Comp3402 Computational Fluid Dynamics

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Purpose	(i) To become acquainted with CFD, (ii) To investigate fluid flow around objects in 2D, (iii) To observe airflow around a model turbine blade, (iv) To have a quick look at one Vibration Energy Harvester.
Files Required	Lilypad (Processing) Sketchbook.
ILO Contribution	LO 4
Send to Me	nix
Homework	Read chapter 4

Investigations

This worksheet is intended to be 'light touch' even fun! I would like you to learn something about CFD and in general how fluids (air and water) behave when they collide with bodies. The context is wind turbines, but this work has broad application, cars, planes, fishes, buildings, chimneys, people.

Please do collaborate around your table; have 'learning conversations' (hehe) and share simulation runs.

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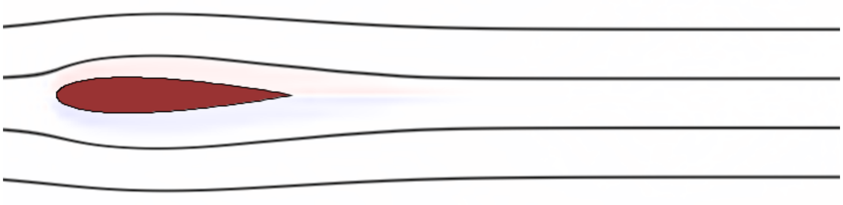
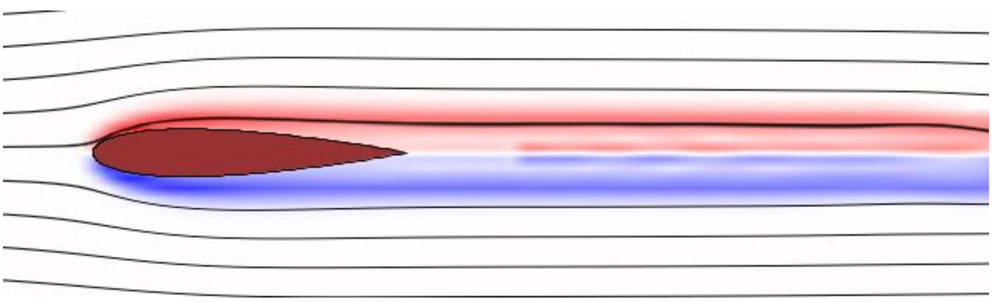
1 Streamlined Flow around an Airfoil

(a) Run the sketch **MAS14_StreamPlot** and make sure **nrLines = 100;** and **velocity = 0.1;** You should find the following plot which shows streamlined flow, there is no *vorticity* (red or blue areas)



(b) Now increase the velocity to 1.0 and reduced the number of line to 20. You should see the air now has vorticity, red means clockwise, blue anti-clockwise

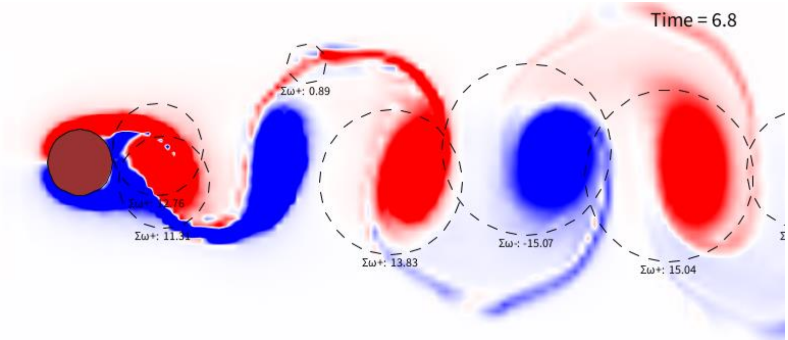


(c) Investigate higher velocities. You can also experiment setting an angle of attack of the airfoil. Look for the line (commented out) **body.rotate(2.0*PI/180);** which sets a 2 degree angle.

1 The Von-Karmen 'Vortex Street'

(a) Run the sketch **MAS14_Cylinder**. This is configured with a windspeed to the right of 1.0 units. You should get a vortex street looking like the one below. The numbers next to the dotted circles show how fast the air is circulating in the vortices. Red means air circulating clockwise, and blue means anticlockwise.

You can pause and restart the simulation by left mouse-click in the canvas. It takes time for the computation to stabilize; you will have to judge this.



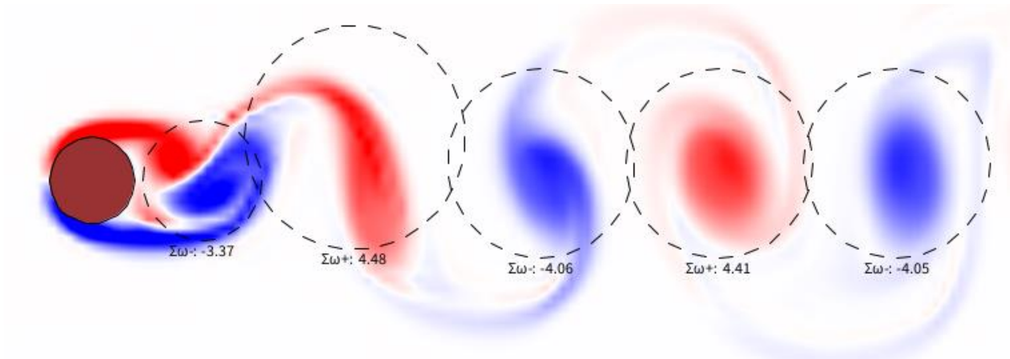
(b) Increase the velocity of the wind in stages (in my code this is line 49) and make direct observations how the street changes its behaviour.

2 Investigate other shapes

You can select other shapes in the sketch **MAS14_Cylinder**. Let's set the velocity to 1.0. You can select several objects, (i) Cylinder, (ii) Ellipse, (iii) Aerofoil, (iv) Rectangle. All you need to do is to comment and uncomment the appropriate line **body = new ….**.

For each shape make direct observations of the flow. After a fixed time (100 secs perhaps) pause the simulation and look at the values of circulation.

Here's an example. The circulation values are -3.37, 4.48, -4.06, 4.41, -4.05. All around 4.



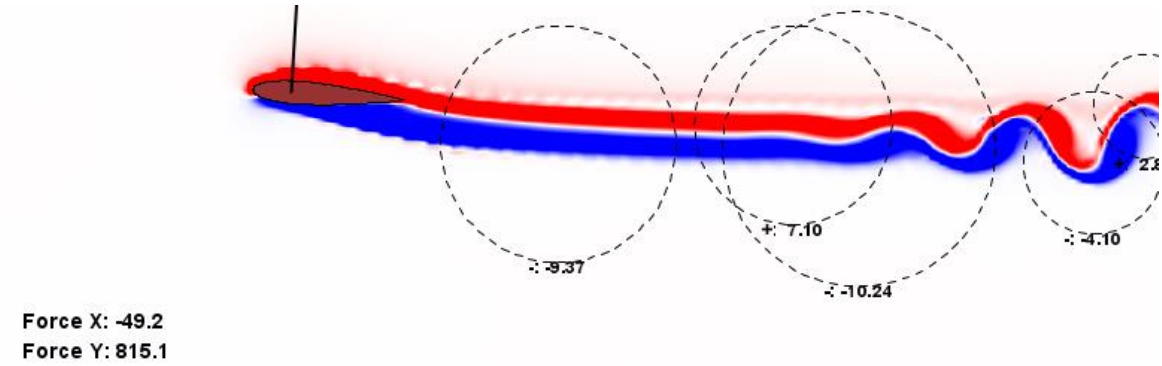
Perhaps make a table

Shape	Size of Circulation (approximate)
Cylinder	4

Summarize your findings. Remember that the **circulation** value indicates the forces exerted by the object onto the wind to make it circulate. By Newton's 3rd Law these forces will impact onto the object. This results in *drag* on the object, a resistance force, slowing it down. So, you will discover which shapes experience more or less drag forces.

3 CFD Study of a Turbine Blade

Here we shall have a look at the flow of air around a single turbine blade. The simulation **MAS14_NACA** has been configured to show the fluid flow, but more importantly to give us the forces in the Y-direction (lift) which makes the turbine rotate, and also in the X-direction (drag) which ultimately makes the tower bend. Here is an example for a wind velocity of 5.0 units and a blade pitch angle of 4.0 degrees. The stick on the blade shows the magnitude and direction of the force, here alost vertical.



An interesting study would be to keep the wind speed constant and vary the pitch angle. This should give you a feeling of how the force on the blade varies with angle, but also how the wake changes in size and structure.

4 Vibration Energy Harvesters

These are devices currently being researched. The simulation presented in **MAS14_Cylinder_React** shows a cylinder placed in air moving to the right. Think of the cylinder as connected between a couple of springs to restore its position to its starting place, if it moves away. This is actually a good model of overhead power lines; telephone lines of bridge stay cables.

Running the simulation shows that a steady flow of wind past the cylinder causes it to oscillate up and down. So a steady wind flow is converted (partially) into mechanical vibrations which in turn can be turned into electrical power.

Experiment with the system, perhaps changing the wind speed (increasing and decreasing it).

The power absorbed is proportional to the amplitude of oscillation squared, times the frequency of oscillation.

You should be able to get a feel for how power absorbed depends on windspeed, at leas qualitatively. This experiment will be revisited in the
Design-Build-Test' unit of work.