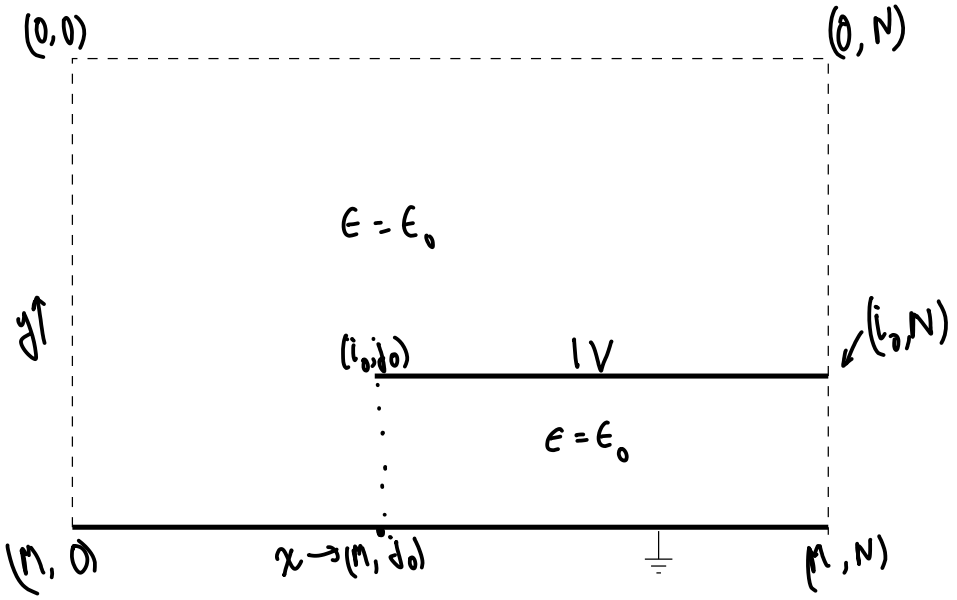
exam-c (20 Marks) Feb 14, 2021

Dept. of Electrical Engineering, IIT Madras
Applied Programming Lab

- You have six hours in which to do this exam.
- Use vector operations or lose marks!!
- Label all plots. Add legends. Make the plots professional looking.
- Comments are not optional. They are required.
- The pseudocode should be readable and neatly formatted.
- Include the plots in the report (which should be a pdf file).
- zip your python file and the report (which should be in the form *rollno.py* and *rollno.pdf*). The zip file should be called *rollno.zip*. Upload to moodle
- You do not require any surface plots, but quiver is required. To understand it, just type 'quiver ?' in an ipython terminal.
- The code should be listed in the report and should be well commented.

We want to model the fields of a capacitor surrounded by a boundary where the normal Electric field goes to zero.

Only half of the capacitor is modelled, assuming symmetry (see figure).



The bottom surface of our simulation, i.e., points corresponding to $(i = M, j)$, is the symmetry plane, and so the potential is constant (and equal to 0V on it).

The other surfaces have a requirement that there is no normal field, i.e.,

$$\frac{\partial \phi}{\partial n} = 0$$

must be satisfied for the border cells. i.e., for the first column ($i = 1$), we must have

```
phi[0,j]=phi[1,j]
```

Similarly for the top and right surfaces.

The top surface of the capacitor is at $i = i_0$ and stretches from $j = j_0$ to $j = N$. This surface has a boundary condition of 1 Volt. The capacitor is air filled, i.e., there is no dielectric present.

You have to solve for laplace's equation by implementing the iteration

$$\phi_{i,j} = \frac{1}{4}\left(\phi_{i-1,j} + \phi_{i+1,j} + \phi_{i,j-1} + \phi_{i,j+1}\right)$$

at all interior nodes. Your parameters are M, N, i_0, j_0 and the number of iterations N_t.

Note: You may use your lab assignments and your submissions to help you with this exam.

1. **In your report, enter the *pseudocode* to implement the problem.**
2. **Assume the values**

$$M = 30,\ N = 25,\ i_0 = 12,\ j_0 = 10 \text{ and } N_t = 5000$$

3. **Create the simulation array and initialise it. Note that it is $M+1$ by $N+1$ in size.**
4. **Do the iteration: Implement laplace's equation for all interior points (including internal boundaries), assert boundaries (including internal boundaries) and compute the error for that step.**
5. **Plot the error vs iteration number in a semilog plot. Hence determine N_t requred to obtain accuracy to two digits. From now on use that value of N_t for the rest of the work.**

6. **Plot a contour plot of the potential and label it. The orientation of the plot should agree with the above figure (you may need to reflect or transpose the arrays to get the plot right).**

7. **Obtain the Electric field using $E_x(x_j, y_i) \propto (\phi_{i,j-1} - \phi_{i,j+1})/2$ and $E_y(x_j, y_i) \propto (\phi_{i-1,j} - \phi_{i+1,j})/2$ and draw an arrow plot. Note: The arrow plot should agree in orientation with the above figure (you may need to reflect or transpose the arrays to get the plot right).**

8. **Compute D_y at the bottom side of the top plate and obtain the charge induced on the side of the plate, Q.**

9. **Convert the above code into a function, *Q=cap(i0)* that accepts i_0 as the argument and returns Q. Run the function for different values of i_0 and fill the following table:**

i_0	Q_{meas}	Q_{theory}
5		
10		
20		
30		

and determine deviation from

$$Q_{theory} = \frac{\epsilon_0 (N - j_0)}{i_0} V$$

10. **What is the deviation due to?**

Useful Python Commands (use "?" to get help on these from ipython)

```
from pylab import *
import system-function as name
Note: lstsq is found as scipy.linalg.lstsq
ones(List)
zeros(List)
range(N0,N1,Nstep)
arange(N0,N1,Nstep)
linspace(a,b,N)
logspace(log10(a),log10(b),N)
X,Y=meshgrid(x,y)
where(condition)
where(condition & condition)
where(condition | condition)
a=b.copy()
lstsq(A,b) to fit A*x=b
A.max() to find max value of numpy array (similalry min)
A.astype(type) to convert a numpy array to another type (eg int)
trunc(A) to truncate values of A to integer.
def func(args):
  ...
  return List
matrix=c_[vector,vector,...] to create a matrix from vectors
w=0.54+0.46*cos(2*pi*n/(N-1)) to generate a window of N points, where n=linspace(-N
fftshift(v) to shift a vector from -max to +max to lie on unit circle.
```

Python commands (contd)

figure(n) to switch to, or start a new figure labelled n

plot(x,y,style,...,lw=...)

semilogx(x,y,style,...,lw=...)

semilogy(x,y,style,...,lw=...)

loglog(x,y,style,...,lw=...)

contour(x,y,matrix,levels...)

quiver(X,Y,U,V) # X,Y,U,V all matrices

xlabel(label,size=)

ylabel(label,size=)

title(label,size=)

xticks(size=) # to change size of xaxis numbers

yticks(size=)

legend(*List*) to create a list of strings in plot

annotate(str,pos,lblpos,...) to create annotation in plot

grid(Boolean)

show()