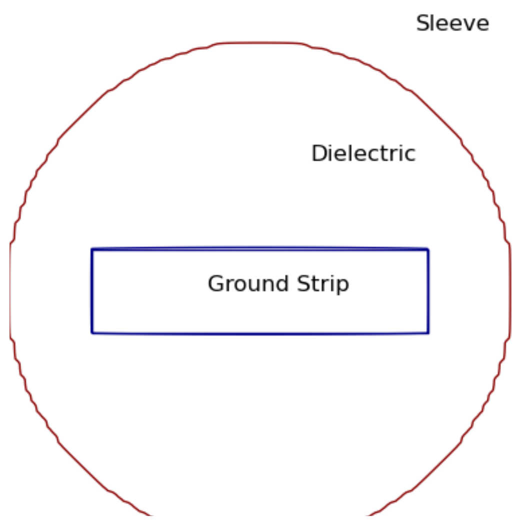
Final Exam for Group B (20 Marks) **Nov 10, 2015**

Dept. of Electrical Engineering, IIT Madras
CADLAB July 2015 session

- ▷ **Time duration of exam is two hours**
- ▷ **vector operations are a must or lose lots of marks!!**
- ▷ **Label all plots. Add legends. Make the plots professional looking.**
- ▷ **Comments are not optional. They are required. Note that I expect LyX discussion and python comments.**
- ▷ **pseudocode should be readable and neatly formatted.**
- ▷ **code should be written as part of a LyX file.**
- ▷ **Please download the blank LyX file with noweb enabled. This is compatible with earlier LyX versions, and should work on all machines.**
- ▷ **LyX file should be named *your-roll-number.lyx***
- ▷ **I should be able to extract the python code using the view menu.**
- ▷ **Include the plots in the lyx file and generate a pdf.**
- ▷ **Internet will be turned off at the beginning of the exam.**
- ▷ **Zip the LyX file and the pdf file together and name it as *your-roll-number.zip*. Leave it in the home directory of your machine and show the same to the TA before leaving.**
- ▷ **Late submission will result in reduced marks.**

A circular copper grounding strip is connected to a copper sleeve as shown in the figure. The region between the two is a dielectric whose conductivity is zero. We wish to determine the potential between the strip and the sleeve if a voltage of 1 volt is applied to the sleeve.



The grounding strip is 1 cm wide and 0.25 cm thick. The sleeve has a radius of 0.75cm. The equation to solve is

$$\nabla^2\phi = 0$$

The finite difference equation for this problem is

$$\phi_{mn} = \frac{1}{4}\left(\phi_{m+1,n} + \phi_{m-1,n} + \phi_{m,n-1} + \phi_{m,n+1}\right)$$

We simplify the model to a square block that is the sleeve with a circular hollow region. The sleeve is held at 1 volt. In the middle is the ground strip, held at 0 volts.

1. **Define your simulation region, and the number of grid points, N_x and N_y, you are choosing along each direction. Initialize ϕ to 0.5 volts Note: Use $N_x = 31$ by $N_y = 31$ grid for simulation with the grounding strip being 16 grids long and 4 grids in thickness. The radius of the sleeve is 12 grids.**

2. **Define x and y coordinates with the origin at $(15,15)$. Use meshgrid to create arrays X and Y.**

3. **Use the where command to find the indices corresponding to 1 volt. Call the list of indices `ii`. Set those grid points to 1 volt. Hint: use X and Y in your where command.**

4. **Use the where command to find the indices corrresponding to 0 volts. Call list of indices `jj`. Set those grid points to zero volts.**

5. **In a separate figure, create a contour plot of the initial potential, with 11 levels. Label appropriately.**

6. **Create a function that takes a number N and iterates the solution for N iterations. In each iteration, iterate the entire square region, and then impose the two electrode voltages. Vectorise the iteration loop, and obtain the error at each iteration. Run initially for 200 iterations.**

7. **Plot the error vs iteration number. Fit the error to an exponential fit and determine the residual error. Predict where to stop the iteration when you have 0.1% residual error.**

8. **Run the code for the predicted number of iterations and save the solution in phi1. Run the code for 5 times longer and save the solution in phi2. Assume that phi2 is exact, and obtain the error in phi1. Is it 10^{-3}? i.e., Have you estimated the initial error and the slope of the error curve correctly in q7?**

9. **Plot the contours of the error potential, given by**

$$\Delta\phi = \mathbf{phi1} - \mathbf{phi2}$$

after the predicted number of iterations in earlier contour figure. Where is the error maximum? Discuss why the error is maximum there. Compare to the lab resistor problem.

Notes:

1. **In LyX, write pseudocode showing how you will solve the problem. The individual pieces of code can be under each line of pseudocode.**
   (a) **What will your data structures be?**
   (b) **How will you find the sleeve points and the strip points?**
   (c) **Iteration loop**
   (d) **Error estimation to find stopping index**
2. **Enter the python code in LyX and verify that you can extract it from LyX. If this does not work, include the python code as LyX-Code and mention at the top that python extraction did not work. Instead include the python code itself in the zip file.**
3. **Include the figures generated by the python program, with appropriate captions.**
4. **Have a discussion section where you discuss the results.**

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
A.astype(type) to convert a numpy array to another type (eg int)
def func(args):
  ...
  return List
matrix=c_[vector,vector,...] to create a matrix from vectors
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=...)
contour(x,y,matrix,levels...)
xlabel(label,size=)
ylabel(label,size=)
title(label,size=)
legend(List) to create a list of strings in plot
annotate(str,pos,lblpos,...) to create annotation in plot
grid(Boolean)
show()
```