# HW3 Q2

```
clc;

clear all;
clf;
%% Dimensions
Rc = 0.5;
Rm = 10;
%%Inlet conditions
Uinf = 1;
%%Mesh Size
Nr = 100;
Nt = 100;
th =(linspace(0,2*pi,Nt))';
r = linspace(Rc,Rm,Nr);
dr = (Rm-Rc)./(Nr-1);
dt = (2.*pi)./(Nt-1);


tol = 1e-8;




Psi=zeros(Nr,Nt);
Psi(Nr,:) = (Uinf.*Rm.*sin(th));




%discretization
for j = 1:Nr
    for k=1:Nt
      rj(j,k)=Rc+(j-1)*dr;
      tk(j,k)=(k-1)*dt;
      x(j,k)=rj(j,k)*cos(tk(j,k));
      y(j,k)=rj(j,k)*sin(tk(j,k));
    end
end


%% Calculating for stream function
omega=2./(1 + sqrt(1-(cos(pi./(Nr-1))*cos(pi./(Nt-1)))));
Res(1)=1;
itr=1;


while(Res(itr)>tol)

    for j=2:(Nr-1)
        for k=2:(Nt-1)
         den=((((2./dr.^2))+2./(rj(j,k).^2.*dt.^2)));
```

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           dPsi(j,k)=((1/(rj(j,k)).*((Psi(j+1,k)-Psi(j-
1,k))/(2*dr))+((1/dr^2)*(Psi(j+1,k)+Psi(j-
1,k)))+((1.0/(rj(j,k)^2*dt^2))*(Psi(j,k+1)+Psi(j,k-1)))))/den-Psi(j,k);
           Psi(j,k)=Psi(j,k)+omega*dPsi(j,k);
        end
    end
    err=norm(dPsi);
    itr=itr+1;
    Res(itr)=err;
    disp(Res(itr));

end


figure(1)
pcolor(x,y,Psi)
colorbar


figure(2)
plot(1:itr,log10(Res))
grid on
title('Convergence history')
xlabel('No. of Iterations')
ylabel('residual')


Cp=zeros(Nr,Nt);
ur=zeros(Nr,Nt);
ut=zeros(Nr,Nt);


%% Calculating Velocity in interior
for j=2:Nr-1
    for k=2:Nt-1
          ur(j,k)=((Psi(j,k+1)-Psi(j,k-1))/2/dr)./r(j);
          ut(j,k)=(-Psi(j+1,k)+Psi(j-1,k))/2/dr;
    end
end







% Calculating Velocity on boundary


j=1;
for k=1:Nt
            ur(j,k)=0;
            ut(j,k)=3*Psi(j,k)-4*Psi(j+1,k)+Psi(j+2,k)./(2*dr);
end
```

```
j=Nr-2;
for k=1:Nt
            ur(j,k)=Uinf*cos(th(k));
            ut(j,k)=-Uinf*sin(th(k));
end


k=1;
for j=1:Nr
            ur(j,k)=(-3*Psi(j,k)+4*Psi(j,k+1)-Psi(j,k+2)./(2*dr))./r(j);
            ut(j,k)=0;
end


k=Nt;
for j=1:Nr
            ur(j,k)=(3*Psi(j,k)-4*Psi(j,k-1)+Psi(j,k-2)./(2*dr))./r(j);
            ut(j,k)=0;
end


%% Calculating Cpressure numerical and exact
% Calculate Cp
for j=1:Nr
    for k=1:Nt
          Cp(j,k)=1.0-(ur(j,k)^2+ut(j,k)^2)/Uinf;
    end
end
for i = 1:Nt
    Cpex(i)= 1-(4*(sin(th(i)).^2));
end


figure(3)
pcolor(x,y,Cp)
colorbar
title('Pressure distribution')


%%Error calculation
error=(norm ((Cpex-Cp(2,(1:Nr))))./(sqrt(Nr.*Nt));
disp(error);


figure(4)
plot(th,Cp(2,1:Nt));
hold on;
plot(th,Cpex);
legend({'Cpnum','Cpexact'})
title('Cp vs thetha')
xlabel('thetha')
ylabel('Cp')
```

**Figure 1**

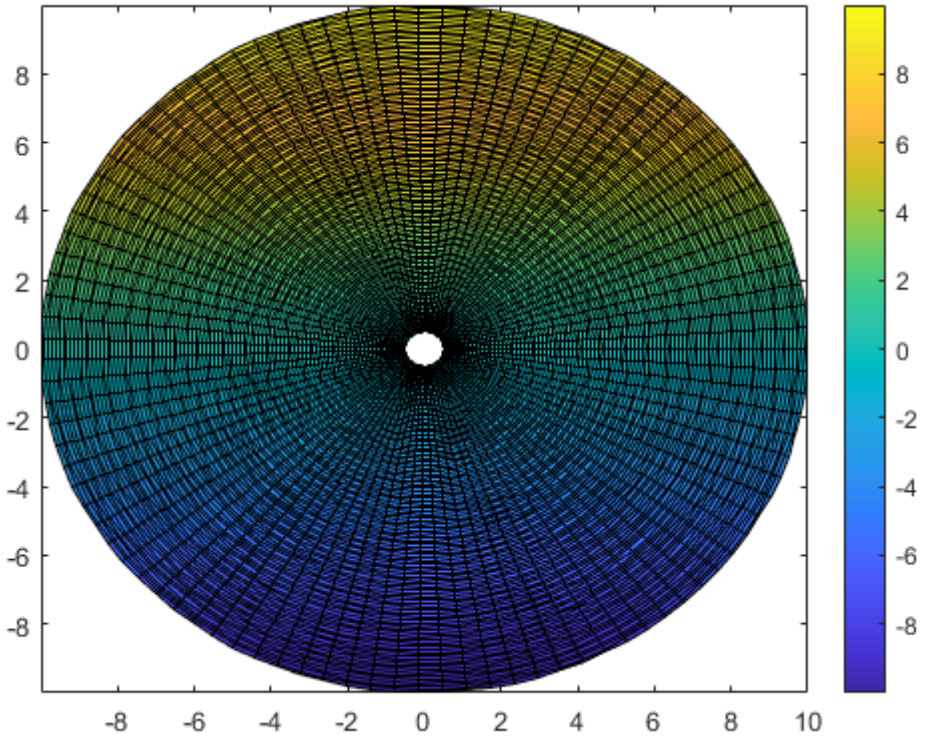
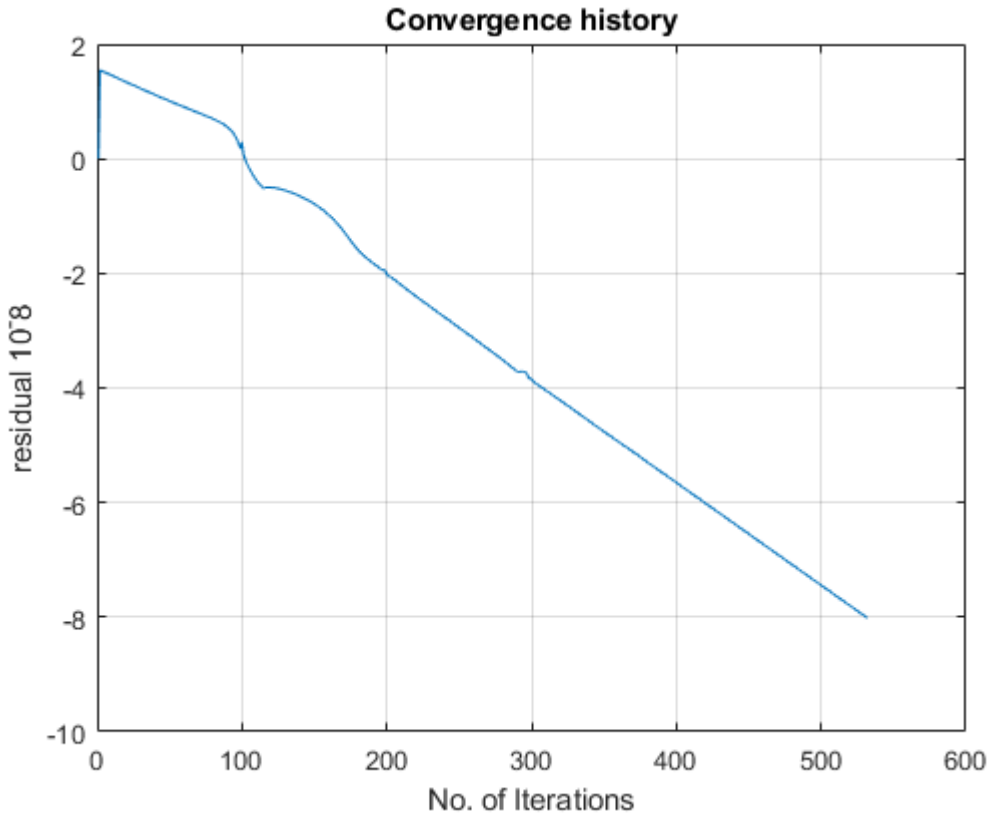
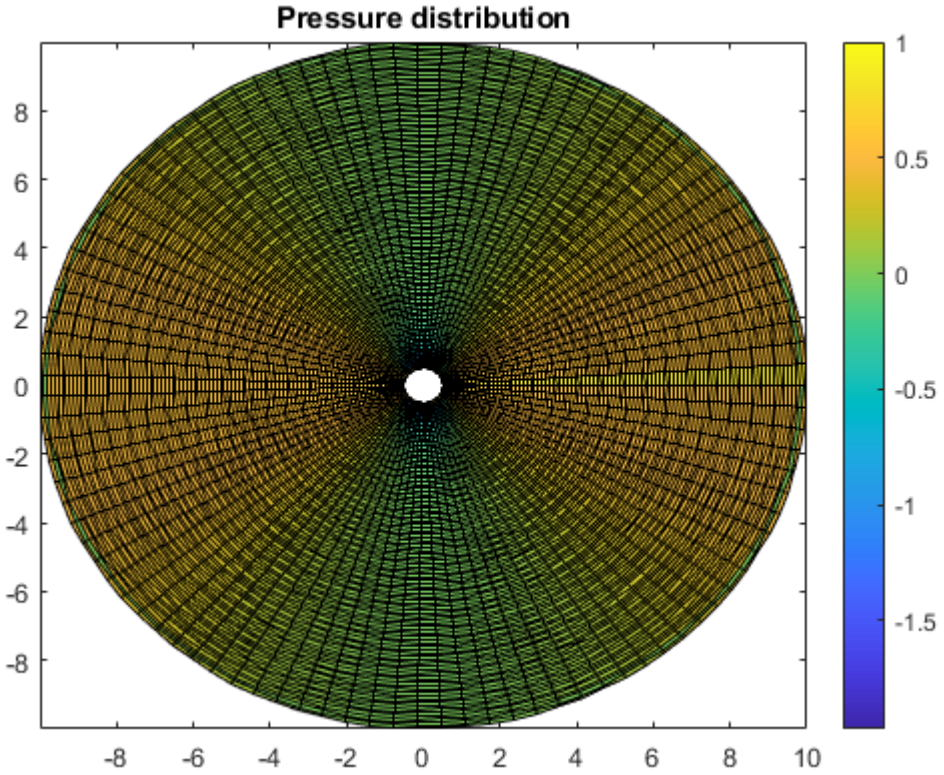


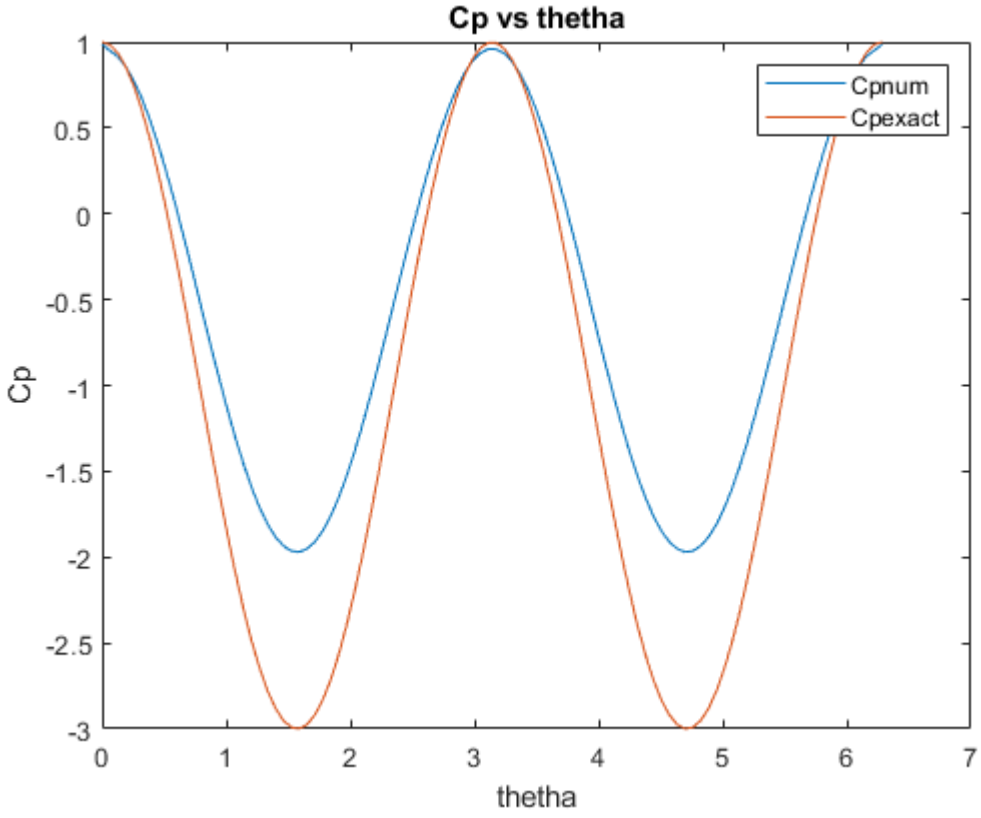

**Figure 2**



## Figure 3

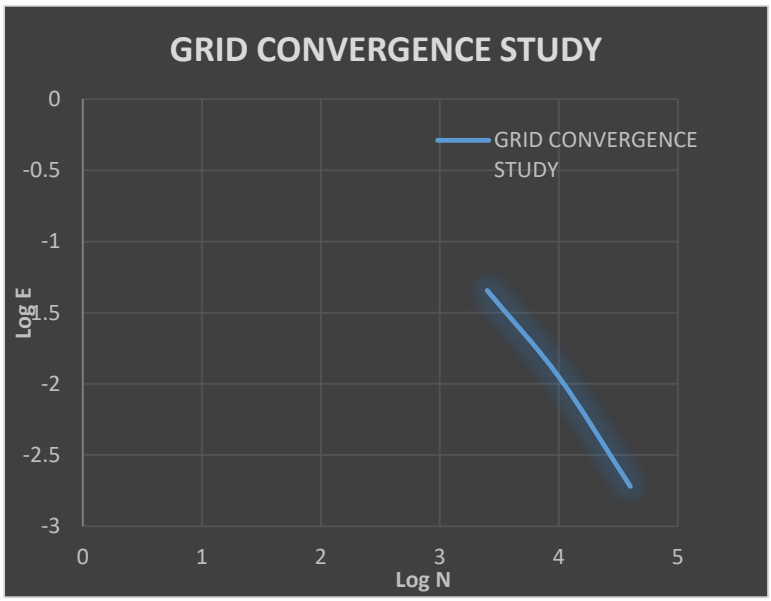



## Figure 4



# Grid Convergence Study

| NODES | ERROR | LOG E | LOG N |
|---|---|---|---|
| 2500 | 0.131 | -0.88273 | 3.39794 |
| 10000 | 0.062 | -1.20761 | 4 |
| 40000 | 0.0259 | -1.5867 | 4.60206 |
| | | | |
| | SLOPE | -0.58464 | |




| NODES | ERROR | LOG E | LOG N |
|---|---|---|---|
| 2500 | 0.0453 | -1.3439 | 3.39794 |
| 10000 | 0.0112 | -1.95078 | 4 |
| 40000 | 0.0019 | -2.72125 | 4.60206 |
| | | | |
| | SLOPE | -1.14386 | |