Task 1 (a)

(1)An estimation of Reynolds number of the system.

$$R \sim \frac{UD}{\nu} \quad and\ \nu = \frac{\mu}{\rho}$$

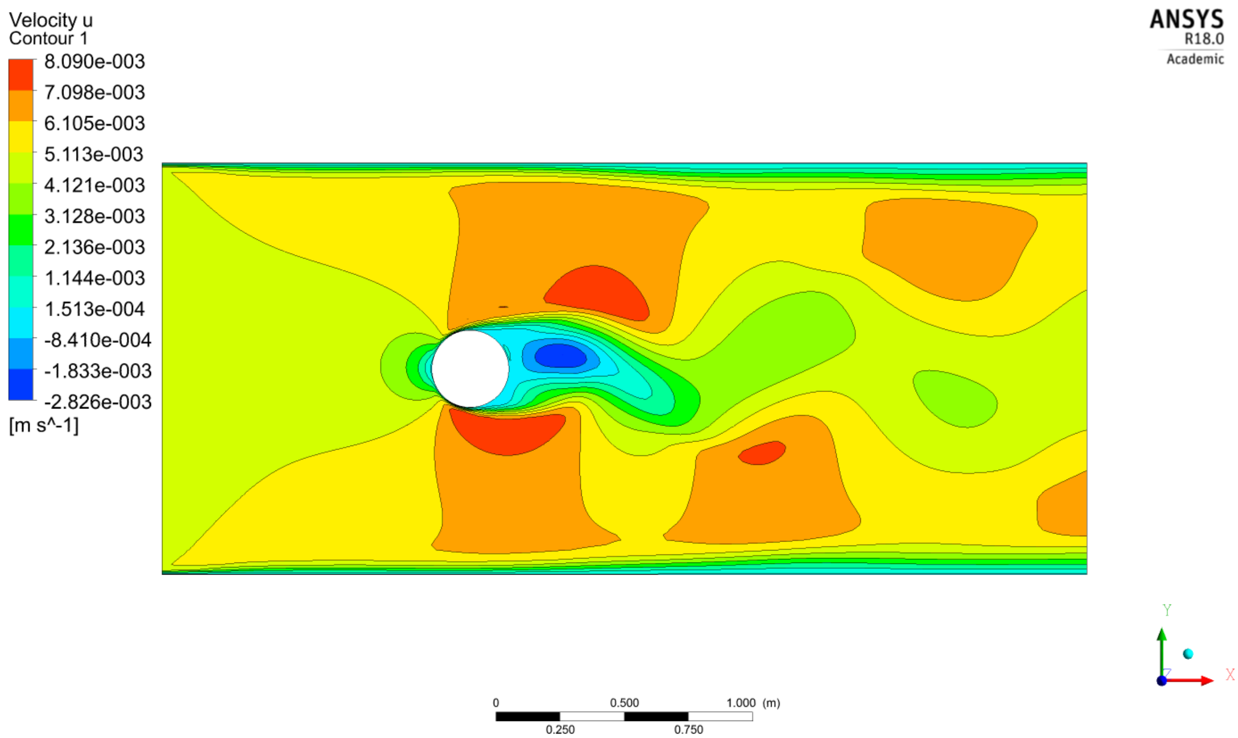
For liquid kerosene and given conditions,

$$U = 0.005\frac{m}{s}, D = 30cm, \mu = 0.0024\frac{kg}{ms}, \rho = 780\ kg/m^3$$

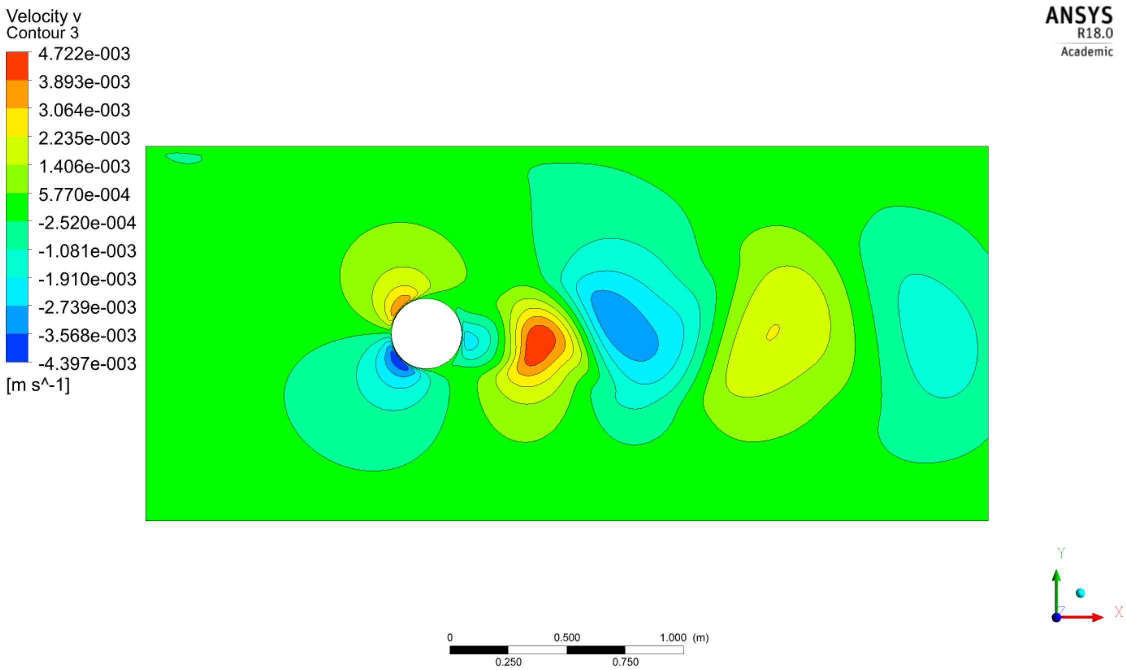
$$R \sim \frac{(0.005\frac{m}{s})(30cm)(780\frac{kg}{m^3})}{0.0024\frac{kg}{ms}} = 487.5$$

(2) Contour Plots of x-velocity, y-velocity, and static pressure at t = 1 hour.

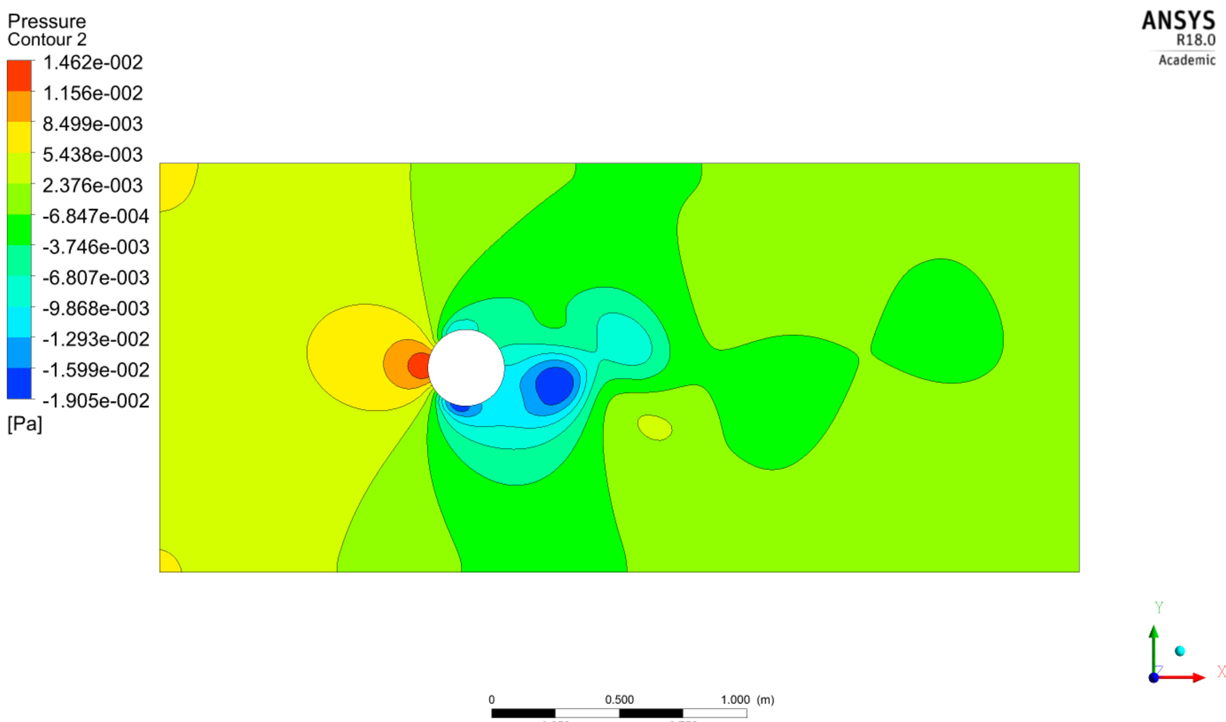
(i) x-velocity



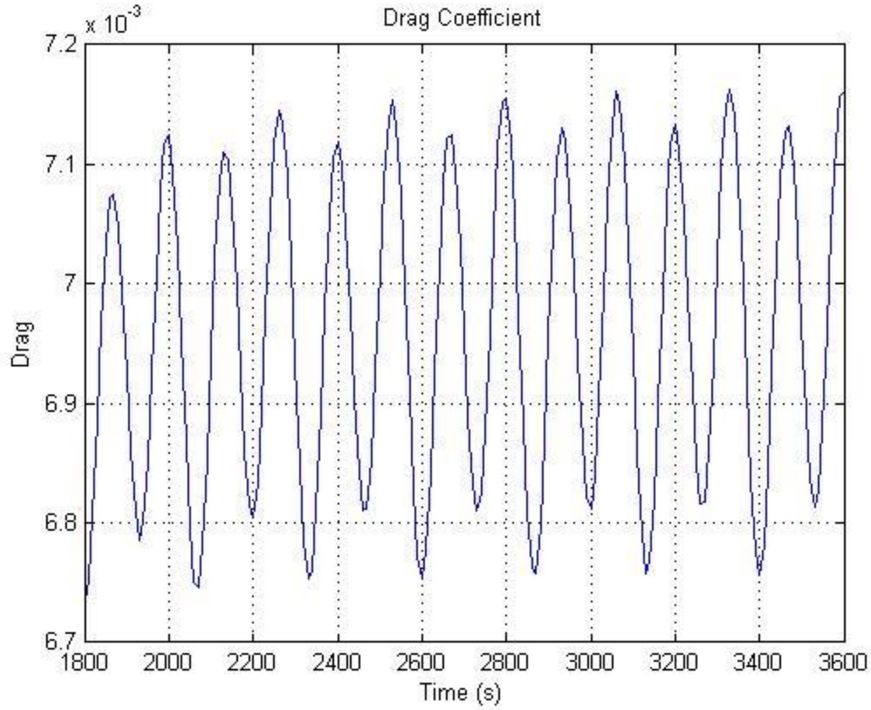
(ii) y-velocity



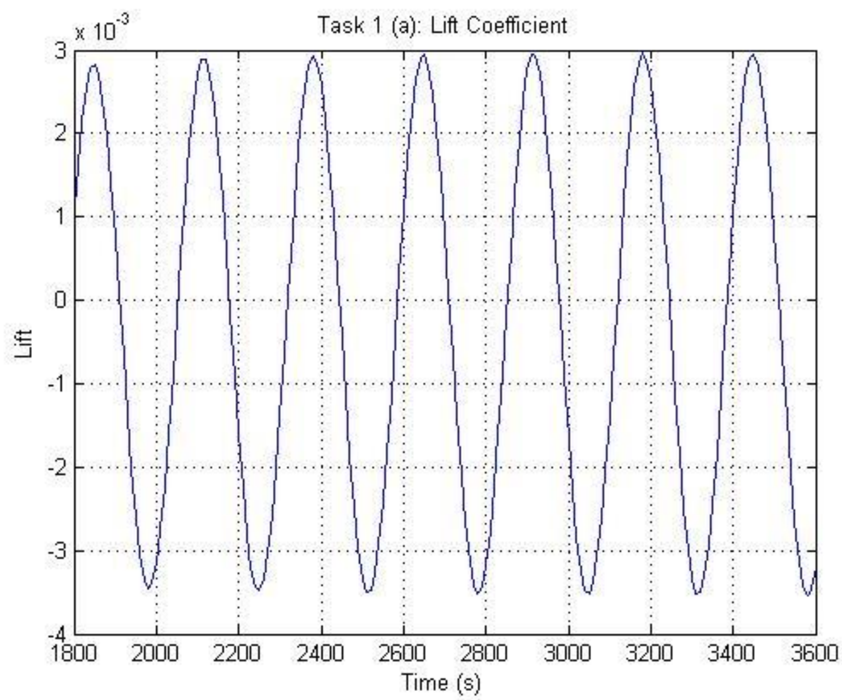
(iii) Static pressure



(3) Plot of drag coefficient and lift coefficient.



The flow does oscillate in time for this case. The estimation of period of oscillation is made from the above graph, and it is around 135s for drag.



The estimation of period of oscillation for the lift is 265s.

Task 1 (b)

(1) An estimation of Reynolds number of the system.

$$R \sim \frac{UD}{\nu} \quad and\ \nu = \frac{\mu}{\rho}$$

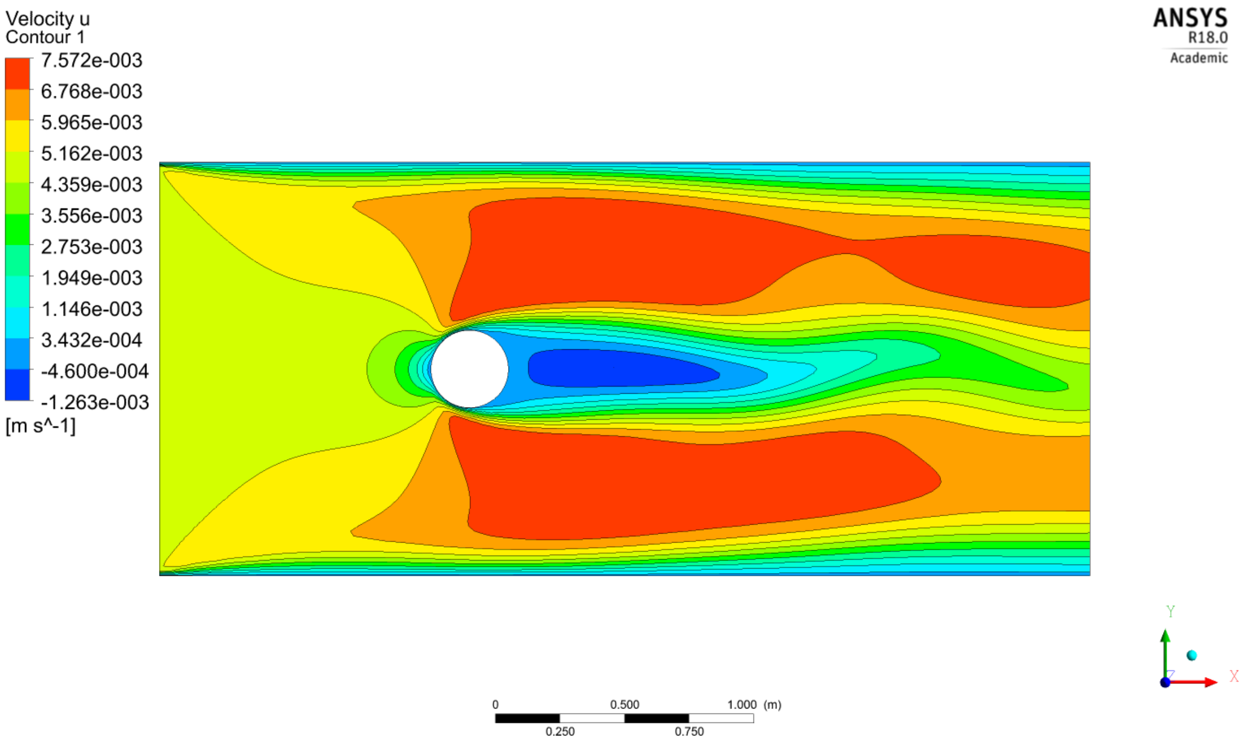
For air and given conditions,

$$U = 0.005\frac{m}{s}, D = 30cm, \mu = 1.7894 \times 10^{-5}\frac{kg}{ms}, \rho = 1.225\ kg/m^3$$

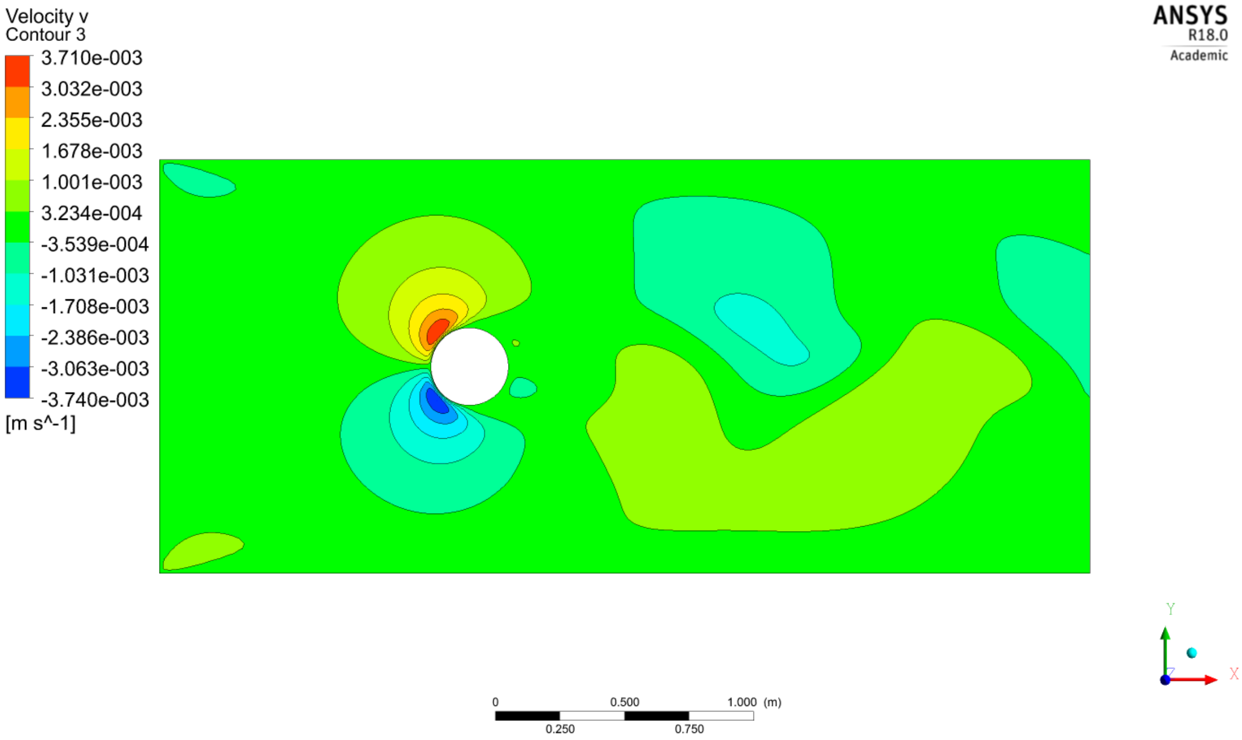
$$R \sim \frac{(0.005\frac{m}{s})(30cm)(1.225\frac{kg}{m^3})}{1.7894 \times 10^{-5}\frac{kg}{ms}} = 102.6$$

(2) Contour Plots of x-velocity, y-velocity, and static pressure at t = 1 hour.

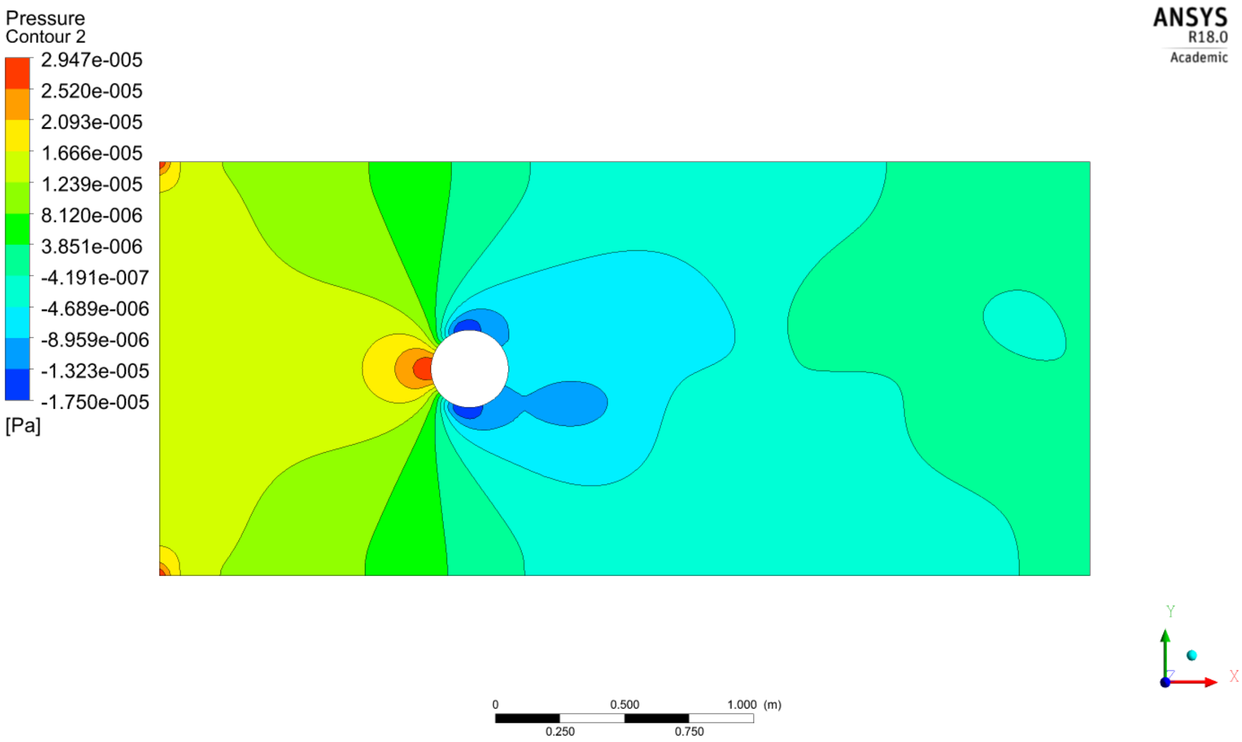
(i) x-velocity



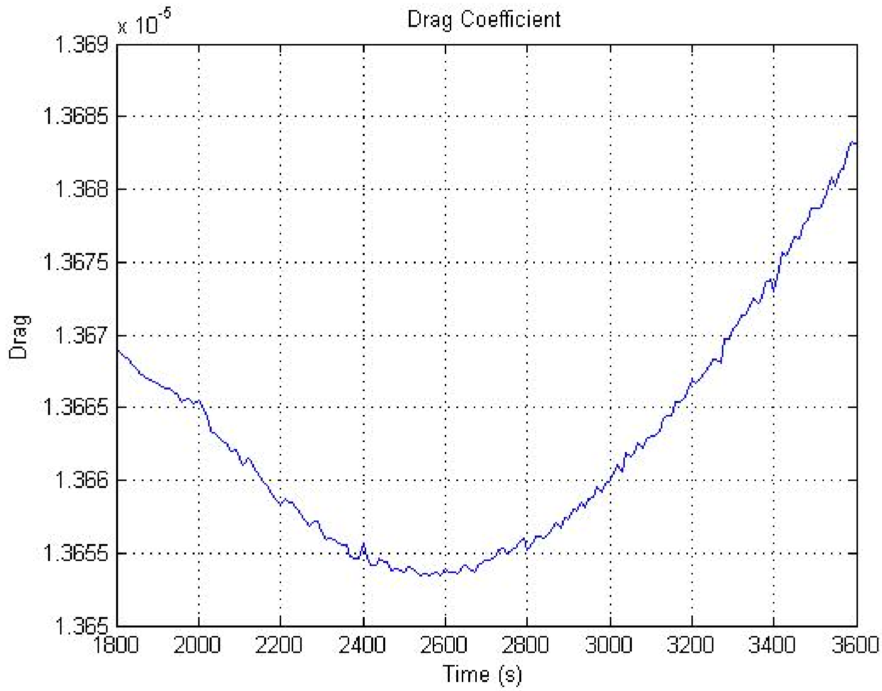
(ii) y-velocity



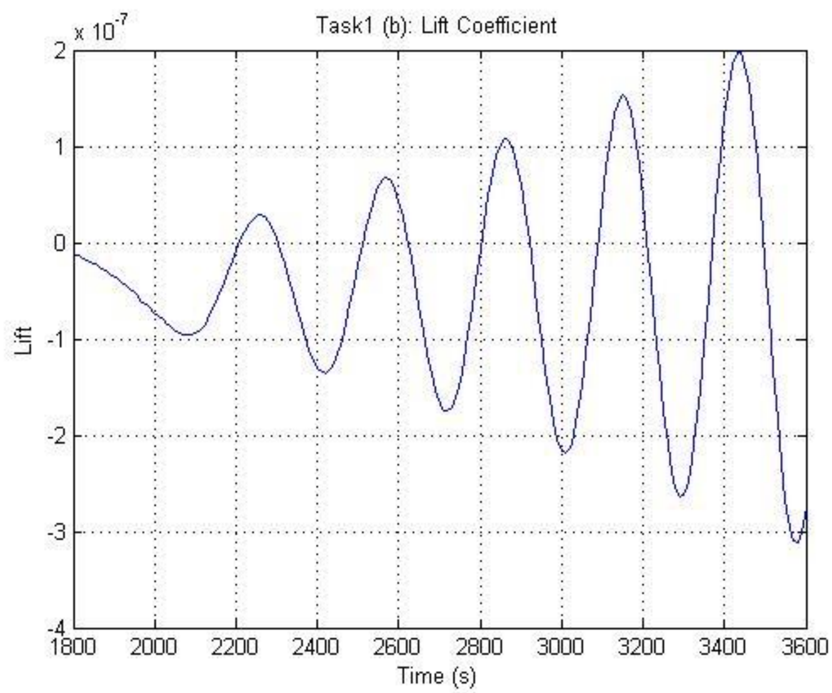
(iii) static pressure



(3) Plot of drag coefficient and lift coefficient.



The flow dos not oscillate for drag.



The flow in y-direction appears to oscillate. The estimation of period of oscillation is 290s.

Task 1 (c) (i) elongated in y-dir.

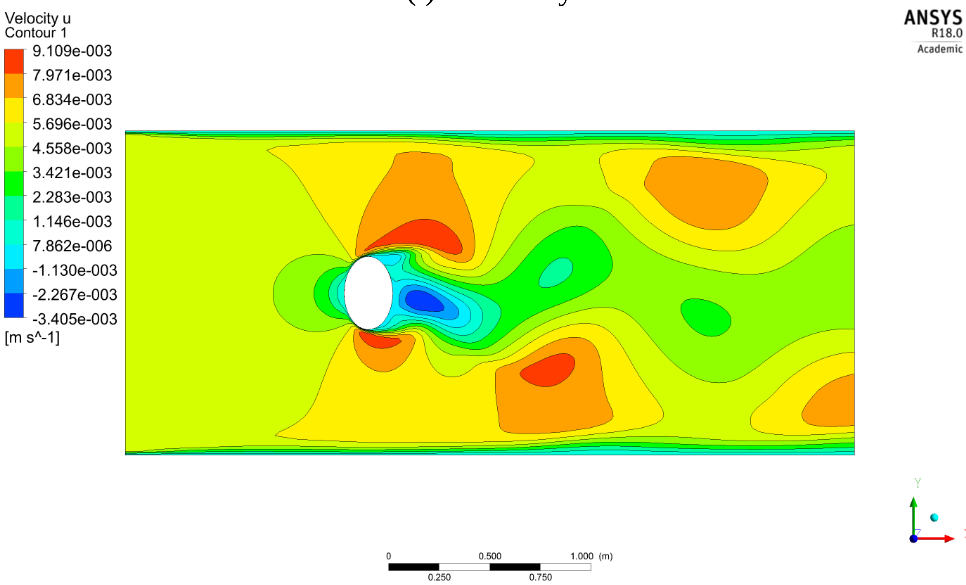
(1) For liquid kerosene and given conditions,

$$U = 0.005\frac{m}{s}, D = 36cm, \mu = 0.0024\frac{kg}{ms}, \rho = 780\ kg/m^3$$

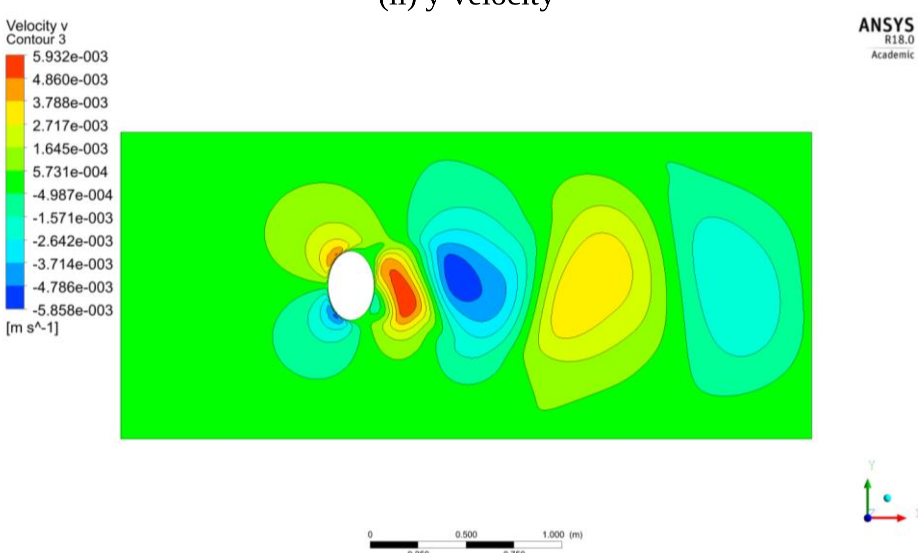
$$R \sim \frac{(0.005\frac{m}{s})(36cm)(780\frac{kg}{m^3})}{0.0024\frac{kg}{ms}} = 585$$

(2) Contour Plots of x-velocity, y-velocity, and static pressure at t = 1 hour.

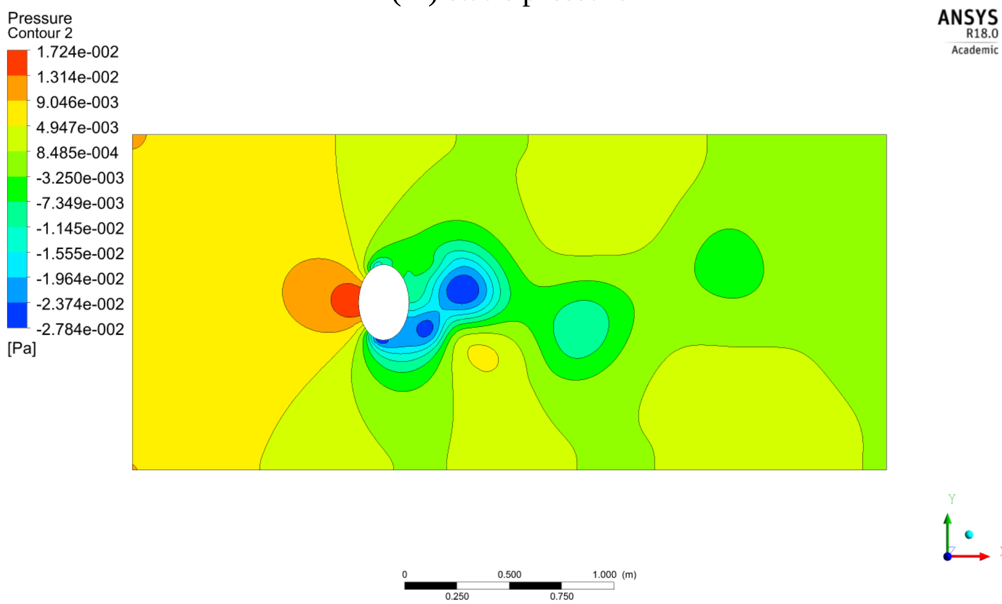
(i) x-velocity



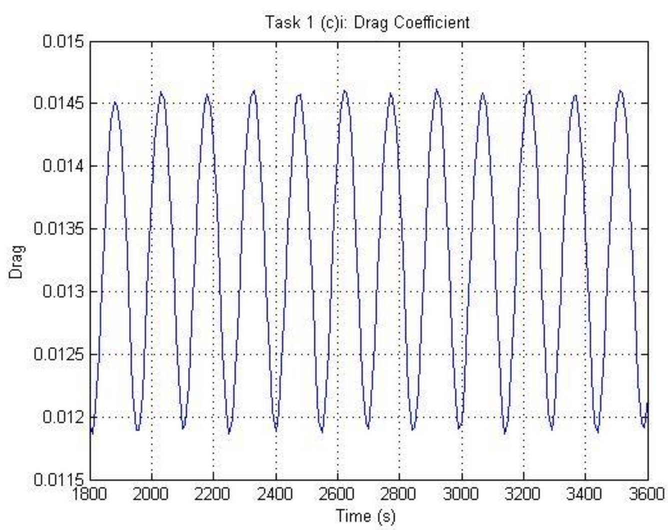
(ii) y-velocity

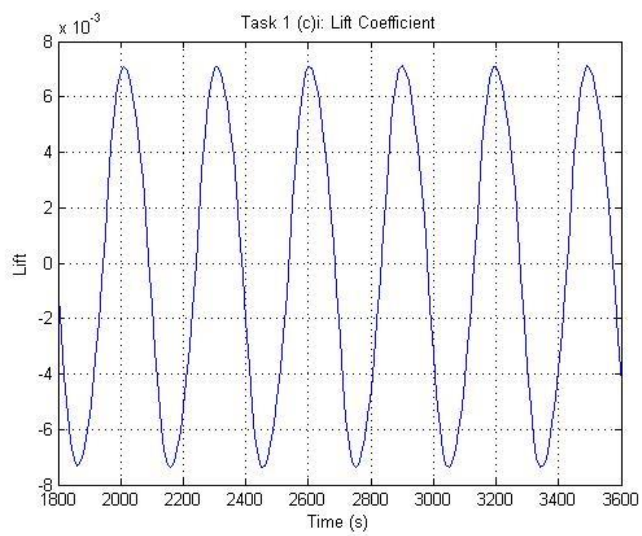


(iii) static pressure



(3) Plot of drag coefficient and lift coefficient.





Amplitude: ~ 0.00272
Oscillation period: ~145s

Amplitude: ~0.1446
Oscillation period: ~ 295s

Compared to the results from task 1a, the flow oscillation in x-direction is more uniform, and period of oscillation is slightly longer for both drag and lift. The coefficient value of drag and lift are larger than of task 1a.

Task 1 (c) (ii) elongated in x-dir.

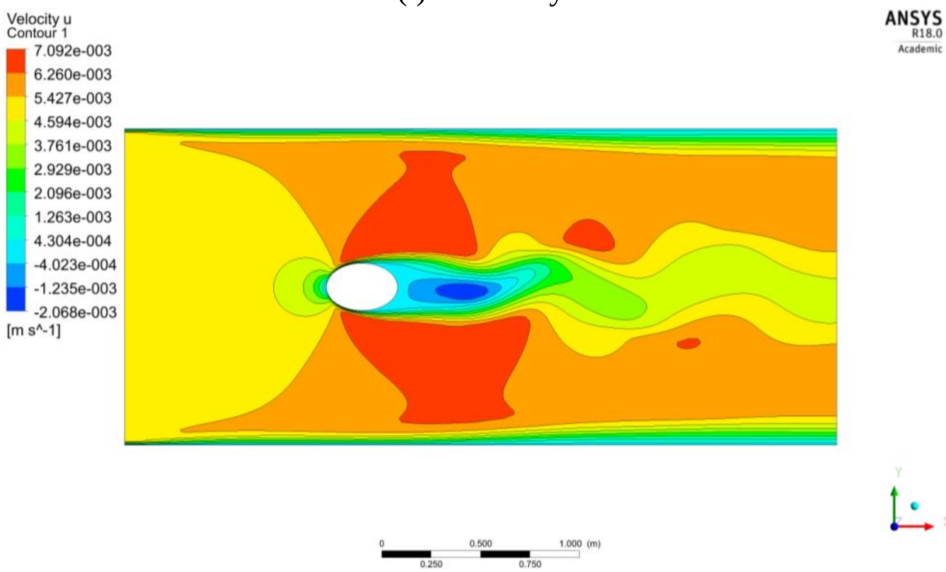
(1) For liquid kerosene and given conditions,

$$U = 0.005\frac{m}{s}, D = 24cm, \mu = 0.0024\frac{kg}{ms}, \rho = 780\ kg/m^3$$

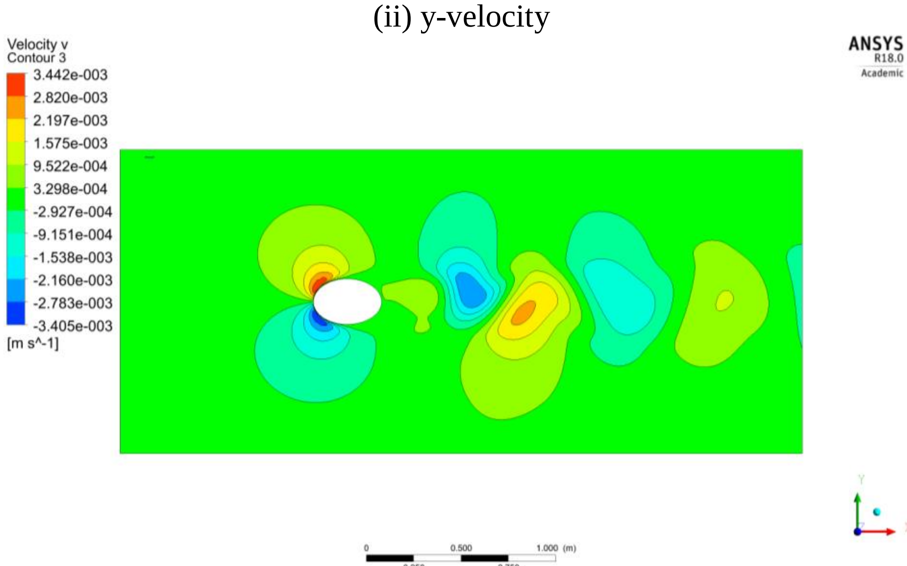
$$R \sim \frac{(0.005\frac{m}{s})(24cm)(780\frac{kg}{m^3})}{0.0024\frac{kg}{ms}} = 390$$

(2) Contour Plots of x-velocity, y-velocity, and static pressure at t = 1 hour.

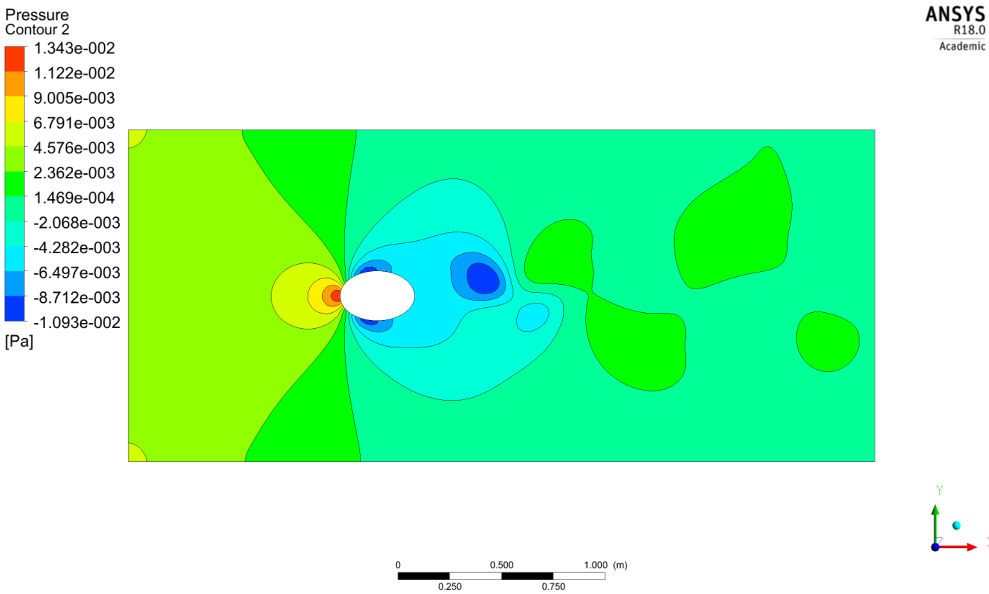
(i) x-velocity



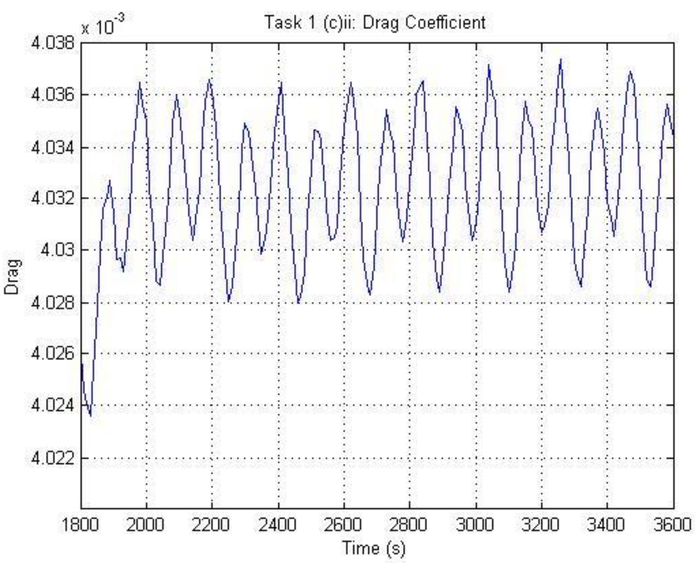
(ii) y-velocity

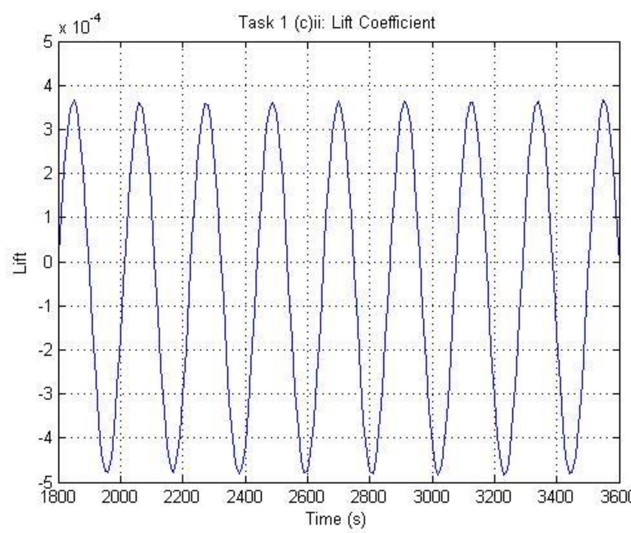


(iii) static pressure



(3) Plot of drag coefficient and lift coefficient.





Amplitude: $\sim 7 \times 10^{-6}$
Oscillation period: ~110s

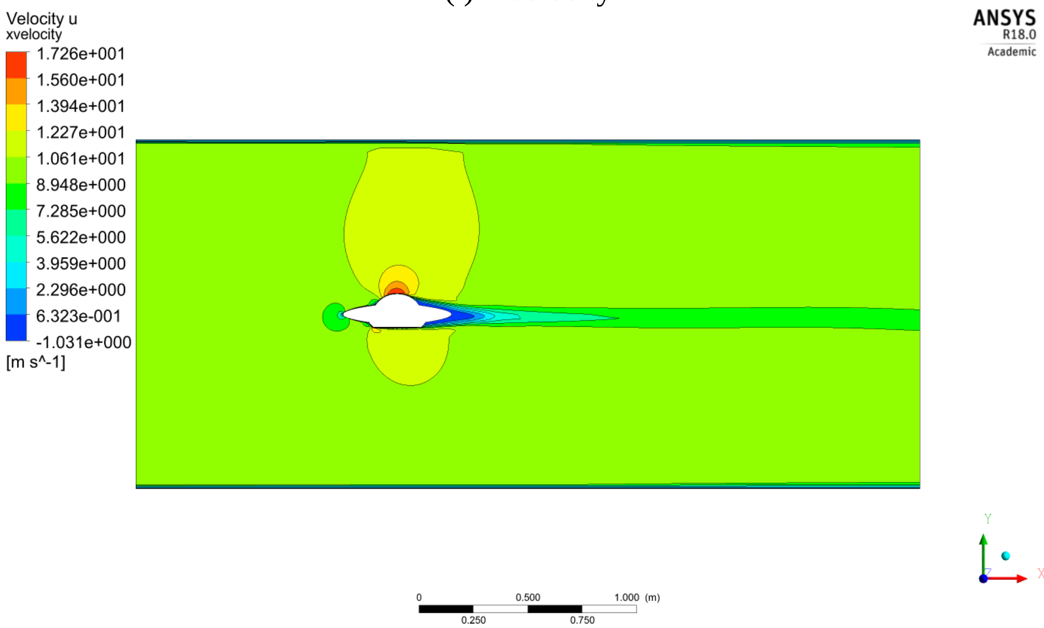
Amplitude: ~0.002986
Oscillation period: ~ 210s

The shape of flow oscillation for lift and drag are smellier to the results from task 1a. However, the oscillation period is shorter for both drag and lint coefficient.

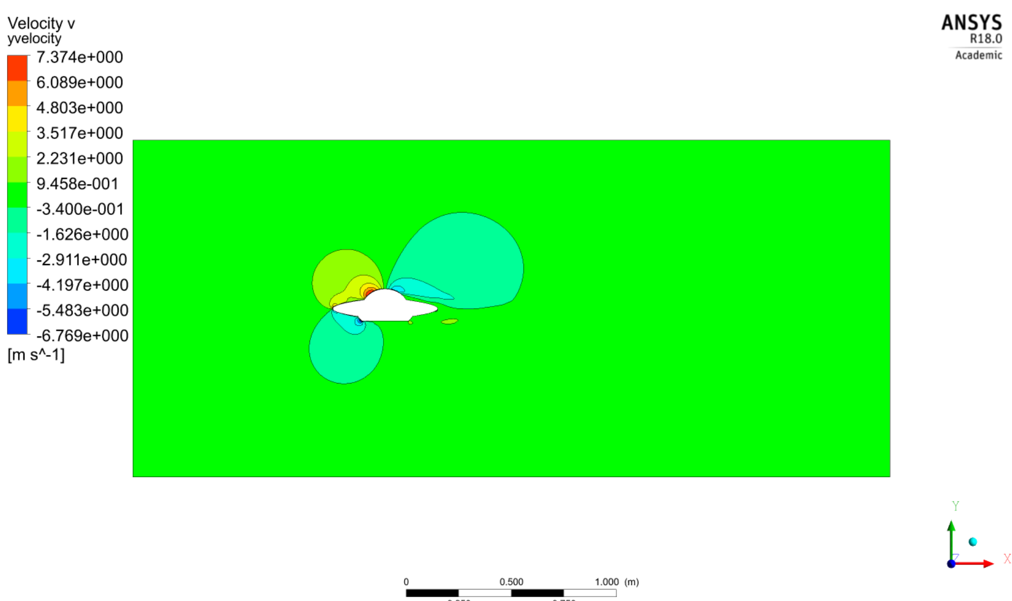
Task 2 (a)

(1) Contour Plots of x-velocity, y-velocity, and static pressure for the steady solution.

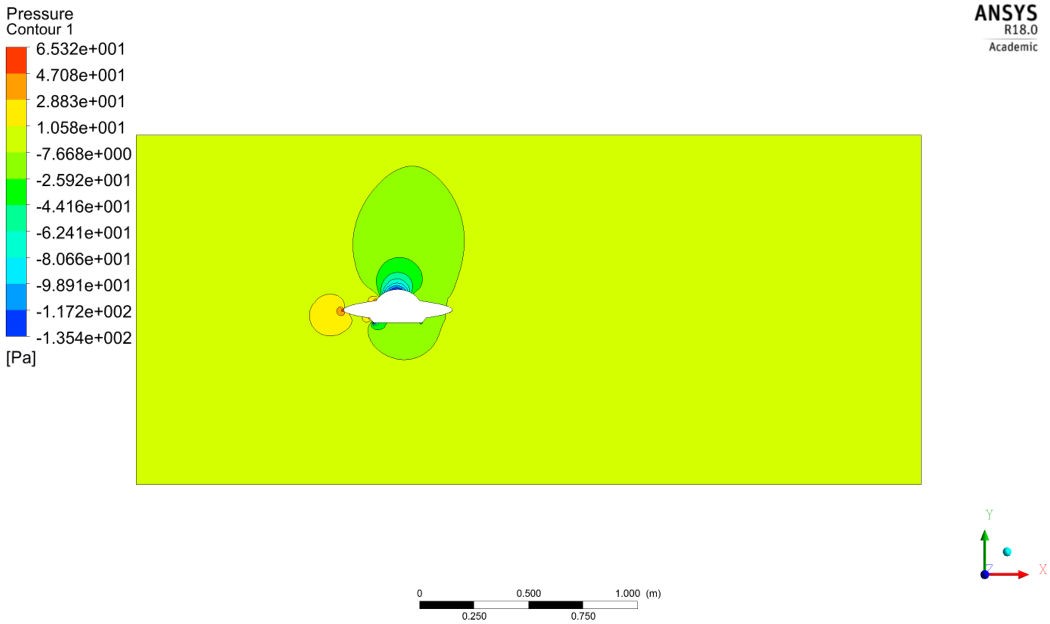
(i) x-velocity



(i) y-velocity



(iii) static pressure



(2) The drag force and lift force.

From drag force report below: $Total\ drag\ force = 2.0128431\ N$

Forces - Direction Vector (1 0 0)

Zone	Forces (n) Pressure	Viscous	Total
saucer	1.7239244	0.28891873	2.0128431
Net	1.7239244	0.28891873	2.0128431

From lift force report below: $Total\ lift\ force = 10.629214\ N$

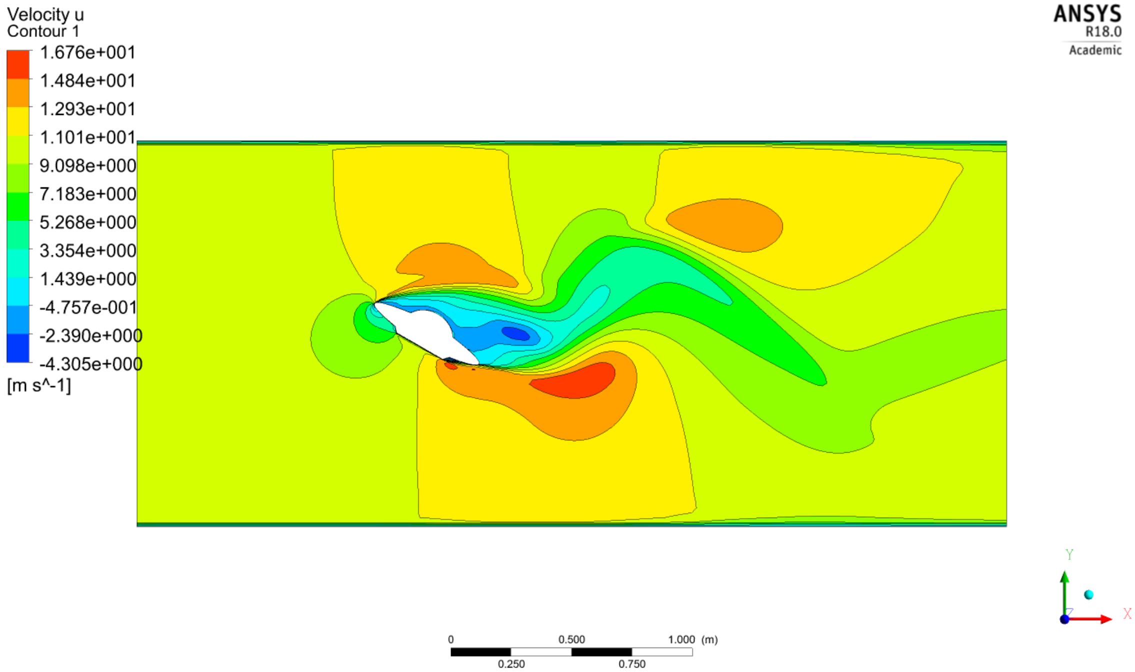
Forces - Direction Vector (0 1 0)

Zone	Forces (n) Pressure	Viscous	Total
saucer	10.615856	0.013358061	10.629214
Net	10.615856	0.013358061	10.629214

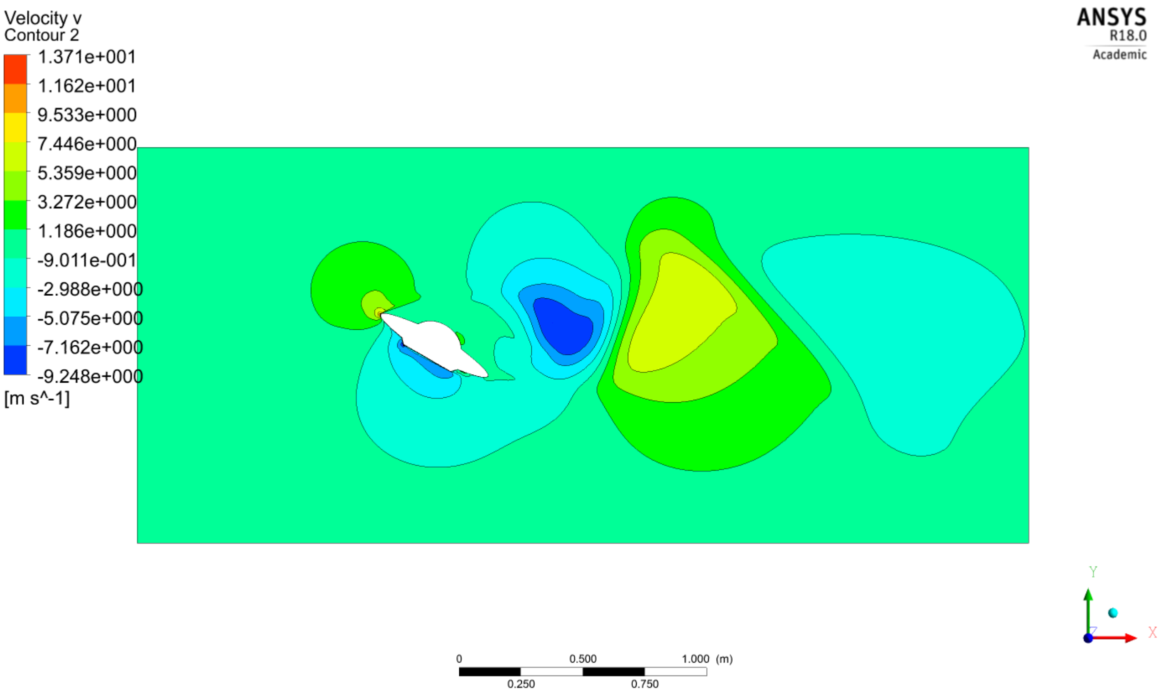
Task 2 (b)

(1) Contour Plots of x-velocity, y-velocity, and static pressure for the transient solution, t = 3600s.

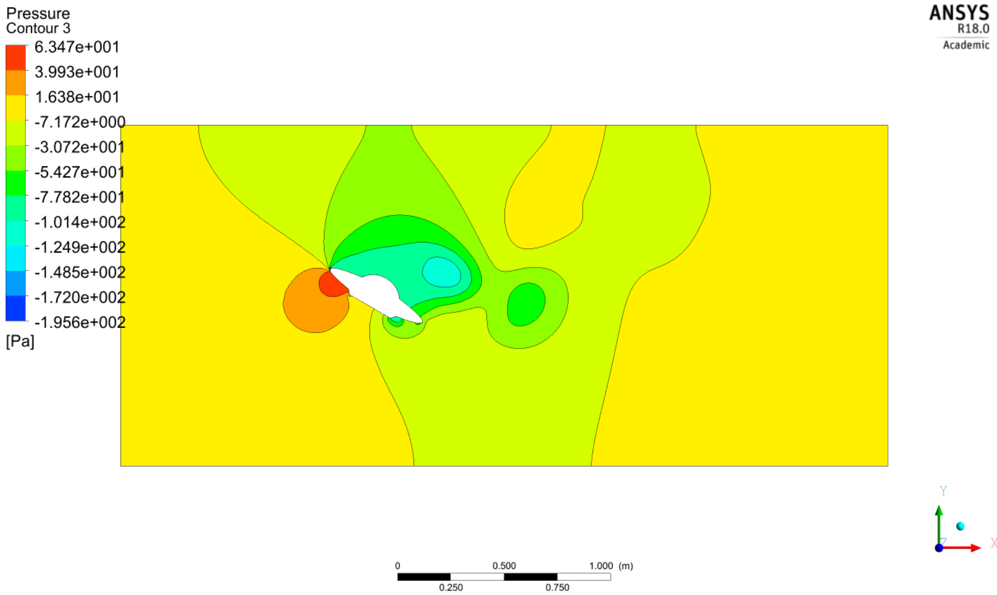
(i) x-velocity



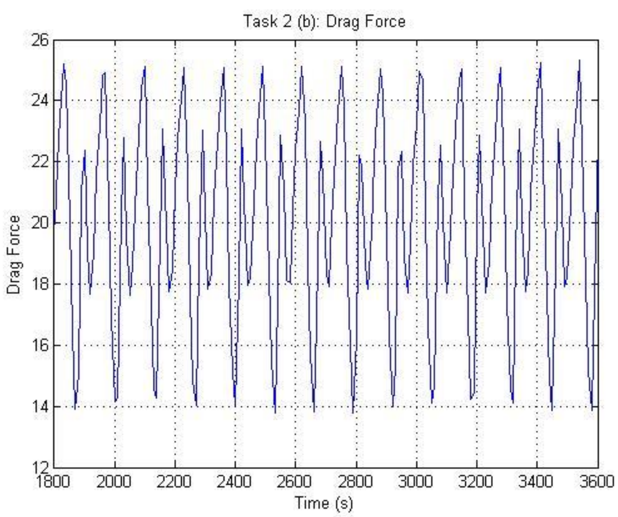
(ii) y-velocity

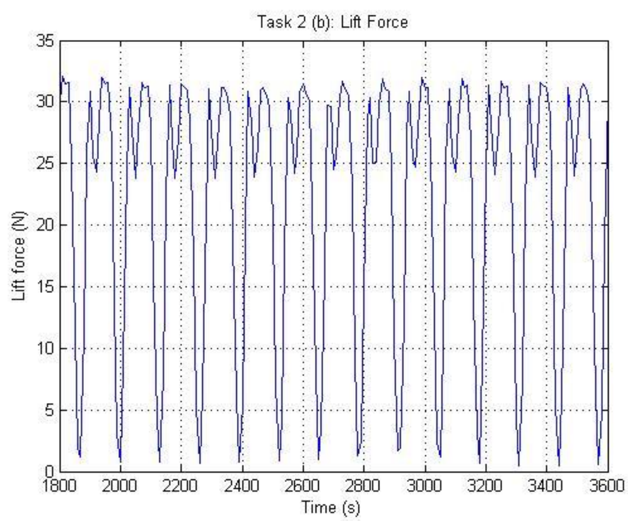


(iii) static pressure



(2) The stedy solution was seeked first, but it appeared that there is a flow occilation. Therefore, transient simulation was performed, similer to task 1.



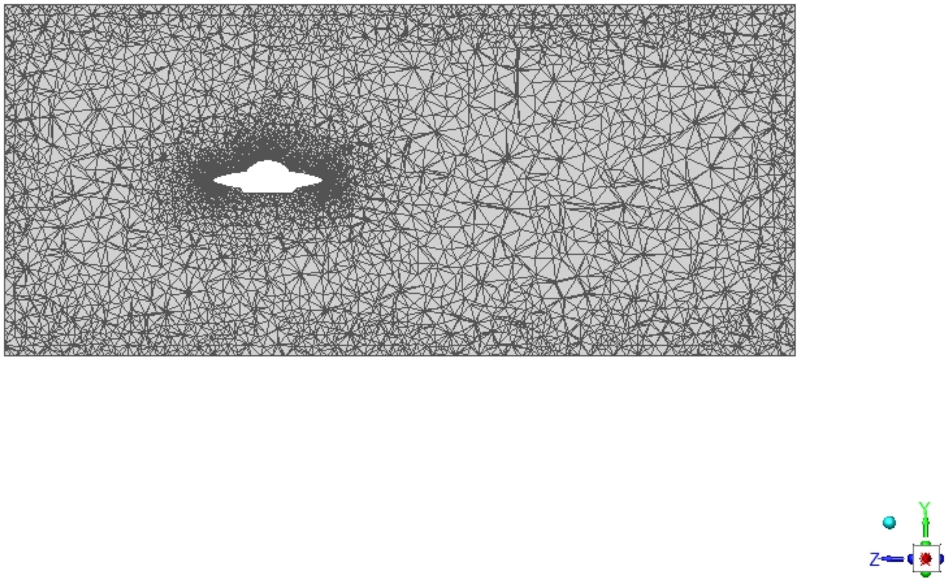


Average value for drag force:
20.0072 N

Average value for lift force:
21.7060N

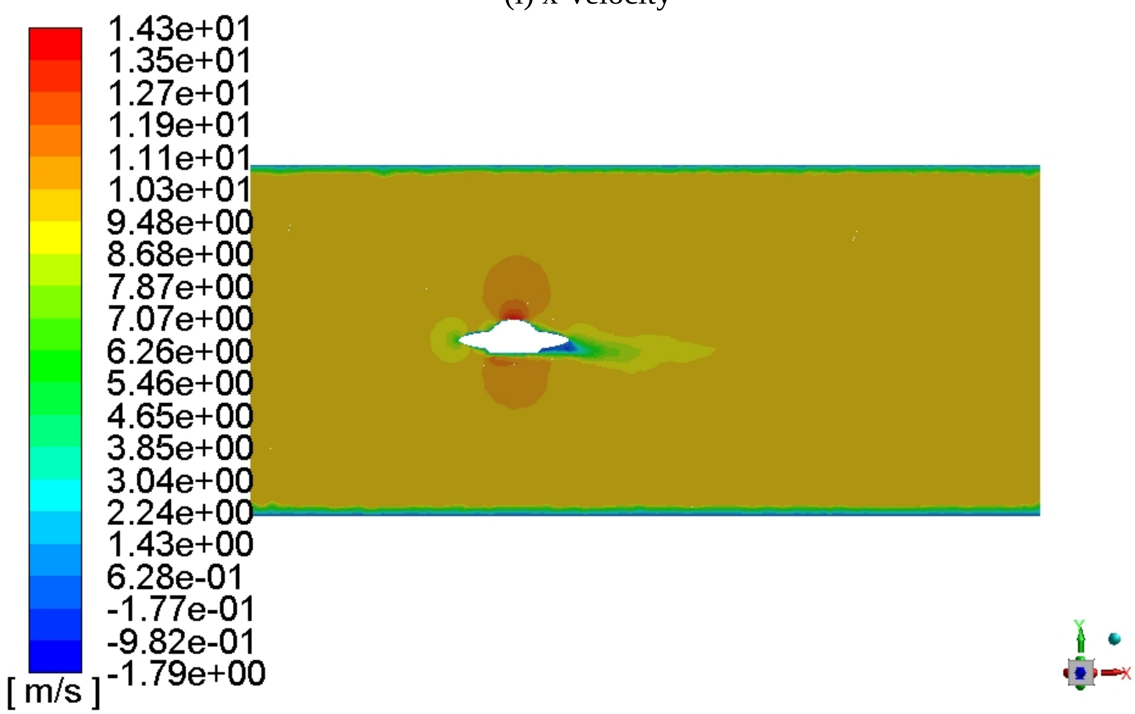
Task 3 (a)

(1) Mesh along the plane of symmetry: Fine size mesh was generated.

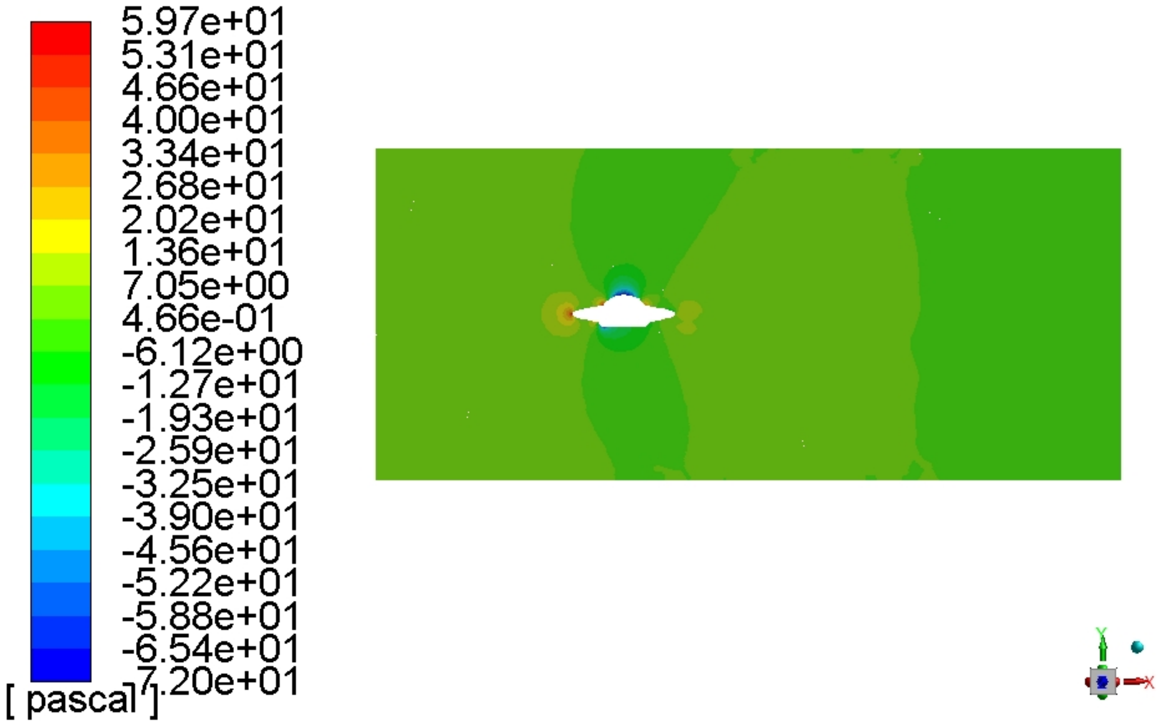


(2) Contour plot of x-velocity and static pressure along the plane of symmetry.

(i) x-velocity

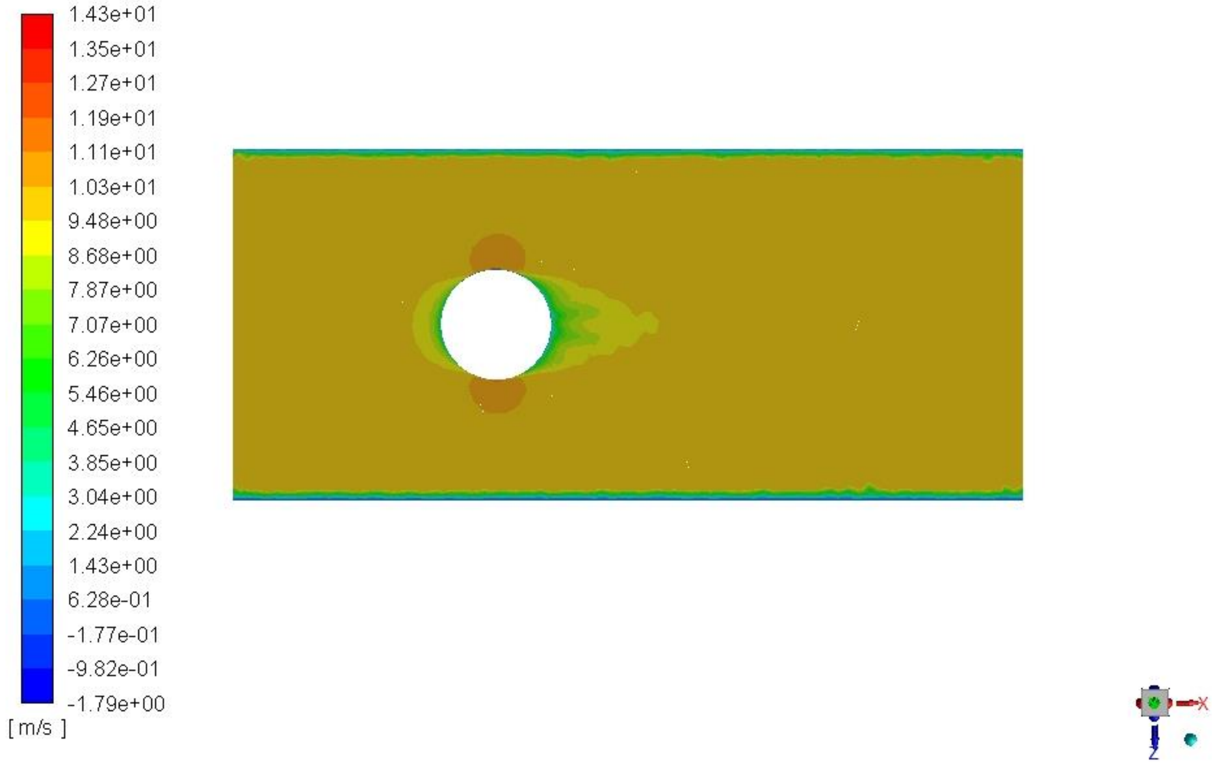


(ii) static pressure

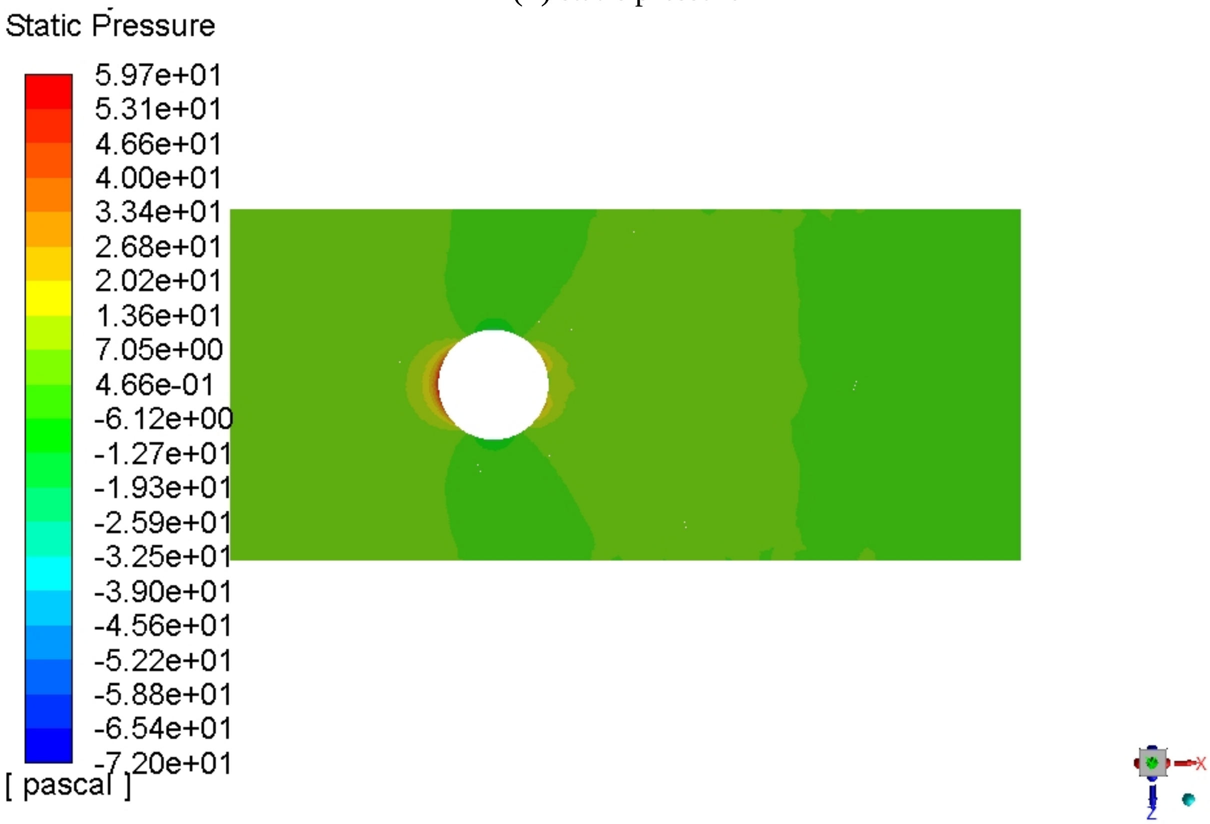


(3) Contour plot of x-velocity and static pressure along the plane that pass through the origin and is perpendicular to the plane of symmetry.

(i) x-velocity



(ii) static pressure



(3) Drag and lift force

From drag force report below: $Total\ drag\ force = 0.4505362\ N$

Forces - Direction Vector (1 0 0)

	Forces (n)		
Zone	Pressure	Viscous	Total
wall-fluid	0.33493409	0.11560211	0.4505362
Net	0.33493409	0.11560211	0.4505362

From lift force report below: $Total\ lift\ force = 0.54925193\ N$

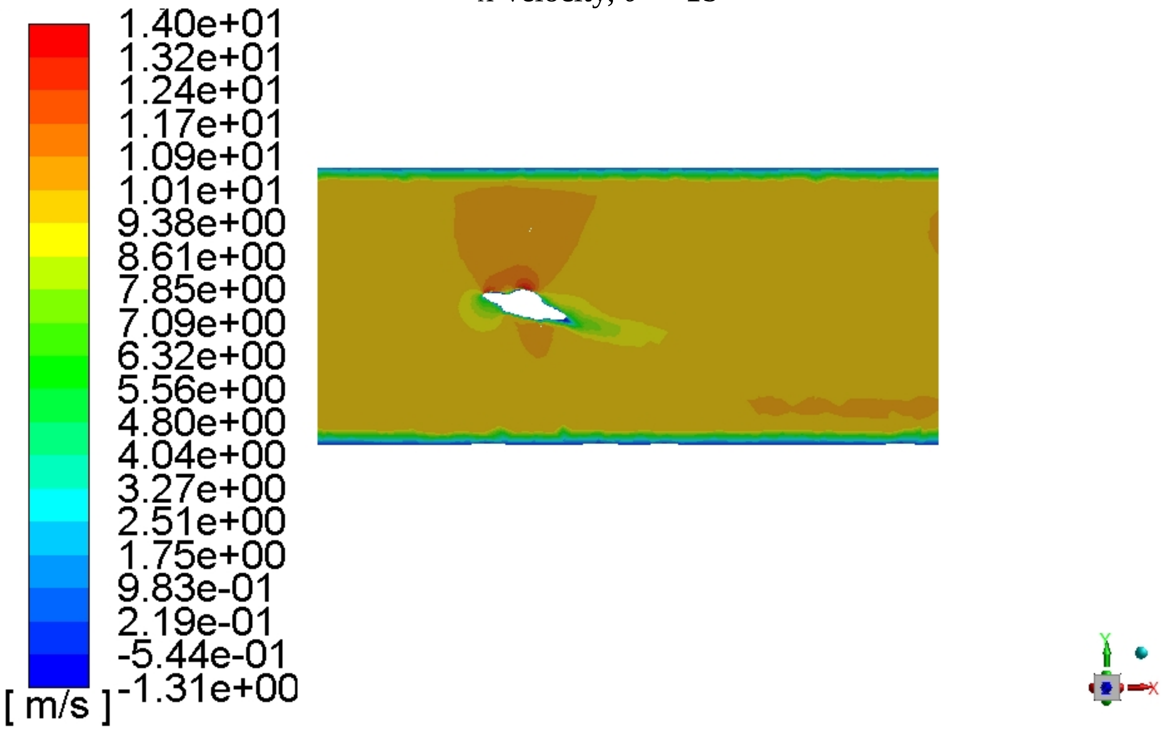
Forces - Direction Vector (0 1 0)

	Forces (n)		
Zone	Pressure	Viscous	Total
wall-fluid	0.54950821	-0.00025628504	0.54925193
Net	0.54950821	-0.00025628504	0.54925193

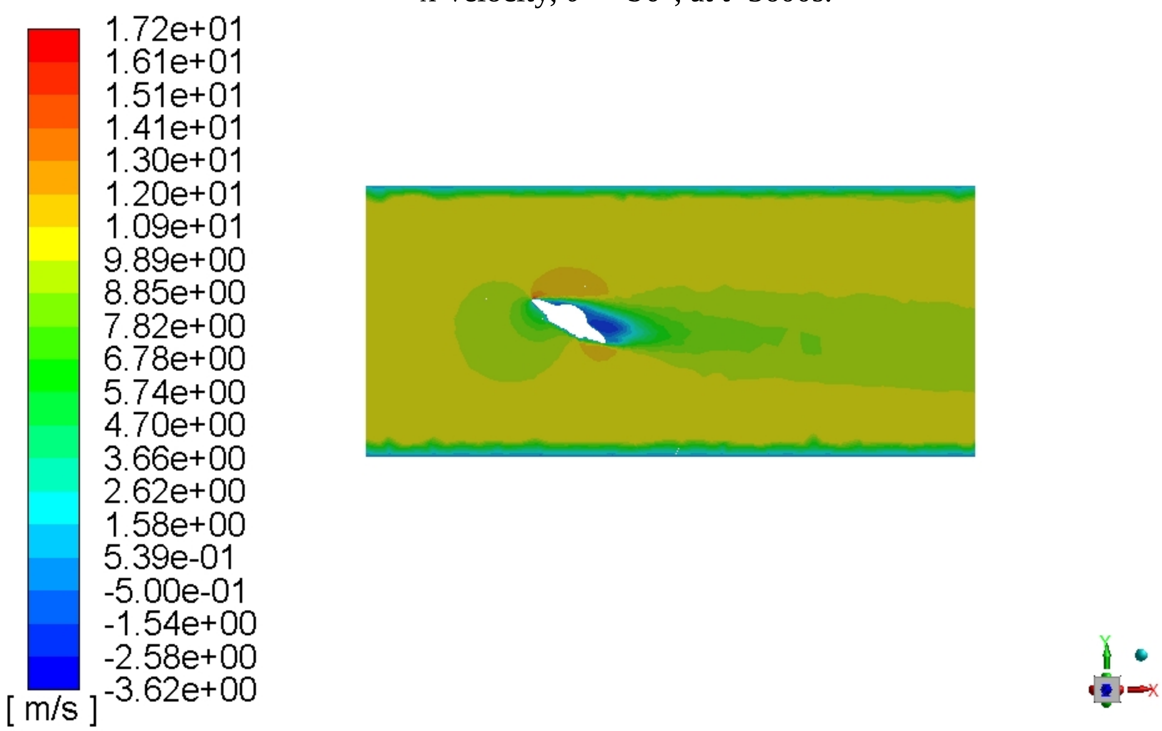
Task 3 (b)

(1) Contour plots of the x-velocity along the plane of symmetry for $\theta = 15°, 30°, and\ 45°$.

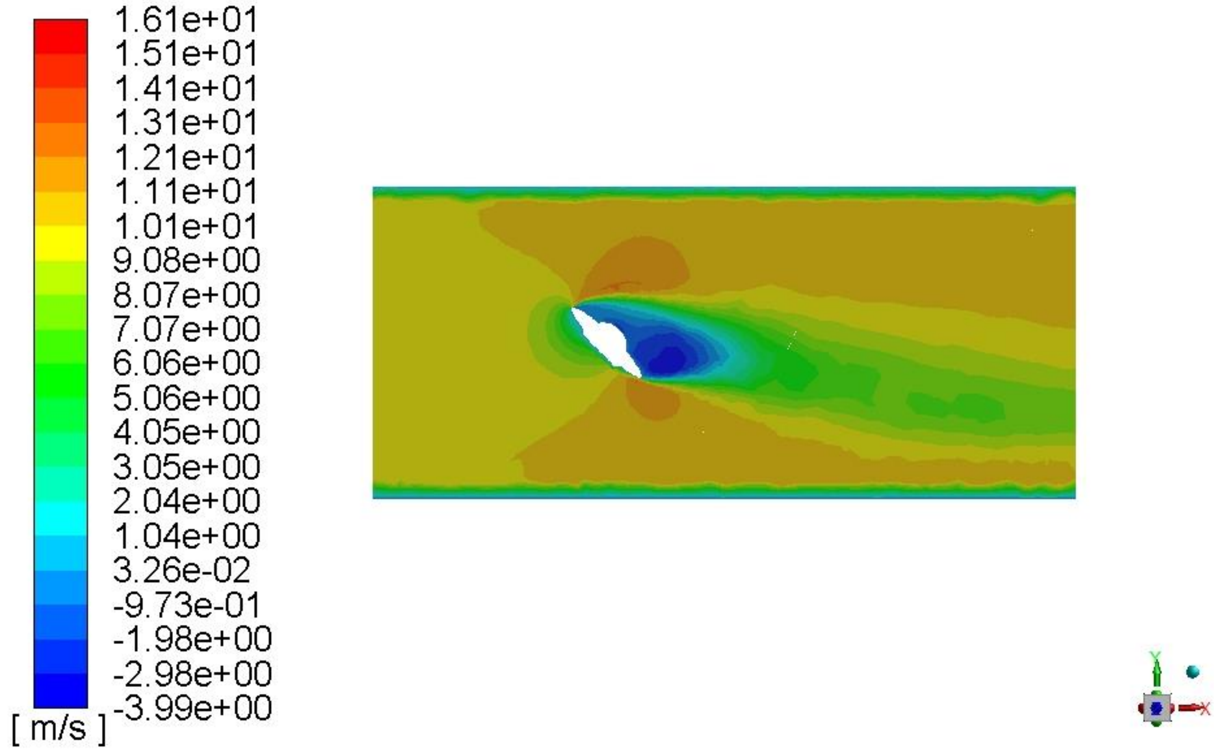
x-velocity, $\theta = 15°$



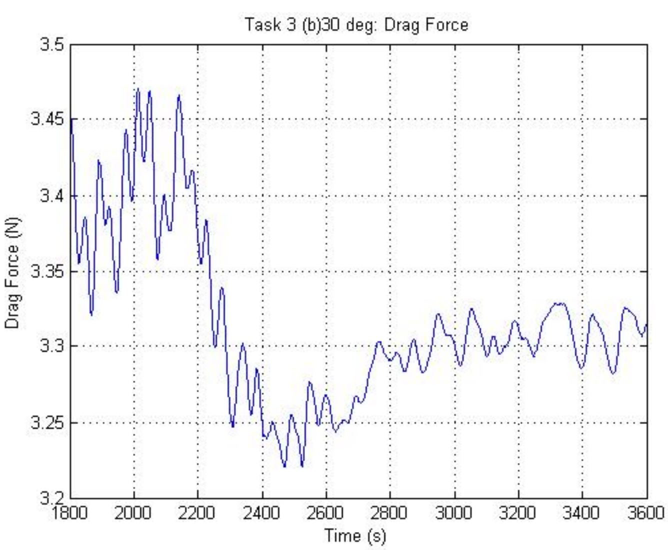
x-velocity, $\theta = 30°$, at t=3600s.

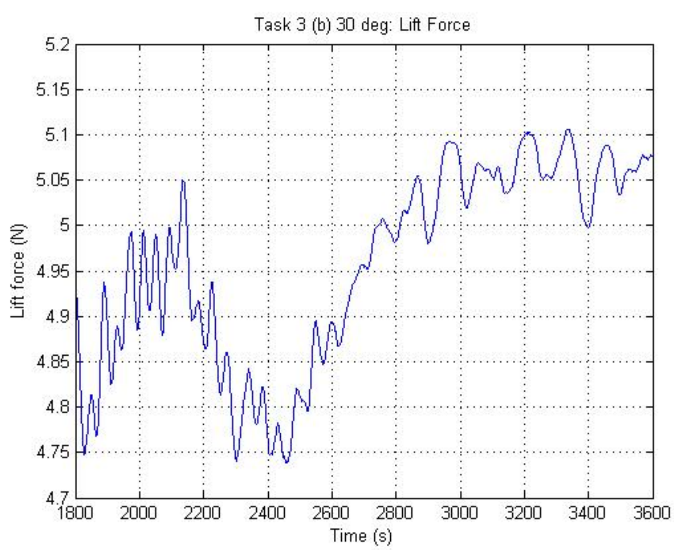


x-velocity, $\theta = 45°$, at t = 3600s.



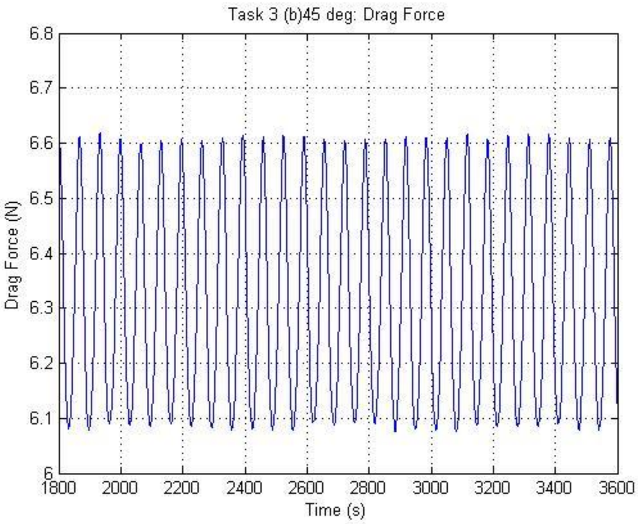
For $\theta = 30°, and\ 45°$, it appeared that there is flow oscillation in both drag and lift, so transient simulation was performed.

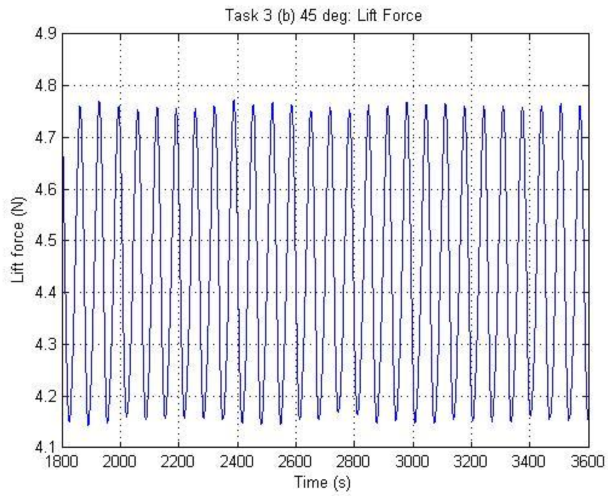




Average value for drag force, $\theta = 30°$,: 3.3163 N

Average value for lift force, $\theta = 30°$: 4.9578N

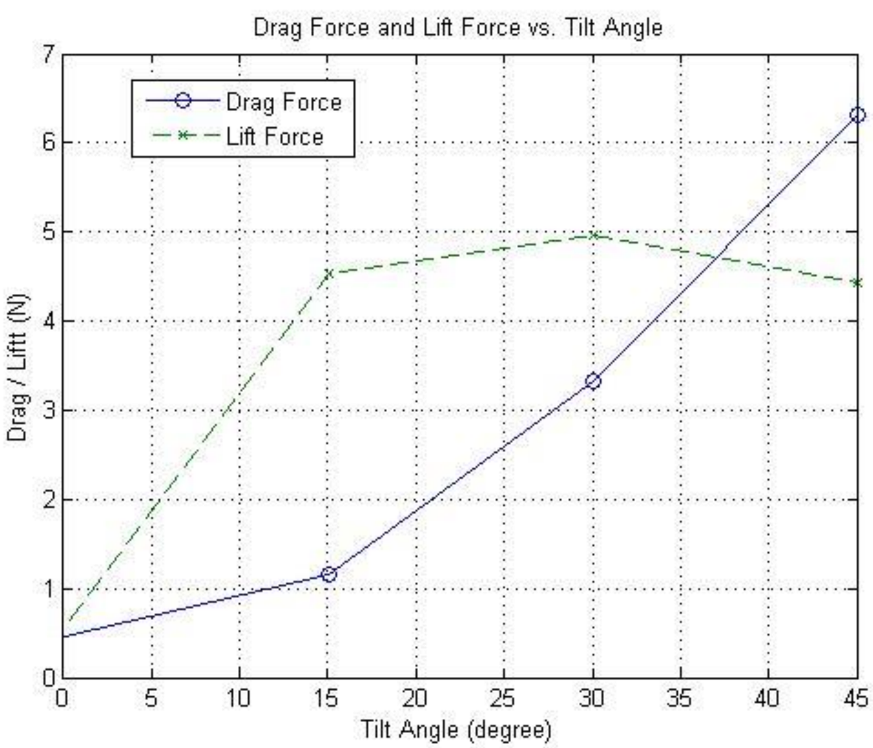




Average value for drag force, $\theta = 45°$,: 6.3189 N

Average value for lift force, $\theta = 45°$: 4.4400N

(2) Plot of drag force and lift force as a function of the tilt angle θ.



Drag force increases as tilt angle increases, but lift force is maximum at the tilt angle of 30 degree, and seems to decreases thereafter.