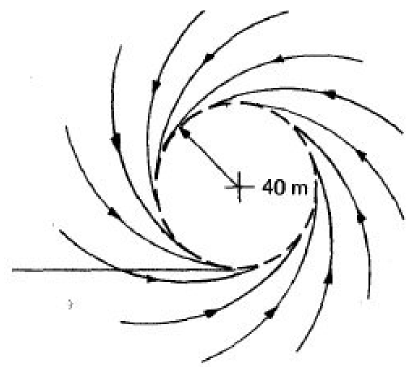
Problem Set #8

Due: Friday 11/8/2013
(6 problems; 30 points total)

1.[5 points] The velocity field of a stationary hurricane can be approximated as a counterclockwise vortex and a line sink. Thus the velocity potential is

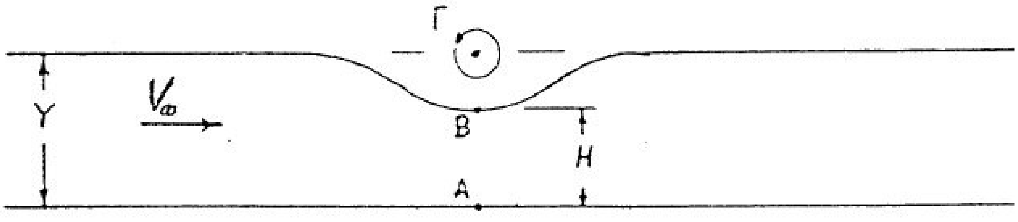
$$\phi = -\frac{\Gamma}{2\pi}\theta - \frac{Q}{2\pi}\ln r$$

As shown in the figure below this potential function can be used to represent the flow for r>40 m (i.e., except near the core). Assume that the pressure at r=40 m is -1,400 Pa gage (i.e, relative to the atmosphere far from the storm) and that the density is constant at 1.2 kg/m^3. Assume also that the influx of air across the (invisible) cylinder at r=40 m is 4,000 m^2/s per meter of depth into the paper.



Calculate: a) the total wind speed at r=40 m
b) the strength of the sink (Q) in m^2/s
c) the gage pressure at r=80 m
d) the angle at which the streamlines cross the cylinder at r=40 m.

2.[5 points] We wish to represent flow through the sketched constriction in an otherwise straight, parallel-wall, two dimensional channel of height *Y*. Flow through the channel is inviscid, incompressible and uniform far upstream with velocity V_∞. One way to study this problem is to introduce a concentrated vortex at a height *Y* above the lower wall. You will need to install an appropriate image to complete the system.



a) Write a formula for the stream function ψ of the complete flow; check that ψ is constant at the lower wall.
b) Find the strength Γ needed for a given constriction height *H*.
c) Find the velocities at points *A* and *B*. Which one is higher?
d) Is the flow irrotational everywhere? (why?)

3.[5 points] Consider a potential flow made up of the superposition of a uniform flow in the x-direction with velocity $V_\infty = 1$, a source of strength $Q = 1$ at $(x,y) = (-0.5,0)$, a source of strength $Q = 0.5$ at $(x,y) = (-0.25,0)$, and a source of strength $Q=-0.5$ at $(x,y) = (0.25,0)$.

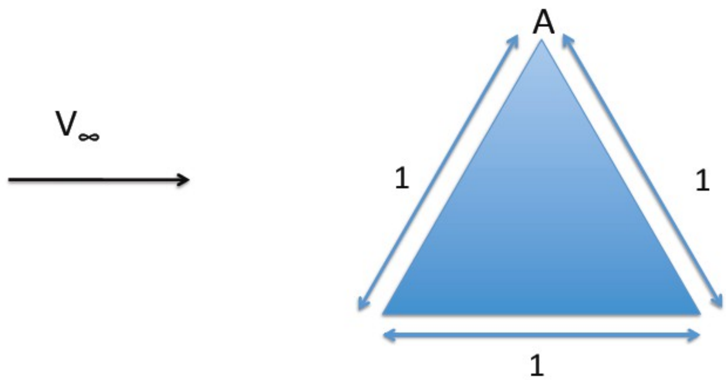
a) Locate the stagnation point(s).

b) Find the stream function $\psi(x,y)$ for the combined flow.

c) Equation of the stagnation streamline.

d) Ese *Ideal Flow Machine* (http://www.aoe.vt.edu/~devenpor/aoe5104/ifm/ifm.html) to draw streamlines of the flow and print the results.

4.[5 points] Consider the 2D, incompressible potential flow with a velocity V around a triangular shape as shown below.



a) Apply the crude panel method to find a system of sources that represents such as flow.

b) Find the velocity and pressure coefficient at point A.

c) Find the stream function for this flow and location of stagnation point(s)?

5.[10 points] You are going to find the incompressible potential flow over an NACA 2418 airfoil at angle of attack using the source/vortex panel method described in class.

There are three matlab files you will need – velfrompanel.m; airfoil_examp.m and naca4.m.

```
function [U,V]=velfrompanel(x1,y1,x2,y2,xc,yc)
```

```
calculates the x & y velocity components (U,V) at a specified point
(xc,yc) induced by a unit strength source sheet connecting specified points
(x1,y1) and (x2,y2). (or, equivalently, the velocities induced by a uniform
strength vortex sheet)
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The second is an example for a different airfoil:

```
airfoil_examp.m
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Before doing anything for the NACA2418 airfoil, make sure you can run the example, varying the angle of attack and the thickness/chord ratio.

a)Consider the NACAabcd ("4 digit series") airfoils. What is the meaning of the four digits: abcd? Specifically, what tells you the thickness/chord ratio? What tells you the location of the max camber? What tells you the value of the max camber? What are the values of these quantities for the 2418?

b)The geometry of the NACA 4 series is coded in the Matlab function naca4.m, available on piazza (The formulas coded there are from Abbott & von Doenhoff). The basic shape has a “chopped off” trailing edge. What is the thickness of that TE (in units of the chord length)?

c) The naca4 function has a closure option, which removes the chopped off TE by slightly altering the aft of the airfoil to a point. Compare the open and closed shapes… especially near the TE.

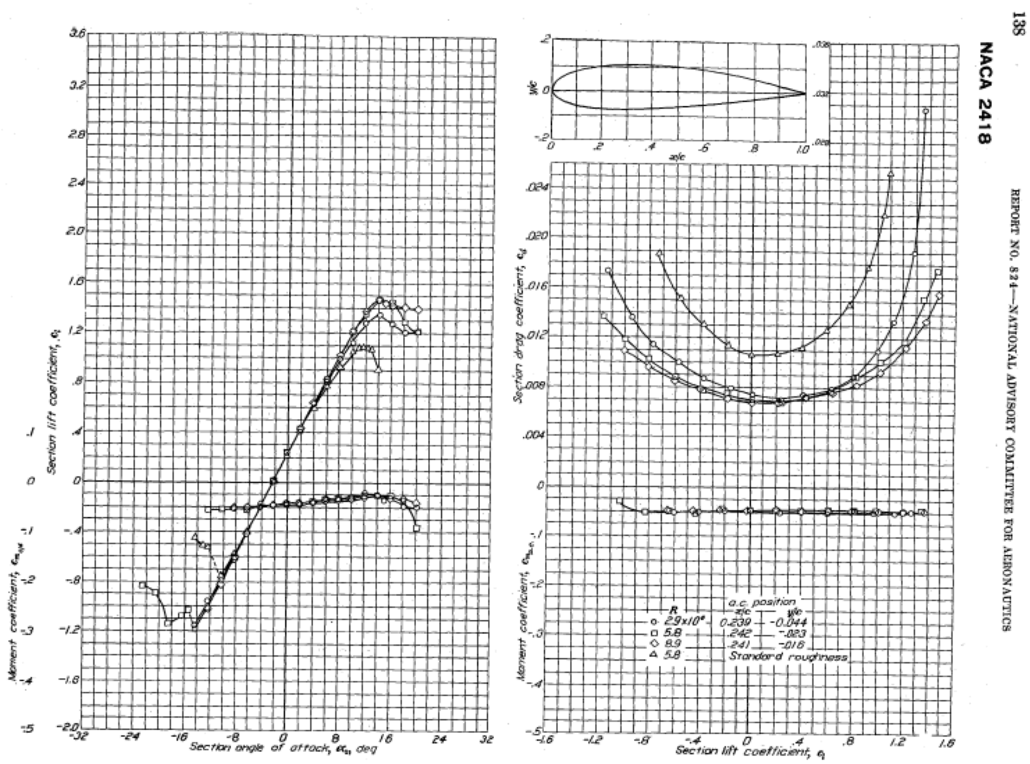
d) Calculate the pressure distribution on the NACA2418 at 10deg aoa, using both the “open” and “closed” shapes. Examine the pressure distribution near the TE in particular. What’s the difference?

e) Calculate the lift coefficient by using the Kutta-Joukowski law. Also calculate it by direct integration of the pressure. Do you get the same answer?

f) Compare pressure distributions, lift coefficients, drag coefficients as you increase the number of panels: 80, 160, 320. Use the closed TE option. How many significant figures do you have in Cl at 80 panels? Does the value of Cd tell you anything about the error in Cl?

g) Compare the Lift Coefficient/angle of attack curve obtained from the code to the one given in Abbott & von Doenhoff (reproduced below).

h) Compare the Drag Coefficient/angle of attack curve obtained from the code to the one given in Abbott & von Doenhoff.



Aerodynamic characteristics of the NACA 2418 airfoil section, 24-inch chord.