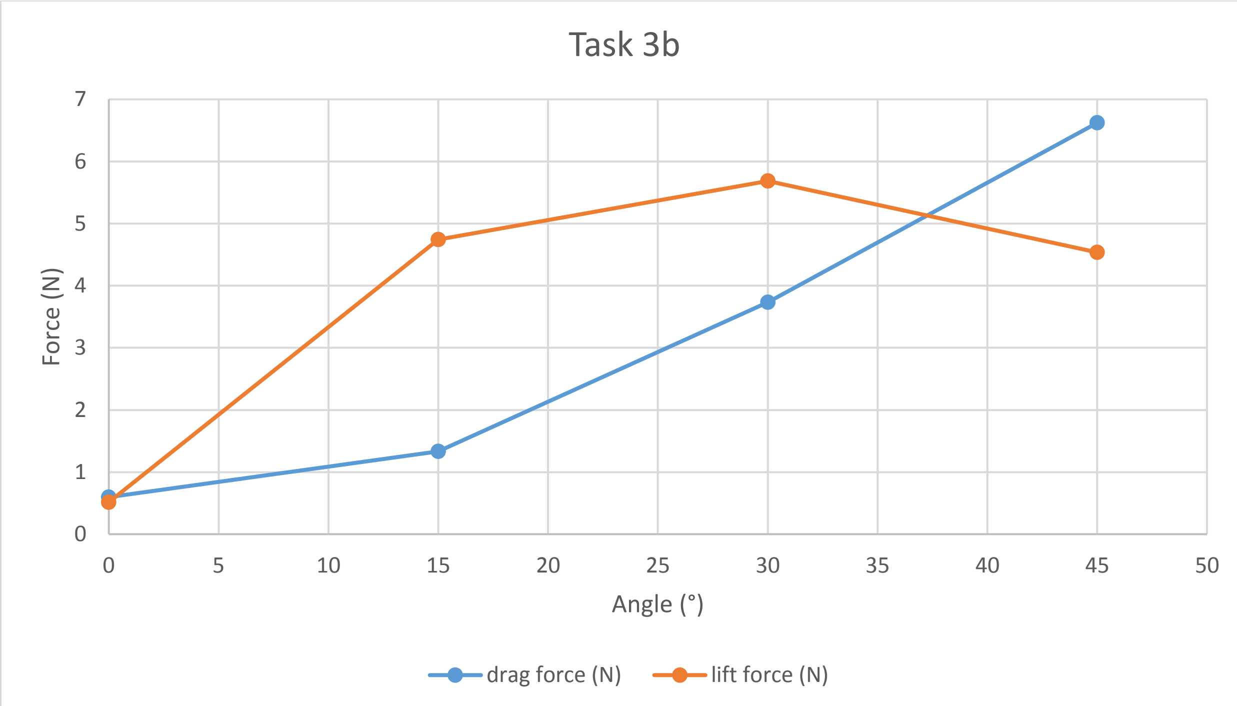


Figure 28: Shows the drag force and lift force as a function of the tilt angle θ.

References

1. Cengel, Y. A., & Ghajar, A. J. (2011). *Heat and Mass Transfer (4th ed.).* Green Park Extension, New Dehli: McGraw Hill Education.