# Assignment 5: Applied Programming Lab

Aman Singhal, EP17B002

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## 1 Abstract

To implement algorithm for determining the voltages and currents in a given copper plate of 1 cm square dimension inside which a potential of 1V is maintained within a radius r. One side of the copper plate has been grounded.

## 2 My Code

```python
from pylab import *
import mpl_toolkits.mplot3d.axes3d as p3
from numpy import *
import matplotlib.pyplot as plt
import sys

Nx = 25 # size along x
Ny = 25 # size along y
r = 0.35  # radius of central lead
Niter = 1500 # number of iterations to perform
nx = (Nx - 1)//2
ny = (Ny - 1)//2

print("pass values of sizex, sizey, radius and number of iterations")
x = sys.argv
if(len(x) != 5):
    print('invalid input')
    sys.exit()
else:
    Nx = int(x[1]) # size along x
    Ny = int(x[2]) # size along y
    r = float(x[3])  # radius of central lead
    Niter = int(x[4]) # number of iterations to perform
    nx = (Nx - 1)//2
    ny = (Ny - 1)//2

    #initialising phi
    phi = zeros((Nx,Ny))
    x = linspace(-0.5,0.5,Nx)
    y = linspace(-0.5,0.5,Ny)
    Y,X = meshgrid(y,x)
    ij = where(X*X + Y*Y <= r*r)
    phi[ij] = 1
```

```
    #plotting initial phi
    plt.contourf(X,Y,phi)
    plt.xlabel(r'x',size=15)
    plt.ylabel(r'y',size=15)
    plt.title(r'Contour plot of voltage initially')
    plt.legend()
    plt.show()

    #iterations
    errors = zeros(Niter)
    zero_row = zeros((1,Nx-2))
    for k in range(Niter):
        oldphi = phi.copy()

        phi[1:-1,1:-1]=0.25*(phi[1:-1,0:-2] + phi[1:-1,2:] + phi[0:-2,1:-1] + phi[2:,1:-1])
        #averaging the potential

        #boundary conditions
        phi[1:-1,0] = phi[1:-1,1]    # left col
        phi[1:-1,-1] = phi[1:-1,-2]  # right col
        phi[-1,1:-1] = phi[-2,1:-1]    # top row

        #corners boundary condition
        phi[-1,-1] = phi[-1,-2]
        phi[-1,0] = phi[-1,1]

        #maintaining 1V in the middle
        phi[ij] = 1

        #error
        errors[k]=(abs(phi-oldphi)).max()

    #plotting error
    ax = range(0,Niter,Niter//30)
    axis = range(Niter//3,Niter+1,Niter//30)
    plt.semilogy(ax,errors[0:Niter:Niter//30],'ro',label="semilog plot of error")
    #plt.loglog(axis,errors[(Niter//3)-1:Niter:Niter//30],'bo',label="semilog plot of error")
    plt.xlabel(r'$x$',size=15)
    plt.ylabel(r"$error",size=15)
    plt.title(r'Plot of error')
    plt.legend()
    plt.show()

    #plotting 3d voltage
    fig1 = plt.figure(4) # open a new figure
    ax = p3.Axes3D(fig1) # Axes3D is the means to do a surface plot
    plt.title('The 3-D surface plot of the potential')
    surf = ax.plot_surface(Y, X, phi, rstride=1, cstride=1, cmap=plt.cm.jet)
    plt.show()

    #plotting contour voltage plot
    plt.contour(Y,X,phi)
    plt.plot(Y[ij],X[ij],"ro")
    plt.title(r'Contour plot of voltage')
    plt.xlabel(r'$x$',size=15)
```

```
    plt.ylabel(r'$y$',size=15)
    plt.legend()
    plt.show()

    #jx and jy matrices from differetiation
    jx = zeros((Ny,Nx))
    jy = zeros((Ny,Nx))
    jx[1:-1,1:-1] = 0.5*(phi[1:-1,0:-2] - phi[1:-1,2:])
    jy[1:-1,1:-1] = 0.5*(phi[:-2,1:-1] - phi[2:,1:-1])

    #zeroing tangential and perpendicular components
    jx[0,0:] = 0
    jx[-1,0:] = 0
    jx[0:,0] = 0
    jx[0:,-1] = 0

    jy[0,0:] = 0
    jy[-1,0:] = 0
    jy[0:,0] = 0
    jy[0:,-1] = 0

    #plotting current
    plt.quiver(x,y,jx,jy)
    plt.plot(Y[ij],X[ij],"ro")
    plt.title(r'plot of current flow')
    plt.xlabel(r'x',size=15)
    plt.ylabel(r'y',size=15)
    plt.legend()
    plt.show()

    # finding temeperature similar to finding potential
    T = zeros((Nx,Ny))
    T[ij] = 300
    for k in range(Niter):
        T[1:-1,1:-1]=0.25*(T[1:-1,0:-2] + T[1:-1,2:] + T[0:-2,1:-1] + T[2:,1:-1] - jx[1:-1,1:-1]**2 -jy[1:-1,1:-1]**2)

        T[1:-1,0] = T[1:-1,1]       # left col
        T[1:-1,-1] = T[1:-1,-2]     # right col
        T[-1,1:-1] = T[-2,1:-1]     # top row

        T[-1,-1] = T[-1,-2]         #corners
        T[-1,0] = T[-1,1]           #corners
        T[-1,1:-1] = 300
        T[ij] = 300

    plt.contour(Y,X,T)
    plt.plot(Y[ij],X[ij],"ro")
    plt.xlabel(r'x',size=15)
    plt.ylabel(r'y',size=15)
    plt.title(r'Contour plot of temperature')
    plt.legend()
    plt.show()

    fig2 = plt.figure(4) # open a new figure
    ax = p3.Axes3D(fig2) # Axes3D is the means to do a surface plot
    plt.title('The 3-D surface plot of the temperature')
    surf = ax.plot_surface(Y, X, T, rstride=1, cstride=1, cmap=plt.cm.jet)
    plt.show()
```

# 3 Plots

## 3.1 Question 1

Initialising potential matrix with 1V potential inside radius r.

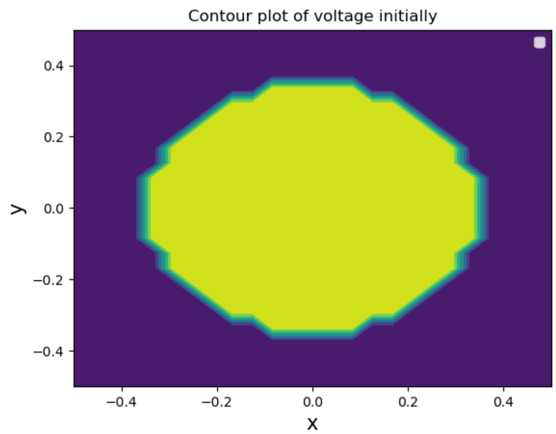
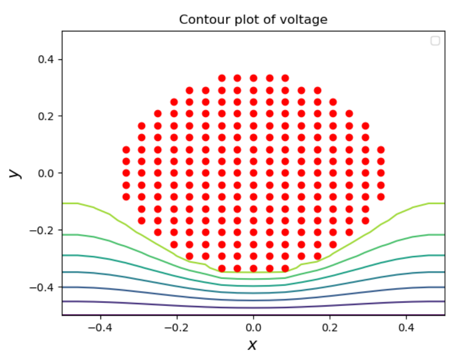
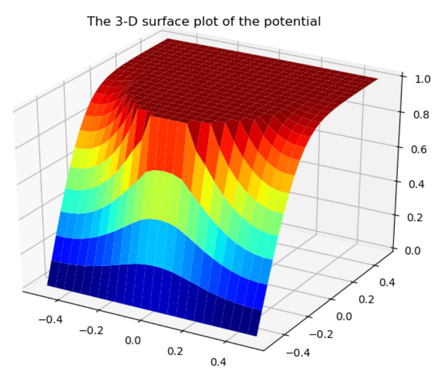



Figure 1: contour plot of potential before iterations

## 3.2 Question 2

After N iterations of:
1) Making a copy of phi
2) Averaging potential around every element
3) Applying boundary conditions
4) Making potential 1V inside the radius
we get the new potential matrix:



### 3.3 Question 3

Finding error in every iteration and plotting semilog graph for every 50th element. We find that it is almost linear after first few iterations.

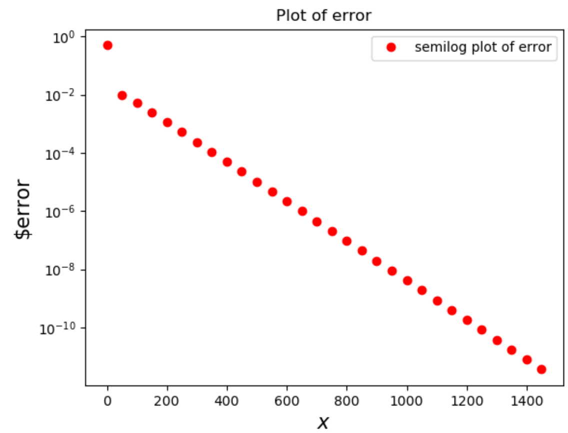



Figure 4: error plot

### 3.4 Question 4

Plotting current in the copper plate using quiver command after defining Jx and Jy matrix (differentiating potential matrix)

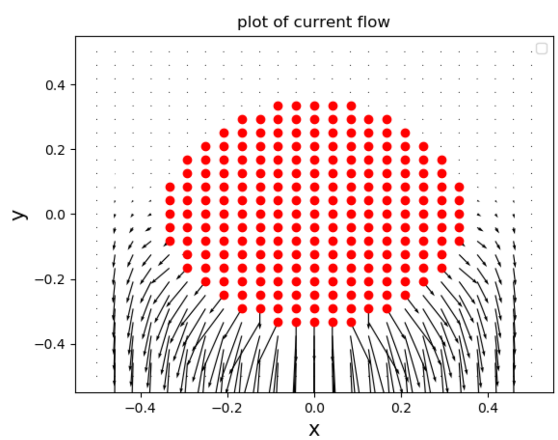
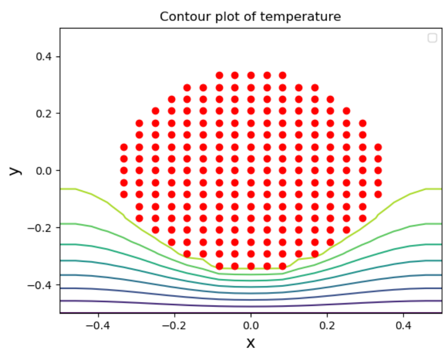
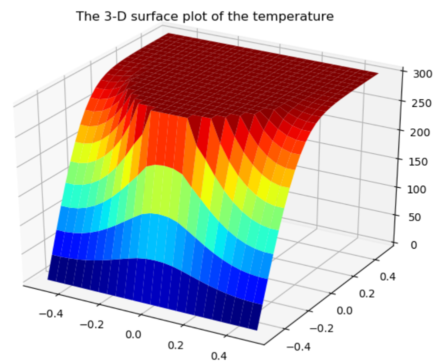



Figure 5: Current Plot

### 3.5 Question 5

Using the same method we used for potential the temperature is plotted assuming it to be 300K inside the radius r.




# 4 Conclusion

1)Due to low resolution (lower values of Nx and Ny) dont get a perfect circular potential.

2) At the boundaries of the copper plate we keep the potential constant by making the edge voltage equal to adjacent voltage.(except the boundary that has been grounded)

3) We keep averaging the potential around the node and giving that value as the potential of that node after every iteration.

4) We get the current density matrices (x and y direction) by differentiating the potential.

5) We observe that all the current flows from the 1V potential to ground.

6) Finally we have also plotted the temperature of the copper plate using the same technique used in potting the voltage.