AE1106: Programming I
Graded Assignment #4
January 5, 2011

Please read these instructions first:
As an individual assignment, the code and solutions you submit should represent your own work. Discussion with others is not allowed, and neither is the use of online resources other than the standard Matlab help pages (i.e., no Wikipedia, Google searches, chat windows, etc.). During this assignment, the student assistants and the lecturer will only answer questions related to what the question is asking you to do, and will not assist you with how to actually complete the assignment. When finished, you will submit your Matlab source code file(s) to BlackBoard for grading (see below for submission instructions). The deadline to complete the assignment is 12:00 for morning sessions, and 17:00 for afternoon sessions. These deadlines are managed automatically by BlackBoard, so it is important that you submit your documents before the deadline in order to receive credit for the assignment (i.e., manage your time so that you start the submission process at least 15 minutes before the deadline). Those students who have been approved by the student counselors to receive extra time on their exams will receive an extra 30 minutes to complete the assignment.

Questions:

1 (2 points)
Write a short script file which uses *quad.m* to calculate the normal force coefficient

$$c_n = \frac{1}{c}\int_0^c (C_{p,l} - C_{p,u})\, dx$$

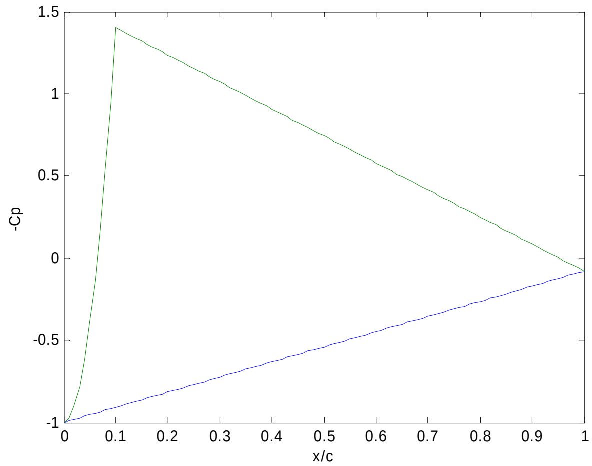
for the following pressure distribution:

$$C_{p,u} = 1 - 240\left(\frac{x}{c}\right)^2 \qquad \text{for } 0 \le \left(\frac{x}{c}\right) \le 0.1$$

$$C_{p,u} = -1.5644 + 1.6444\left(\frac{x}{c}\right) \qquad \text{for } 0.1 < \left(\frac{x}{c}\right) \le 1.0$$

$$C_{p,l} = 1 - 0.92\left(\frac{x}{c}\right) \qquad \text{for } 0 \le \left(\frac{x}{c}\right) \le 1.0$$

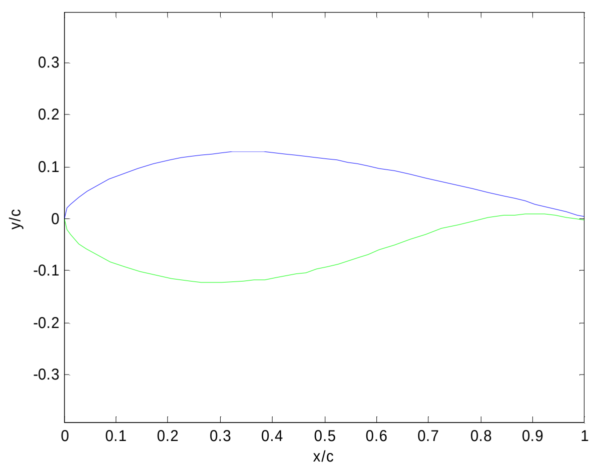
(i.e. integrate pressures at upper and lower surface).



In order to do so you have to write two functions, named ***PresLow.m*** and ***PresUpp.m***, which calculates the pressures given above. Be careful: these two functions should be able to accept a vector as input.

2 (6 points in total)
The coordinates and pressures of a typical wind turbine airfoil (DU 91-W2-250) are given in the two text files *DU46upp.txt* (upper surface) and *DU46low.txt* (lower surface). The first column is the dimensionless coordinate x/c (with c: chord), the second column the dimensionless coordinate y/c and the third column is the pressure coefficient Cp (for α=4.6 degrees).

Write a script file ***DU91airfoil.m*** which performs the following tasks:
A) (1 point) First graph
Make a plot of this airfoil (use: `axis equal`). Reproduce the plot below:

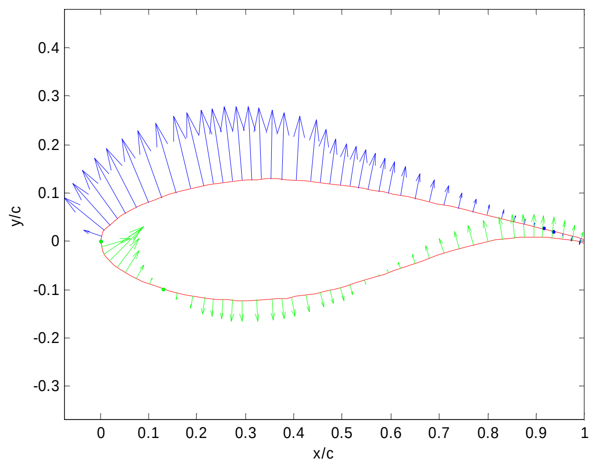


B) (1 point) Second graph
Make a plot of the pressure distribution; by convention –Cp is plotted.

C) (2 points)

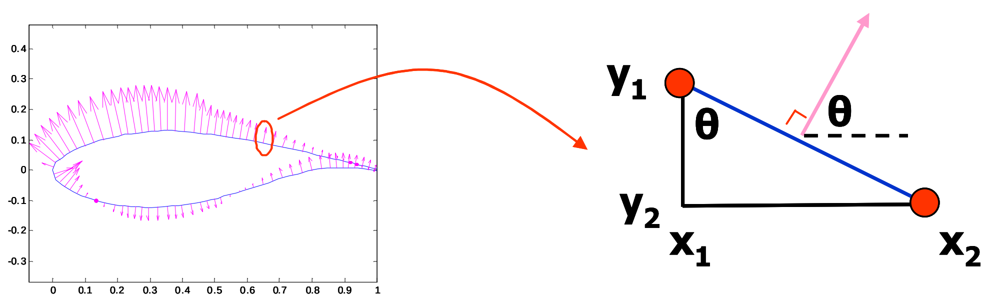
Determine the normal force coefficient $c_n = \frac{1}{c}\int_0^c (C_{p,l} - C_{p,u})\,dx$ from the pressure distribution (apply the trapezium rule; i.e. do NOT use *quad.m*).

D) (2 points) Third graph
Reproduce the following plot:



by means of the following steps for each segment of the upper surface (between two data points):

- Determine the mid position
- Determine the mean pressure coefficient
- Determine the angle θ of the direction normal to the airfoil surface



$$\theta = \arctan \frac{x_2 - x_1}{y_1 - y_2}$$

For the determination of the inverse tangent you may use ***atan2.m***.

- Determine the horizontal and vertical components of the pressure coefficient vector
- Multiply the components by a scaling factor equal to -0.1 (the minus sign is required in order to have the vectors pointing upwards)
- Use *quiver*; set S=0 to plot the arrows without automatic scaling (see help on *quiver*)
- Do the same for each segment of the lower surface; use a scaling factor equal to +0.1

3 (2 points in total + 1 bonus point)

A) (1 point)

On BlackBoard the function ***StreamUniform.m*** is available. This function calculates the stream function Ψ (Psi) of uniform flow. Write in a similar way the function ***StreamVortex.m***, with syntax: *[X,Y,Psi]=StreamVortex(x,y,Gamma,R)*, which determines the stream function of a (two dimensional) vortex at origin:

$$\Psi = \frac{\Gamma}{2\pi} \ln r \quad r > R$$

$$\Psi = 0 \quad r \leq R$$

with Γ the circulation and R the radius of a circle (with center at origin).

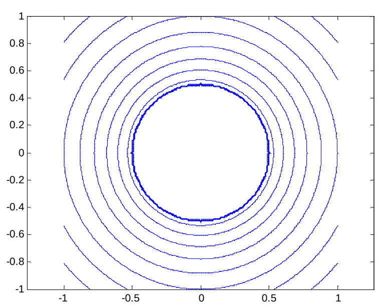
Hint: convert first Cartesian coordinates to polar ones:

$$r = \sqrt{(x^2 + y^2)}$$

$$\theta = \arctan \frac{y}{x}$$

You can check your code yourself: you should obtain the graph below with the following commands:

```
>> x=-1:0.01:1;
>> y=-1:0.01:1;
>> Gamma=1;
>> R=0.5;
>> [X,Y,Psi]=StreamVortex(x,y,Gamma,R);
>> contour(X,Y,Psi,'b')
>> axis equal
```



B) (1 point)

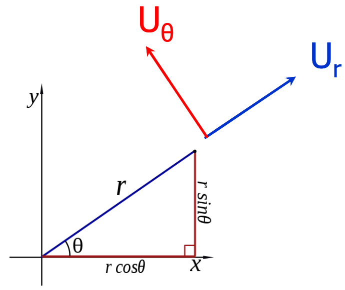
Also, the function ***VelocityUniform.m*** is provided which determines the velocity components of uniform flow. Write in a similar way the function ***VelocityVortex.m***, with syntax: *[X,Y,U,V]=VelocityVortex(x,y,Gamma,R)*, which determines the velocity components of a vortex:

$$U_r = 0 \quad r > R$$

$$U_\theta = -\frac{\Gamma}{2\pi r} \quad r > R$$

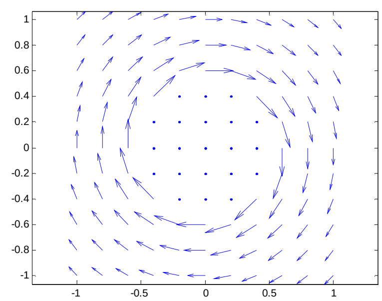
$$U_r = 0 \quad r \leq R$$

$$U_\theta = 0 \quad r \leq R$$

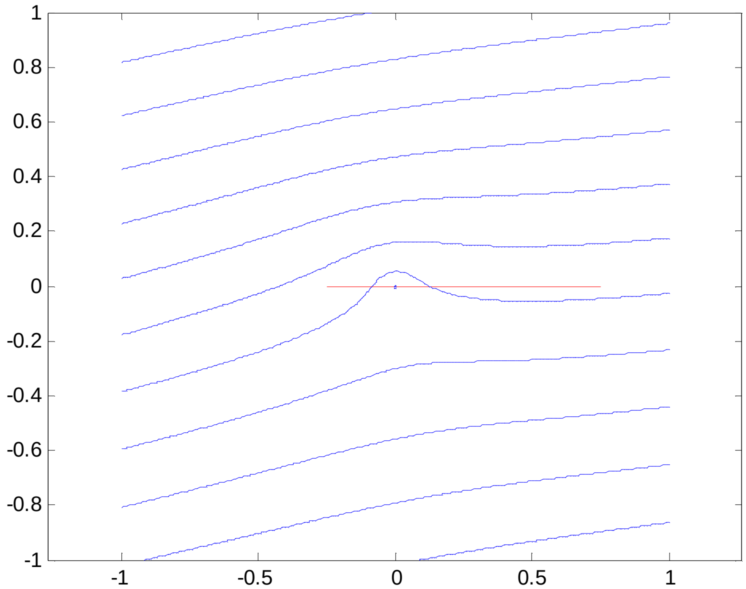


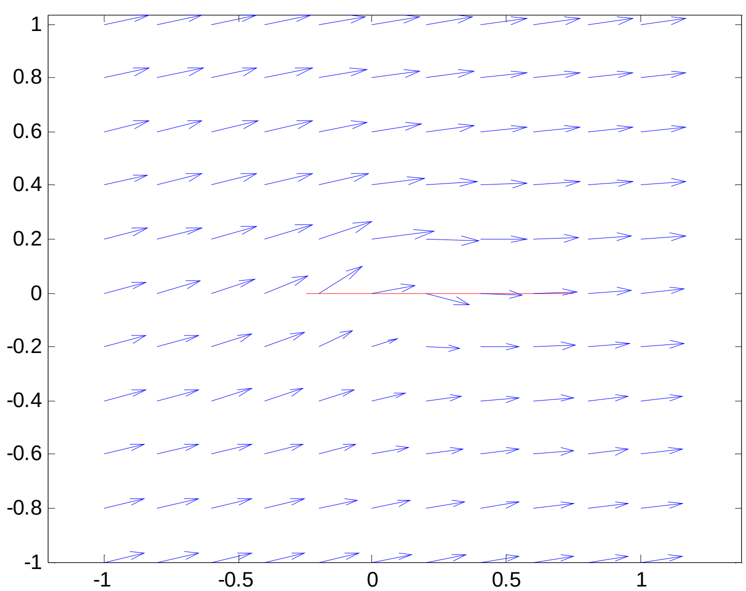
Hint: apply the equations above and next convert to the Cartesian velocity components U and V.
You can check your code yourself: you should obtain the graph below with the following commands:

```
>> x=-1:0.2:1;
>> y=-1:0.2:1;
>> Gamma=1;
>> R=0.5;
>> [X,Y,U,V]=VelocityVortex(x,y,Gamma,R);
>> quiver(X,Y,U,V,'b')
>> axis equal
```



C) (1 bonus point; Note: grade can not be higher than 10)
The flow around a flat plate (or airfoil) can be modeled by the summation of uniform flow and a vortex. Write a script file which reproduces the two graphs below:





Take the following values: W=50 m/s; α=10 degrees; Γ=27 m^2/s; R=0.01 m. For the first graph a spacing of the grid points of 0.01 can be taken; for the second graph the spacing is 0.2. The x-coordinates of the flat plate runs from -0.25 to 0.75 (so quarter-chord is at the origin).

Note: the flow near the leading edge of the flat plate and the smooth flow at the trailing edge (Kutta condition) are correctly captured. Flow through the flat plate, as shown in both graphs, is of course physical not correct; more sophisticated models (distribution of circulation rather than a single vortex) are required in order to model this correctly.

You have to upload 7 files in total:

- ***PresLow.m***
- ***PresUpp.m***
- ***script file question 1***
- ***DU91airfoil.m***
- ***StreamVortex.m***
- ***VelocityVortex.m***
- ***script file question 3C***

Submission Instructions

1) When you are ready to submit your files to BlackBoard, go to the Assignments and then click on the "Graded Assignment 4" item. This will open a page where you can upload your assignment files.

2) By clicking on the "Browse My Computer" button next to the "Attach File" label, you can add one or more files to your assignment submission. You can save the current state of your submission at any time using the "Save as Draft" but your work will not be officially recorded in the system until you click the "Submit" button. After you have submitted the assignment, BlackBoard should then show you a summary page, which lets you know the submission went successfully. Please be patient after submitting your files, as sometimes it takes a few seconds before BlackBoard registers everything properly. We recommend that after submission, you wait 15-20 seconds, then go back to the course homepage and proceed again through to the "Graded Assignments 4" item. After doing this, you should see all of your submitted files in the summary page if everything went smoothly.

3) Remember that the submission folder automatically disappears at the deadline, so please make sure you start the submission process well before this time.

4) If you made an error and you wish to change a file after your have hit the submit button, you can go back to the "Graded Assignment 4" link and click on the "Start New Submission" link to repeat the entire process (i.e., do not just submit the updated file, but completely resubmit all files). Note that if you make more than one submission, we will only grade the last attempt.

5) As a reminder, please do NOT include special characters in the names of your files, such as "%", brackets "[ ]", underscores "_", etc., as BlackBoard may have problems with these. Also, do NOT upload a ".mat" or ".asv" file…only upload your ".m" files, or other documents (e.g., MSWord file) if requested.