ASEN 3111 - Computational Assignment 02 - Main

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Simulating the airflow over a thin airfoil by plotting the stream lines, equipotential lines, and pressure contours


```
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```
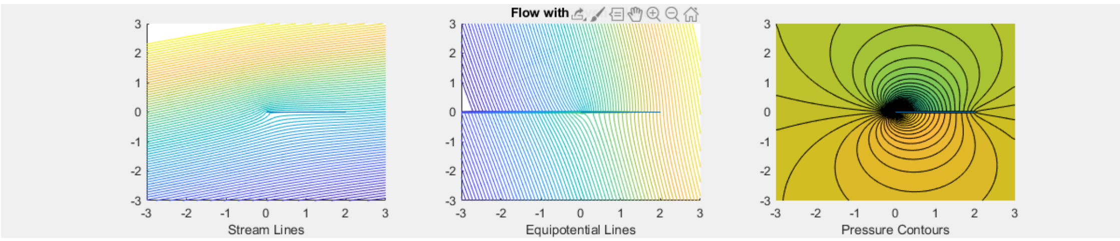


Estaplishing constants

```
clear, clc, close all

c = 2; % m
alpha = 12; % degrees
V_inf = 68; % freestream velocity
p_inf = 101.3e3; % freestream pressure
rho_inf = 1.225; % freestream density
plotting = true;
V = zeros(100,100,98);
P = zeros(100,100,98);
N = 1000;
fig = 1;
rows = 1;
row = 0;
```

Visualizing The Flow With Given Values

```
name = 'Flow with given values';
[Vactual,Pactual,fig] =
 Plot_Airfoil_Flow(c,alpha,V_inf,p_inf,rho_inf,N,plotting,fig,rows,row,name);
```

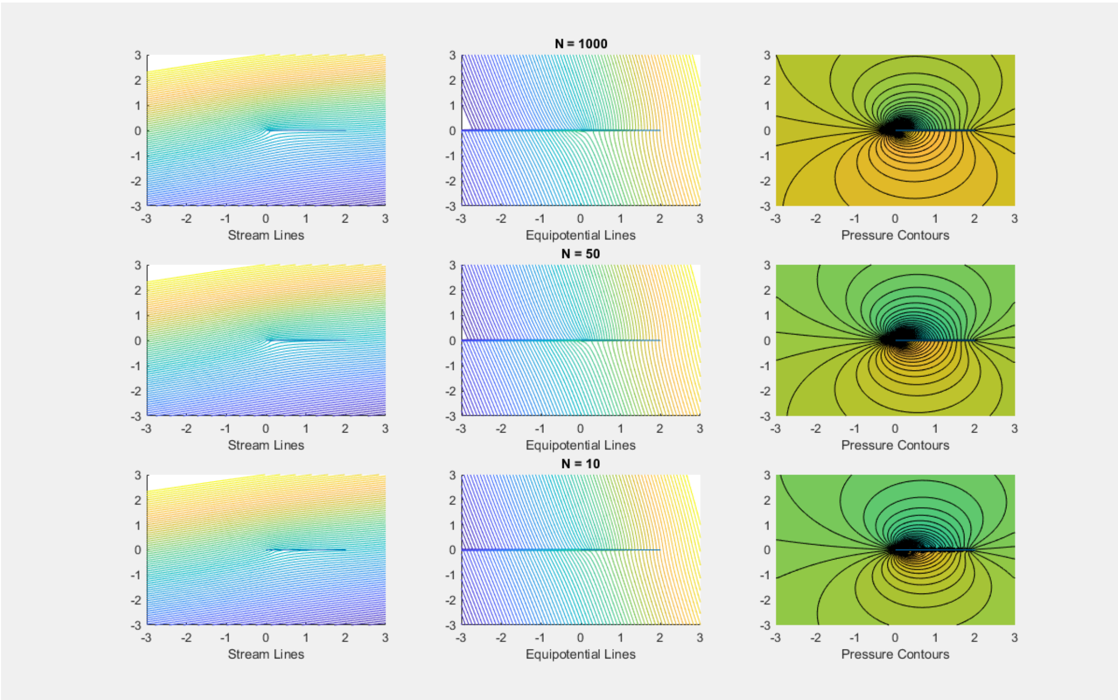


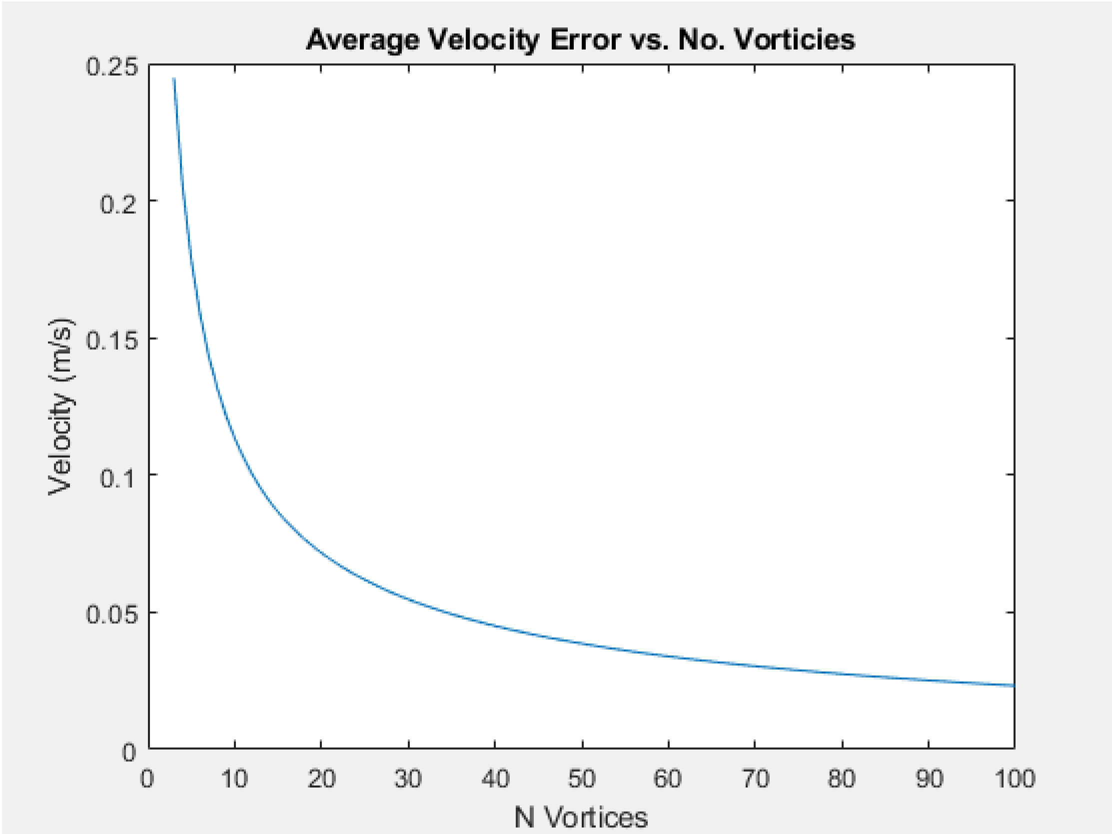
Checking the effect of N on the accuracy of velocity and pressure

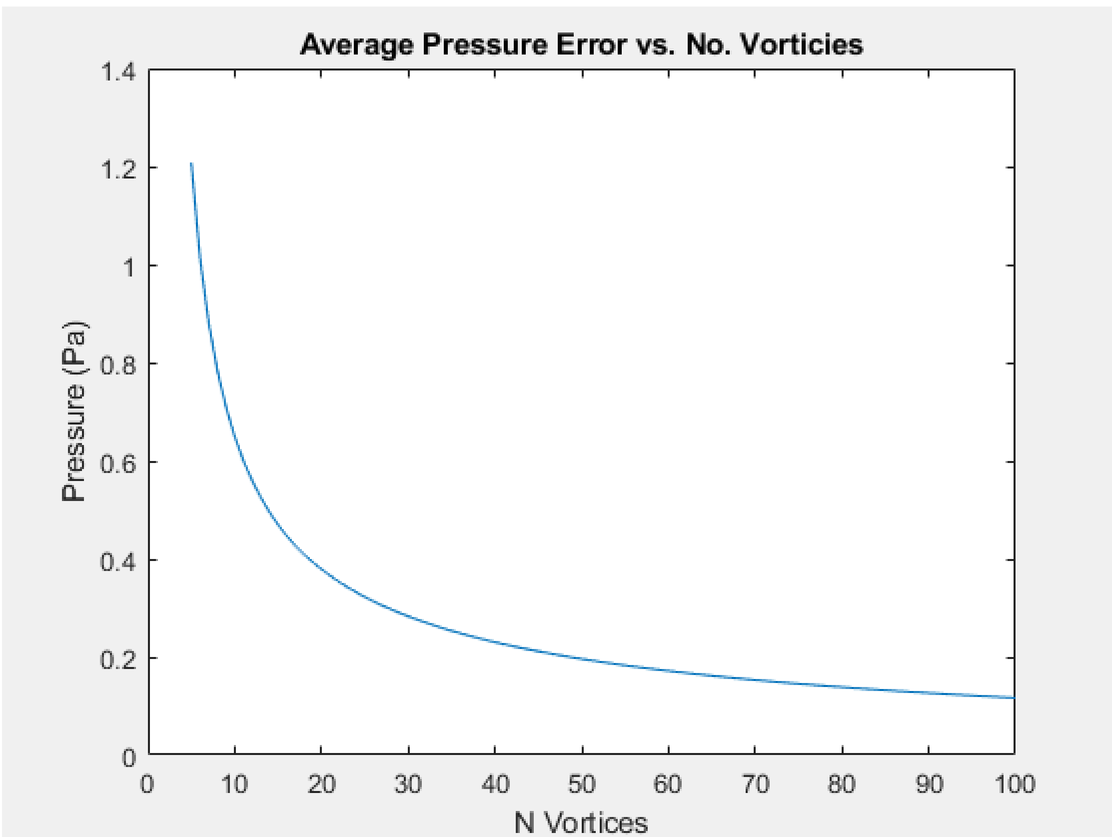
```
close all
plotting = false;
for N = 3:100
    [V(:,:,N-2), P(:,:,N)] =
 Plot_Airfoil_Flow(c,alpha,V_inf,p_inf,rho_inf,N,plotting,rows,row,name);
end

DV = zeros(98,1);
DP = zeros(98,1);
for i = 1:98
    DV(i) = mean(abs(Vactual-V(:,:,i)),'all');
    DP(i) = mean(abs(Pactual-P(:,:,i)),'all');
end
plotting = true;
N = 1000;
rows = 3;
row = 0;
name = 'N = 1000';
Plot_Airfoil_Flow(c,alpha,V_inf,p_inf,rho_inf,N,plotting,fig,rows,row,name);
N = 50;
row = 3;
name = 'N = 50';
Plot_Airfoil_Flow(c,alpha,V_inf,p_inf,rho_inf,N,plotting,fig,rows,row,name);
N = 10;
row = 6;
name = 'N = 10';
[~,~,fig] =
 Plot_Airfoil_Flow(c,alpha,V_inf,p_inf,rho_inf,N,plotting,fig,rows,row,name);
figure
plot(3:100,DV)
title('Average Velocity Error vs. No. Vorticies')
ylabel('Velocity (m/s)')
xlabel('N Vortices')
figure
plot(5:100,DP(3:end))
title('Average Pressure Error vs. No. Vorticies')
ylabel('Pressure (Pa)')
xlabel('N Vortices')

fprintf(['Figure 2 shows that there is not a significant difference in
 '...
'the velocity and pressure graphs in between N=50 and N=1000, but '...
'there is a difference in the pressure contours. Figure 2 also shows
 that '...
'N=10 has a very large difference in all three plots, and does not do
 a '...
'good job of presenting the data. Figures 3 and 4 show how the average
 '...
```

```
'velocity and pressure errors change with respect to N. As expected
 the '...
'error decreases with an exponential decay.\n\n'])
```

Figure 2 shows that there is not a significant difference in the velocity and pressure graphs in between N=50 and N=1000, but there is a difference in the pressure contours. Figure 2 also shows that N=10 has a very large difference in all three plots, and does not do a good job of presenting the data. Figures 3 and 4 show how the average velocity and pressure errors change with respect to N. As expected the error decreases with an exponential decay.




Average Velocity Error vs. No. Vorticies
Velocity (m/s)
N Vortices
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100


Average Pressure Error vs. No. Vorticies
Pressure (Pa)
N Vortices
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100

Studying the Effect of c, alpha, and V_inf

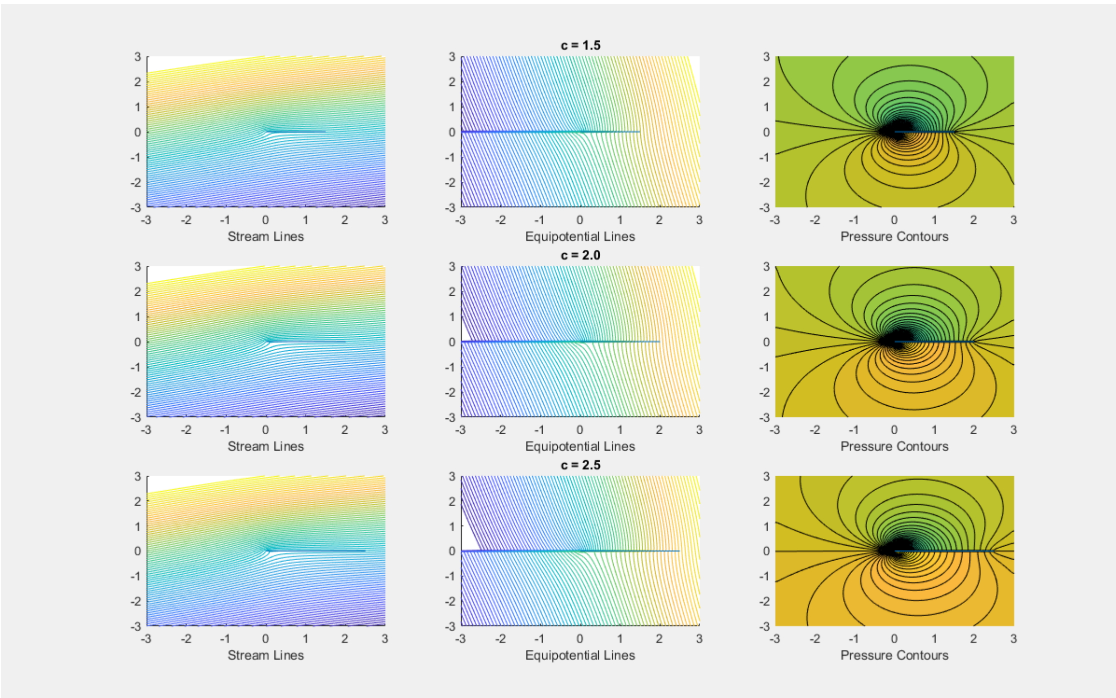
```
close all
plotting = true;
N = 1000;
c = [1.5,2,2.5];
alpha = [6,12,18];
V_inf = [10,68,120];
rows = 3;
row = 0;
name = sprintf('c = %1.1f',c(row/3+1));
Plot_Airfoil_Flow(c(row/3+1),alpha(2),V_inf(2),p_inf,rho_inf,N,plotting,fig,rows,r
row = 3;
name = sprintf('c = %1.1f',c(row/3+1));
Plot_Airfoil_Flow(c(row/3+1),alpha(2),V_inf(2),p_inf,rho_inf,N,plotting,fig,rows,r
row = 6;
name = sprintf('c = %1.1f',c(row/3+1));
[~,~,fig] =
 Plot_Airfoil_Flow(c(row/3+1),alpha(2),V_inf(2),p_inf,rho_inf,N,plotting,fig,rows,

row = 0;
name = sprintf('alpha = %d',alpha(row/3+1));
Plot_Airfoil_Flow(c(2),alpha(row/3+1),V_inf(2),p_inf,rho_inf,N,plotting,fig,rows,r
row = 3;
name = sprintf('alpha = %d',alpha(row/3+1));
Plot_Airfoil_Flow(c(2),alpha(row/3+1),V_inf(2),p_inf,rho_inf,N,plotting,fig,rows,r
row = 6;
name = sprintf('alpha = %d',alpha(row/3+1));
[~,~,fig] =
 Plot_Airfoil_Flow(c(2),alpha(row/3+1),V_inf(2),p_inf,rho_inf,N,plotting,fig,rows,

row = 0;
name = sprintf('V_{inf} = %d',V_inf(row/3+1));
Plot_Airfoil_Flow(c(2),alpha(2),V_inf(row/3+1),p_inf,rho_inf,N,plotting,fig,rows,r
row = 3;
name = sprintf('V_{inf} = %d',V_inf(row/3+1));
Plot_Airfoil_Flow(c(2),alpha(2),V_inf(row/3+1),p_inf,rho_inf,N,plotting,fig,rows,r
row = 6;
name = sprintf('V_{inf} = %d',V_inf(row/3+1));
[~,~,fig] =
 Plot_Airfoil_Flow(c(2),alpha(2),V_inf(row/3+1),p_inf,rho_inf,N,plotting,fig,rows,

fprintf(['The effects of c are slight but noticeable, There are
 changes '...
'in all three plots but the most noticeable are in the stream lines
 and '...
'pressure contours. The stream lines and pressure contours for the
 longer '...
'chord generally have a little more separation between them.\n\n'])
fprintf(['Angle of attack seems to have the most effect on the plots,
 '...
'of course the differences in AOA are probably more significant than
 the '...
```

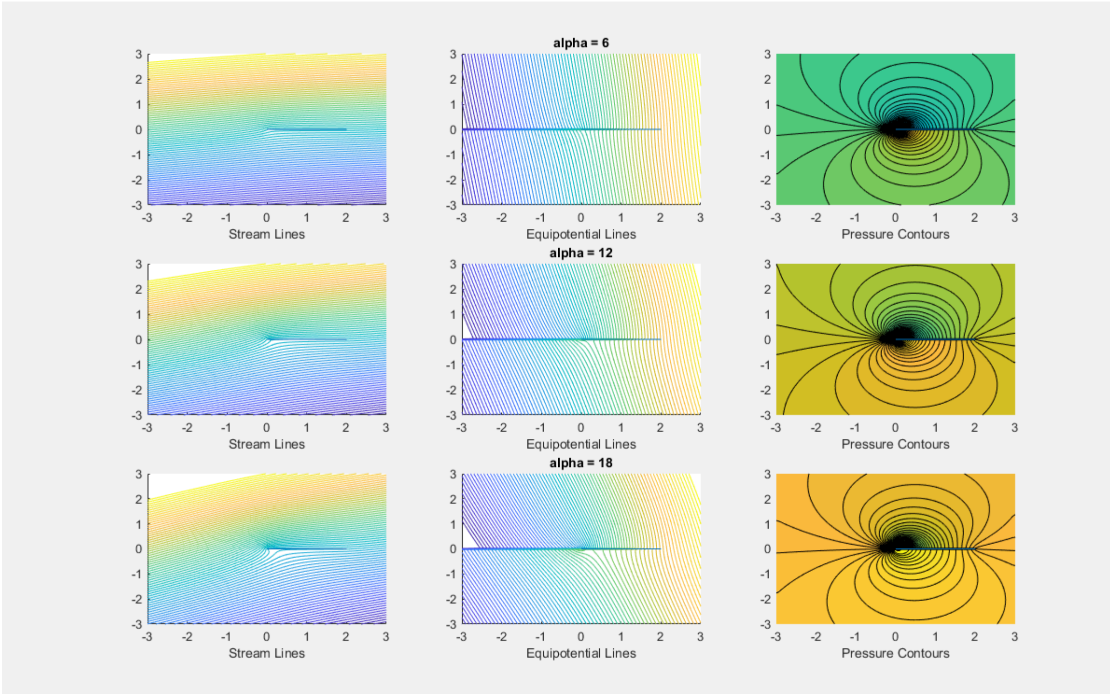
```
'other permutations. Alpha completely changes the plots with an AOA of
 18 '...
'the streamlines have significant separation and the pressure contours
 '...
'mainly change color entirely.\n\n'])
fprintf(['Free stream velocity seems to have the least effect on the
 '...
'plots. I am not really able to tell the difference between the
 different '...
'velocities.\n\n'])
```

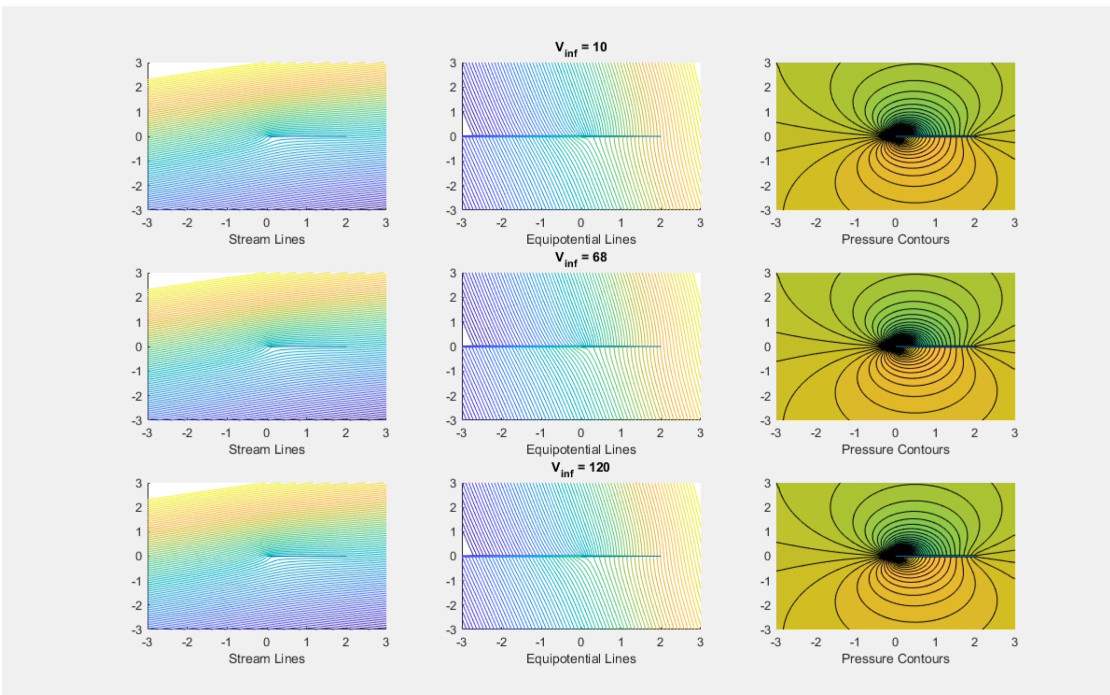
The effects of c are slight but noticeable, There are changes in all three plots but the most noticeable are in the stream lines and pressure contours. The stream lines and pressure contours for the longer chord generally have a little more separation between them.

Angle of attack seems to have the most effect on the plots, of course the differences in AOA are probably more significant than the other permutations. Alpha completely changes the plots with an AOA of 18 the streamlines have significant separation and the pressure contours mainly change color entirely.

Free stream velocity seems to have the least effect on the plots. I am not really able to tell the difference between the different velocities.







Functions Called

The following functions were built and called as part of this assignment.

```
function [V,pressure,fig] =
 Plot_Airfoil_Flow(c,alpha,V_inf,p_inf,rho_inf,N,plots,fig,rows,row,name)
%Plot_Airfoil_Flow plots the contour lines of a given flow
```

```
%   The flow is defined by the cord length(c), angle of attack(alpha),
 the
%   freestream velocity(V_inf), the freastream pressure(p_inf), the
%   freestream density(rho_inf), and the number of discrete
 vorticies(N)

%% Define Domain
xmin=-3;
xmax=3;
ymin=-3;
ymax=3;

%% Define Number of Grid Points
nx=100; % steps in the x direction
ny=100; % steps in the y direction

[x,y]=meshgrid(linspace(xmin,xmax,nx),linspace(ymin,ymax,ny));

alpha = alpha*pi/180;

VorP = linspace(0,c,N);
VorP = VorP(2:end-1);
dx = c/N;

gammas = 2*alpha*V_inf*sqrt((1-VorP/c)./(VorP/c));

Gammas = gammas*dx;

%% Stream and Potential Functions

% Uniform Flow
u = V_inf*cos(alpha);
v = V_inf*sin(alpha);
psiU = u*y - v*x;
phiU = u*x + v*y;

% Vortex Flow
radius=@(x,y,x1,y1) sqrt((x-x1).^2+(y-y1).^2);
theta =@(x,y,x1,y1) atan2((y-y1),(x-x1));
psiV = zeros(nx,ny);
phiV = zeros(nx,ny);

for i=1:numel(VorP)
    psiV = psiV + Gammas(i)./(2*pi).*log(radius(x,y,VorP(i),0));
    phiV = phiV - Gammas(i)./(2*pi).*theta(x,y,VorP(i),0);
end

StreamFunction = psiV + psiU;
PotentialFunction = phiV + phiU;
%% Determine color levels for contours
levmin = StreamFunction(1,nx); % defines the color levels -> trial and
 error to find a good representation
levmax = StreamFunction(ny,nx/2);
levels = linspace(levmin,levmax,80)';
```

```
if plots == true
    figure(fig)
    set(gcf, 'Position',  [200, 150, 1200, 250*rows])
    subplot(rows,3,1+row)
    hold on
    contour(x,y,StreamFunction,levels)
    plot([0 c], [0 0])
    xlabel('Stream Lines')

    subplot(rows,3,2+row)
    hold on
    contour(x,y,PotentialFunction,levels)
    plot([0 c], [0 0])
    title(name)
    xlabel('Equipotential Lines')
end
%% Velocity Functions


V = gradient(PotentialFunction);
q_inf = 1/2*rho_inf*V_inf^2;
pressure = (1-(V./V_inf).^2)*q_inf+p_inf;

levmin = min(min(pressure)); % defines the color levels -> trial and
 error to find a good representation
levmax = max(max(pressure));
levels = linspace(levmin,levmax,100)';

if plots == true
    subplot(rows,3,3+row)
    hold on
    contourf(x,y,pressure,levels)
    plot([0 c], [0 0])
    xlabel('Pressure Contours')
    fig = fig+1;
end
end
```

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