Final Exam for Group A (20 Marks) **Nov 9, 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.**
- ▷ **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.**
- ▷ **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 long wire carries a current $I = 4\pi/\mu_0$ Amp. The wire is along the z-axis exept that it has has a semi-circular bend of radius 10 cm centered about the origin. The semi-circle lies in the $x-z$ plane. The problem is to compute and plot the magnetic field $\vec{B}$ on the $x-y$ plane at $z=0$. Plot both a contour plot of the strength of the field $\left|\vec{B}\right|$ and a vector plot of the field in the plane.

The computation involves the calculation of the Biot-Savart integral:

$$\vec{B}(x,y,0) = \frac{\mu_0}{4\pi}\int \frac{I\vec{dl}\times\vec{R}}{R^3} \approx \frac{\mu_0 I}{4\pi}\sum_{k=0}^{N-1}\frac{\vec{dl}_k\times\vec{R}}{R^3}$$

where $\vec{R} = \vec{r}-\vec{r}'$. Here $\vec{r} = x\hat{x}+y\hat{y}$ is the point where we want the field, and $\vec{r}'$ is the point on the wire and $\vec{dl}$ is the differential length along the wire.

Assume that the wire goes from -30 to 30 cm, and assume that the region to plot is a square $-20 < x,y < 20$. The expression to be computed is

$$\vec{B}_{ij} = \sum_{k=0}^{N-1}\frac{\vec{dl}_k\times\vec{R}_{ijk}}{R^3_{ijk}}$$

where $\vec{R}_{ijk} = \vec{r}_{ij}-\vec{r}'_k$.

- ▷ **Write pseudocode for how you will solve this problem.**
- ▷ **Break the square region into a 101 by 101 mesh and the wire into 200 sections. Use 30% of the points in the wires for each of the straight sections and 40% for the loop. Define the data structures required for the problem. Plot the wire in the $x-z$ plane with bounds $(-20,20)$ along x and $(-30,30)$ along z. Properly label the graph.**
- ▷ **Obtain the vectors $\vec{r}'_k$, $\vec{dl}_k$ and $\vec{r}_{ij}$, where k indexes the segments of the wire and i,j index the x and y positions of the square region.**
- ▷ **Define a function `calc(k)` that calculates $\vec{R}_{ijk}$ for all i,j, for the value of `k` passed to the function (k is the index into the $\vec{r}'$ array, which you have defined earlier.) Note: vectorize this function!**
- ▷ **Extend `calc` to generate the terms in the sum, i.e., write out the cross product and divide by R^3_{ij}, and return the term to add to $\vec{B}$. Note: vectorize the function**
- ▷ **Use the function to compute $\vec{B}_{ij}$ (you can use a for loop here. Justify in a comment)**
- ▷ **Plot the magnetic field (contour and arrow plots). To show more detail, plot the contour of $\log_{10}\left|\vec{B}\right|$ and plot the vector plot of $\vec{B}/\left|\vec{B}\right|$ (arrows of constant length). Locate the (x,y) position of the straight segments. Why is field not going round that**

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)
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...)
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)
```