

Project #4 External flow

MAE 598/494 Applied CFD, Fall 2017, Project 4 (25 points)

Hard copy of report is due at the start of class on the due date. As usual, please follow the rules on collaboration. A cover sheet is required.

All tasks are for both MAE598 and MAE 494, **except Task 3b which is for MAE598 only.**

Task 1

(a) Consider the system of a 2D flow passing a cylinder as illustrated in Fig. 1. The unit in Fig. 1 is "cm". The 2-D cylinder, essentially a circular disk, is centered at $(x, y) = (0, 0)$ with a radius of 15 cm. To perform the simulation using Ansys-Fluent, the cylinder is placed in a "virtual wind tunnel" as defined in Fig 1. The system has a velocity inlet at left and pressure outlet at right. Top and bottom are walls. For this task, consider the following setup for Fluent: Material: *liquid kerosene* with constant density and viscosity (use the default values from Fluent database); Inlet velocity: $u = 0.005$ m/s (uniform); Model: *Viscous-laminar*. The system is initialized with zero velocity inside the domain at $t = 0$. With this setup, run a *transient* simulation to $t = 1$ hour. Produce the following deliverables:

- (1) An estimate of the Reynolds number of the system. Here, you can use the diameter of the cylinder as the length scale.
 - (2) Contour plots of (i) x-velocity, (ii) y-velocity, and (iii) static pressure for the solution at $t = 1$ hour.
 - (3) A plot of *drag coefficient* and *lift coefficient* as a function of time over the last 30 minutes of the simulation (i.e., from $t = 30$ minutes to $t = 1$ hour). Based on the plot, does the flow oscillate in time? If so, estimate the period of oscillation. [Note: The drag force and lift force are the x- and y-component of the force that the fluid exerts on the cylinder. The drag coefficient and lift coefficient are the non-dimensionalized counterparts of the drag force and lift force, as discussed in class. For this task and Task 1c, the plots should show the coefficients, not the forces.]
- (b) Repeat Task 1a but replace *liquid kerosene* with *air* as the material. The deliverables are the same as Task 1a.
- (c) Revert to the setup for Task 1a (i.e., use *liquid kerosene* as the material) and repeat the run, except that the circular disk is replaced by an ellipse. Consider the two cases: (i) An ellipse elongated in y-direction, with the lengths of its major and minor axes 36 cm and 24 cm (the major axis is parallel to y-axis). (ii) An ellipse elongated in x-direction, with the lengths of its major and minor axes 36 cm and 24 cm (the major axis is parallel to x-axis). (See illustration in Fig. 2). Run the simulations for the two cases. For each case, plot *drag coefficient* and *lift coefficient* as a function of time over the last 30 minutes of the simulation. Determine the amplitude and period of oscillation for the two cases and compare them to the case with a circular cylinder from Task 1a.

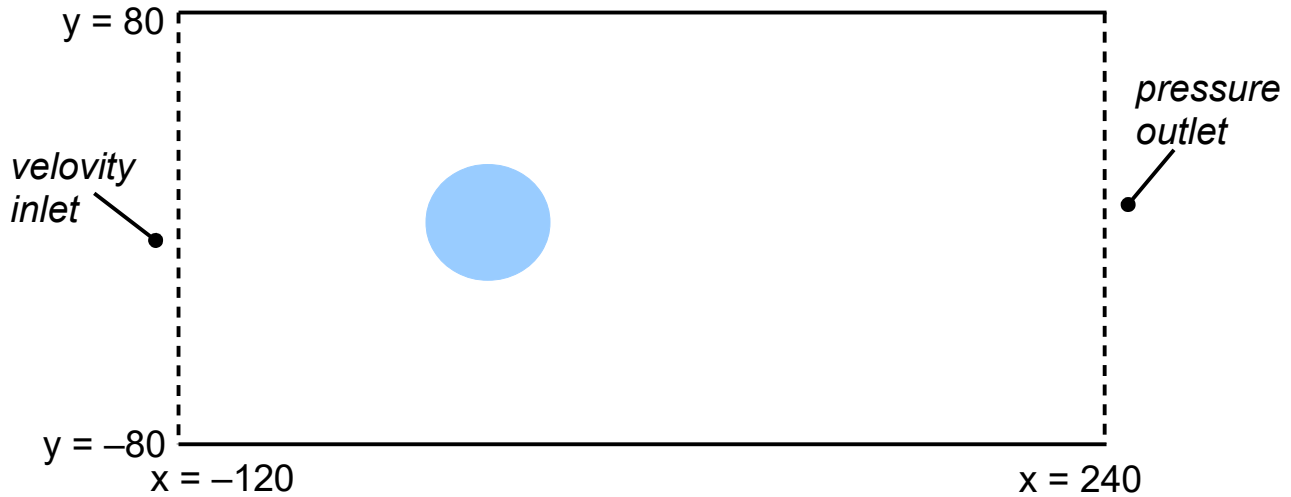


Fig. 1 The geometry of the 2D cylinder and "virtual wind tunnel" for Task 1. (Not drawn to scale.)

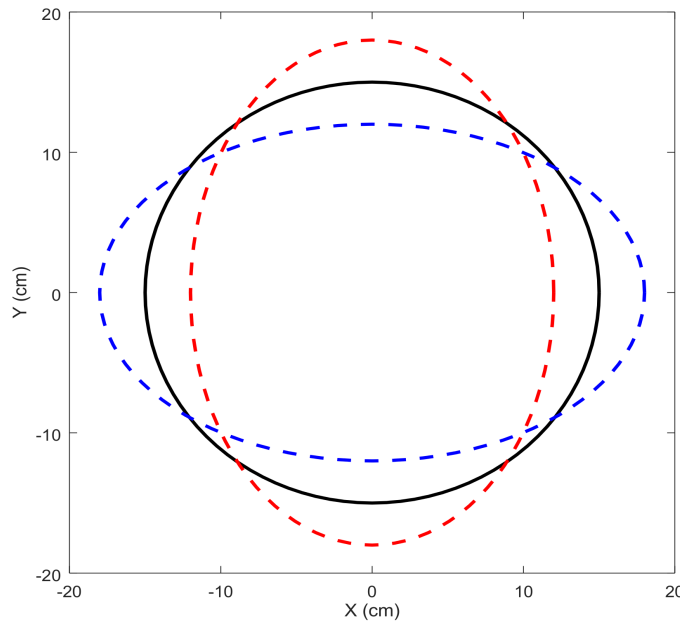


Fig. 2 The shape of the elliptical object used in Task 1c. Black: circle from Task 1a; Red: ellipse elongated in y-direction; Blue: ellipse elongated in x-direction.

Task 2

(a) Consider a 2D system similar to that used in Task 1 but with the cylinder replaced by a body with more complicated shape (hereafter called a "flying saucer"), as shown in Fig. 3. The unit in Fig. 3 is "cm". The profile data for the flying saucer, given in a text file named "flyingsaucer2D.txt", will be posted separately. The profile data can be imported to Ansys to complete the generation of geometry. Similar to Task 1, the 2D flying saucer is placed in a channel to set up the simulation, as illustrated in Fig. 4. Consider the following setup for Fluent: Material: *air* with constant density and viscosity; Inlet velocity: $u = 10$ m/s (uniform); Model: *Viscous (turbulence) k-epsilon*. For this task we only seek *steady solution*. The deliverables are:

- (1) Contour plots of (i) x-velocity, (ii) y-velocity, and (iii) static pressure, for the steady solution.
- (2) Calculation of the drag force and lift force that the fluid exerts on the flying saucer. (Note that here we want the forces instead of coefficients.)
- (b)** Repeat Task 2a but now rotate the flying saucer by a 30° angle around the origin ($x = 0, y = 0$), as shown in Fig. 5. The deliverables are the same as Task 2a.

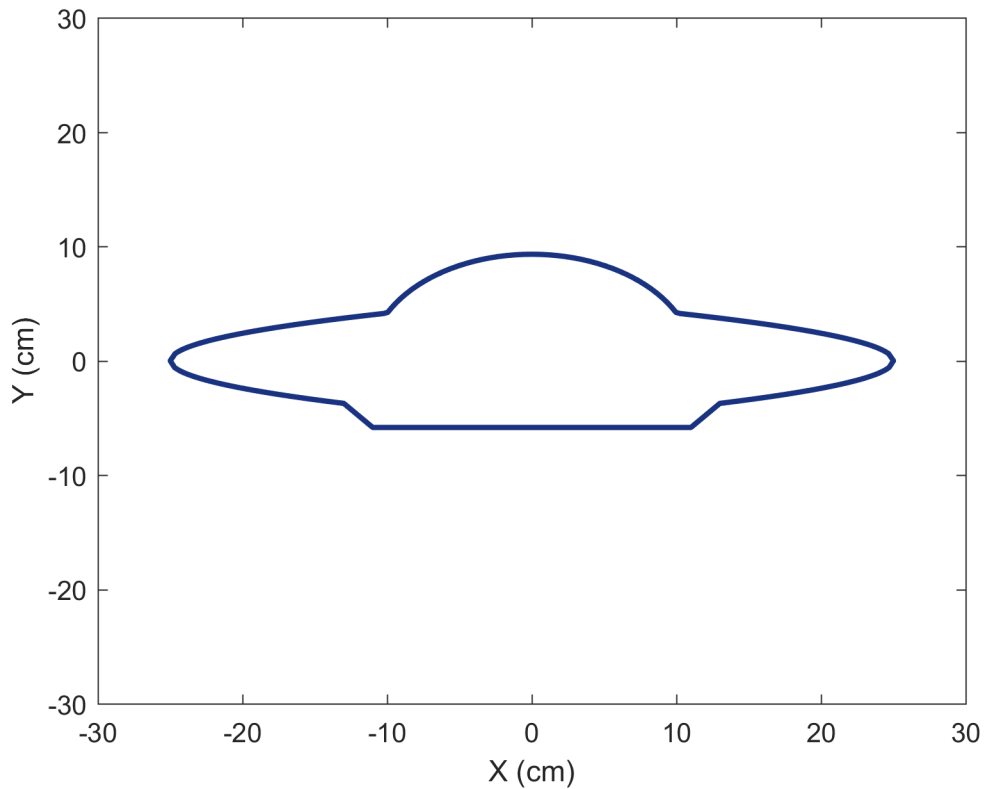


Fig. 3 The x-y profile of the flying saucer. The exact data is given in `flyingsaucer2D.txt`.

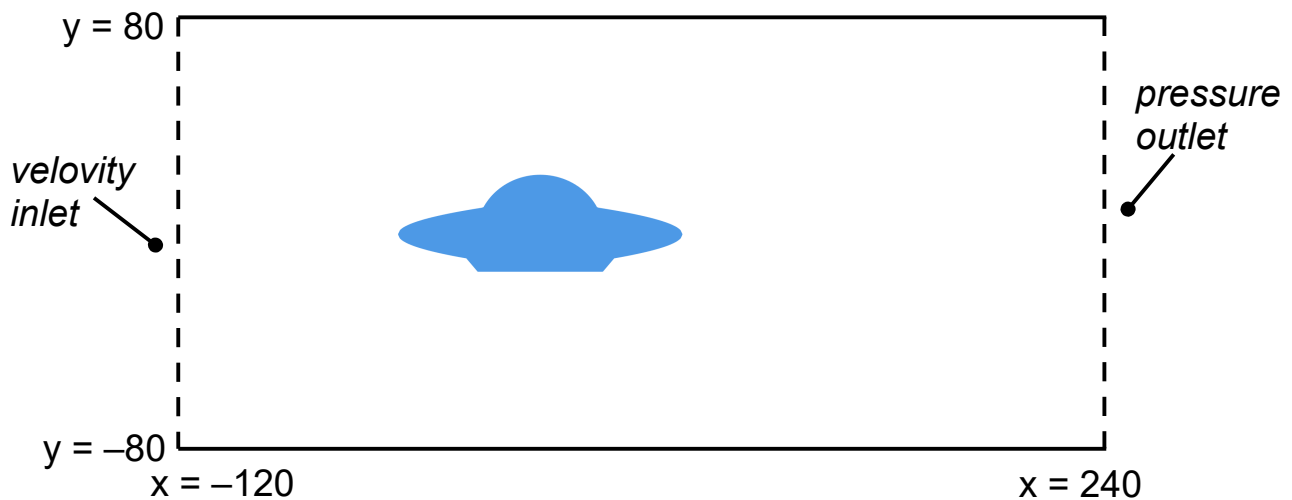


Fig. 4 The geometry of the system for Task 2. (Not drawn to scale.)

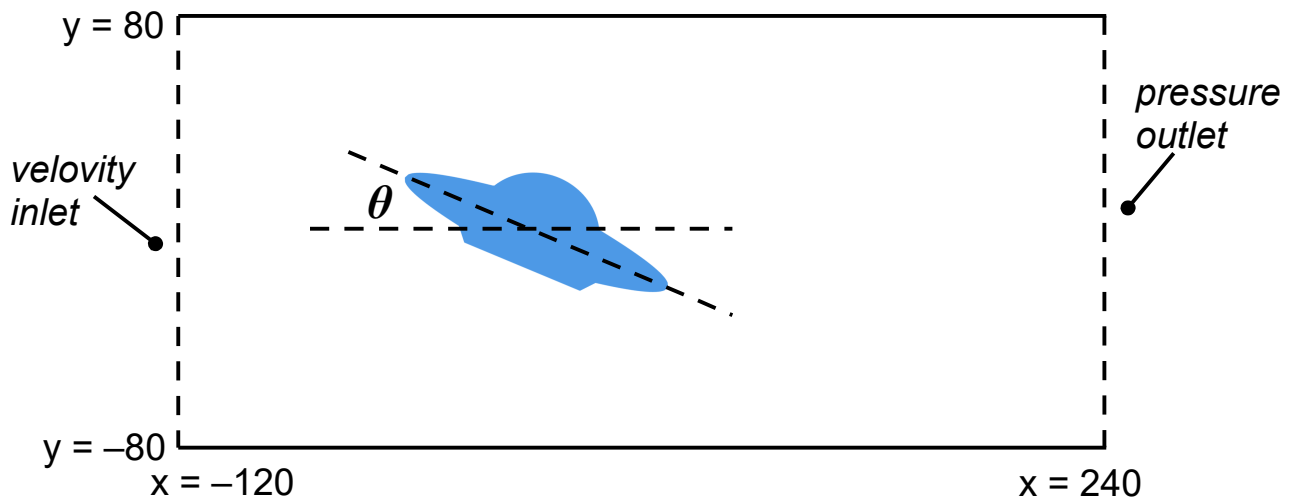


Fig. 5 The tilted flying saucer. For Task 2b, $\theta = 30^\circ$.

Task 3

(a) Consider the 3D version of the system used in Task 2 in which the 2D flying saucer is replaced by a 3D version of it, and the rectangular channel is replaced by a 3D cylindrical tube. The 3D flying saucer is generated by first importing a "half 2D flying saucer" (shown in Fig. 6) into Ansys-Fluent, then revolving it around y-axis to generate the fully 3D body (Fig. 7). The detailed profile data for the half 2D flying saucer is given in the file, "flyingsaucer2DH.txt", to be posted separately. The cylindrical tube has a radius of 80 cm and length of 360 cm. The 3-D fish is placed inside the tube (see Fig. 8) such that the cross section of the system along the plane of symmetry would be just like Fig. 4.

The 3D tube has a velocity inlet and a pressure outlet. Fill the tube with *air* with constant density and viscosity. Set the inlet velocity to a uniform 10 m/s and choose *Viscous (turbulence) k-epsilon* model. With this setup, we seek only *steady solution*. The deliverables are:

- (1) A plot of the mesh along the plane of symmetry.
- (2) Contour plots of (i) x-velocity and (ii) static pressure along the plane of symmetry.
- (3) Contour plot of (i) x-velocity and (ii) static pressure along the plane that passes through the origin and is perpendicular to the plane of symmetry.
- (4) Calculation of drag force and lift force.

(b) [for MAE598 only] Repeat Task 3a except that the 3D flying saucer is now tilted, forming an angle θ with the x-z plane. (Envision the 3D counterpart of Fig. 5.) Task 3a corresponds to the case when $\theta = 0$. Here, perform additional simulations with $\theta = 15^\circ$, 30° and 45° . The deliverables are

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

(2) A plot of drag force and lift force as a function of the tilt angle θ . Essentially, just connect the four data points of the values of drag force for $\theta = 0, 15^\circ, 30^\circ$ and 45° , and similarly for lift force. This plot should include the data point for $\theta = 0$ from Task 3a.

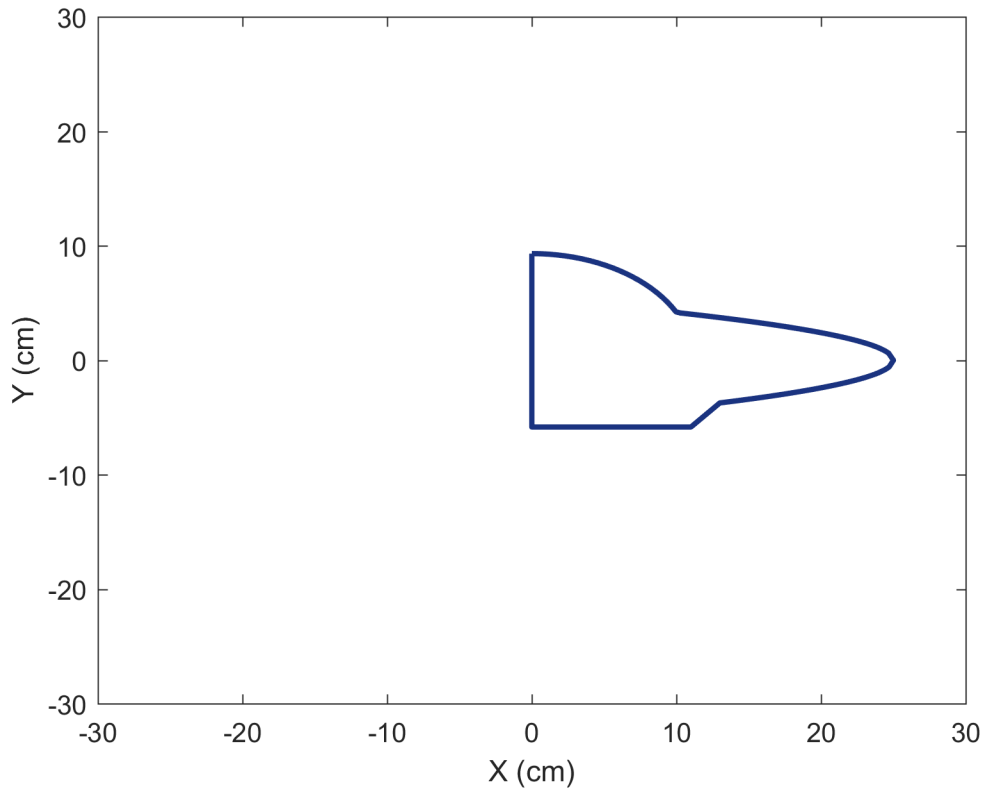


Fig. 6 The profile of the "half 2D flying saucer". The detailed data is in `flyingsaucer2DH.txt`.

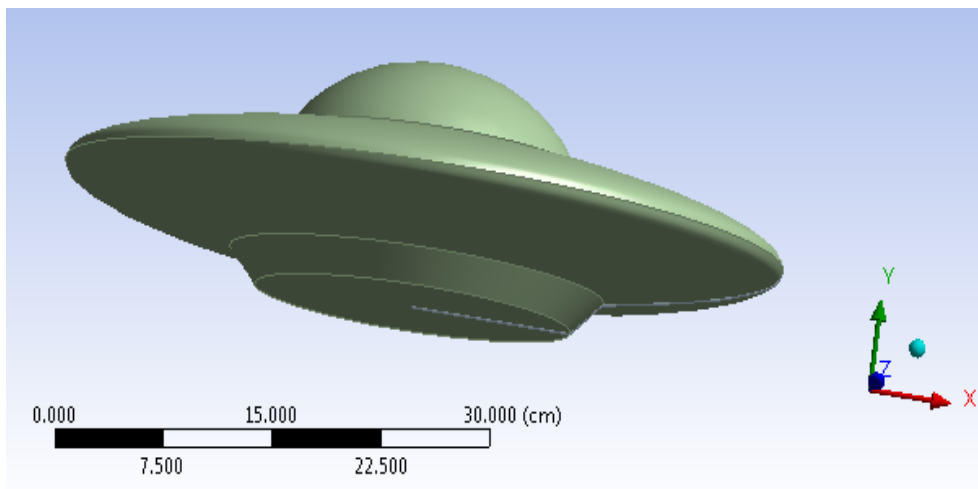


Fig. 7 The 3D flying saucer.

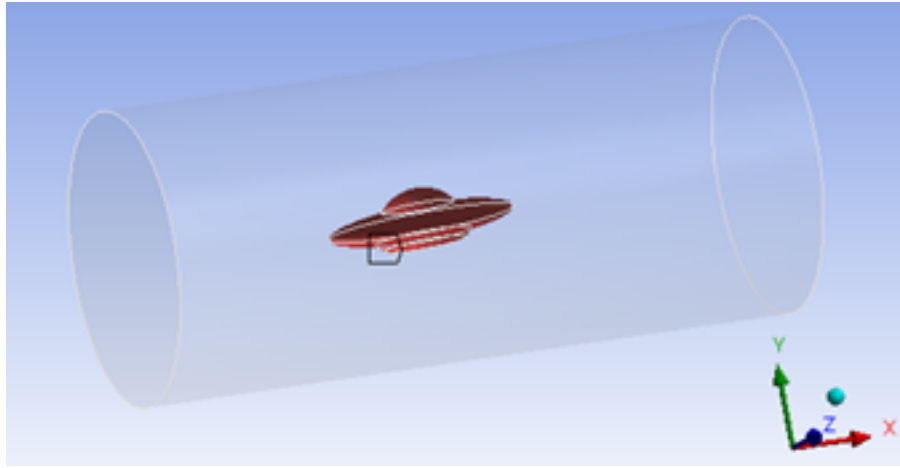


Fig. 8 Putting the 3D flying saucer inside the cylindrical tube for Task 3.